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		EXAMINER A. HIGGINS

APPLICANTS DANIEL L. FLAMM, WALNUT CREEK, CA; JOHN P. VERBONCOEUR, HAYWARD, CA.

\*\*CONTINUING DATA\*\*

VERIFIED *none*

\*\*FOREIGN/PCT APPLICATIONS\*\*

VERIFIED *none*

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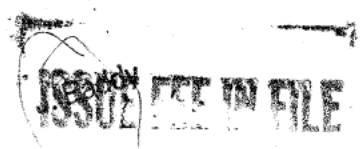
TITLE PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

U.S. DEPT. OF COMM./ PAT. & TM—PTO-436L (Rev.12)

PARTS OF APPLICATION FILED SEPARATELY		Applications Examiner <i>Wimmer</i>	
NOTICE OF ALLOWANCE MAILED	Assistant Examiner	CLAIMS ALLOWED	
<i>4/10/97</i>		Total Claims 29	Print Claim 20
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06/03/96

**PATENT APPLICATION**

**08433623**

APPROVED FOR LICENSE

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	2. LTR RE: FEE, SIGNATURE	5-22-95
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<i>2/4/96</i>	4. <i>Fee Amnt A</i>	11/13/95
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Claim	Date
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SYMBOLS  
 ✓ ..... Rejected  
 - ..... Allowed  
 - (Through numeral) Canceled  
 + ..... Restricted  
 N ..... Non-elected  
 I ..... Interference  
 A ..... Appeal  
 O ..... Objected

(LEFT INSIDE)

PATENT NUMBER		ORIGINAL CLASSIFICATION	
		CLASS	SUBCLASS
		15G	643.1
APPLICATION SERIAL NUMBER		CROSS REFERENCE(S)	
07/433623		CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)
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U.S. DEPARTMENT OF COMMERCE  
PATENT AND TRADEMARK OFFICE

SEARCHED			
Class	Sub.	Date	Exmr.
204 216 156	258,31 258,32 59, 59, 74, 79 246 P 625, 1, 643, 1 626, 1, 646, 1 659, 1, 662, 1	3/1/72	WMT
updated 156	659, 11	1/2/72	WMT
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SEARCH NOTES		
	Date	Exmr.
APB enclosed	3/1/72	WMT
APB enclosed	1/2/72	WMT
None	6/8/72	WMT


INTERFERENCE SEARCHED			
Class	Sub.	Date	Exmr.
204 216 156	258,31 258,32 59, 59, 74 71, 258 246 P 625, 1, 643, 1 626, 1, 646, 1 659, 1, 662, 1	4/7/72	WMT

(RIGHT OUTSIDE)

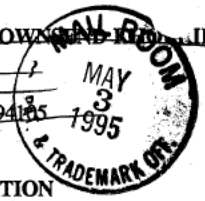
PATENT APPLICATION SERIAL NO. 

U.S. DEPARTMENT OF COMMERCE  
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APPLICANT	DANIEL L. FLAMM, WALNUT CREEK, CA; JOHN P. VERBONCOEUR, HAYWARD, CA.  <b>**CONTINUING DATA*****</b> VERIFIED  <hr/>  <b>**FOREIGN/PCT APPLICATIONS*****</b> VERIFIED  <hr/>  FOREIGN FILING LICENSE GRANTED 08/08/95                      ***** SMALL ENTITY *****				
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TITLE	PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING				
This is to certify that annexed hereto is a true copy from the records of the United States Patent and Trademark Office of the application which is identified above.  By authority of the COMMISSIONER OF PATENTS AND TRADEMARKS  Date _____ Certifying Officer _____					

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**PATENT APPLICATION  
COMMISSIONER OF PATENT AND TRADEMARKS  
Washington, D. C. 20231**

I hereby certify that this is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to the Commissioner of Patents and Trademarks, Washington, D. C. 20231

Sir:  
Transmitted herewith for filing is the  
 patent application of  
 design patent application of  
 continuation-in-part patent application of

By Richard T. Ogawa

Inventor: DANIEL L. FLAMM and JOHN VERBONCOEUR

For: **PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING**

Enclosed are:

- 13 sheet(s) of  formal  informal drawing(s).
- An assignment of the invention to \_\_\_\_\_
- A  signed  unsigned Declaration & Power of Attorney.
- A  signed  unsigned Declaration.
- A Power of Attorney.
- A verified statement to establish small entity status under 37 CFR 1.9 and 37 CFR 1.27.
- A certified copy of a \_\_\_\_\_ application.
- Information Disclosure Statement under 37 CFR 1.97.
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**In view of the Unsigned Declaration as filed with this application and pursuant to 37 CFR §1.53(d), Applicant requests deferral of the filing fee until submission of the Missing Parts of Application.**

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Attorney Docket No. 016655-0001

PATENT APPLICATION



PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

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PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

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BACKGROUND OF THE INVENTION

The present invention relates to integrated circuits and their manufacture. The present invention is illustrated in an example with regard to plasma etching, and more particularly to plasma etching in resist strippers in semiconductor processing. But it will be recognized that the invention has a wider range of applicability in other technologies such as flat panel displays, large area substrate processing, and the like. Merely by way of example, the invention may be applied in plasma etching of materials such as silicon, silicon dioxide, silicon nitride, polysilicon, photoresist, polyimide, tungsten, among others.

10  
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20  
25 Industry utilizes or has proposed several techniques for plasma etching. One such method is conventional chemical gas phase dry etching. Conventional chemical gas phase dry etching relies upon a reaction between a neutral gas phase species and a surface material layer, typically for removal. The reaction generally forms volatile products with the surface material layer for its removal. In such method, the neutral gas phase species may be formed by way of a plasma discharge.

A limitation with the conventional plasma etching technique is obtaining and maintaining etching uniformity within selected predetermined limits. In fact, the conventional technique for obtaining and maintaining uniform etching relies upon a "trial and error" process. The trial and error process often cannot anticipate the effects of parameter changes for actual wafer production. Accordingly, the conventional technique for obtaining and maintaining etching uniformity is often costly, laborious, and difficult to achieve.

30  
35 Another limitation with the conventional plasma etching technique is reaction rates between the etching species and the etched material are often not available. Accordingly, it is often impossible to anticipate actual etch

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rates from reaction rate constants since no accurate reaction rate constants are available. In fact, conventional techniques require the actual construction and operation of an etching apparatus to obtain accurate etch rates. Full scale  
5 prototype equipment and the use of actual semiconductor wafers are often required, thereby being an expensive and time consuming process.

From the above it is seen that a method and apparatus of etching semiconductor wafers that is easy,  
10 reliable, faster, predictable, and cost effective is often desired.

#### SUMMARY OF THE INVENTION

According to the present invention, a plasma etching  
15 method that includes determining a reaction rate coefficient based upon etch profile data is provided. The present plasma etching method provides for an easy and cost effective way to select appropriate etching parameters such as reactor dimensions, temperature, pressure, radio frequency (rf) power,  
20 flow rate and the like by way of the etch profile data.

In a specific embodiment, the present invention provides an integrated circuit fabrication method. The present method includes steps of providing a plasma etching apparatus having a substrate therein. The substrate includes  
25 a top surface and a film overlying the top surface. The film includes a top film surface. The present method also includes chemically etching the top film surface to define an etching profile on the film, and defining etch rate data which includes an etch rate and a spatial coordinate from the  
30 etching profile. A step of extracting a reaction rate constant from the etch rate data, and using the reaction rate constant in adjusting a plasma etching apparatus is also included.

In an alternative specific embodiment, the present  
35 invention also provides a method of designing a reactor. The present method includes providing a first plasma etching apparatus having a substrate therein. The substrate has a top surface and a film overlying the top surface. The film has a

top film surface. The present method also includes chemically etching the top film surface to define an etching profile on the film, and defining etch rate data which has an etch rate and a spatial coordinate from the etching profile. A step of extracting a reaction rate constant from the etch rate data, and using the reaction rate constant in designing a second plasma etching apparatus is also included.

A further alternative embodiment provides another method of fabricating an integrated circuit device. The present method includes steps of providing a uniformity value for an etching reaction. The etching reaction includes a substrate and etchant species. The present method also includes defining etching parameters ranges providing the uniformity value. A step of adjusting at least one of the etching parameters to produce a selected etching rate is also included. The etching rate provides an etching condition for fabrication of an integrated circuit device.

The present invention achieves these benefits in the context of known process technology. However, a further understanding of the nature and advantages of the present invention may be realized by reference to the latter portions of the specification and attached drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a simplified diagram of a plasma etching apparatus according to the present invention;

Fig. 1A is a simplified cross-sectional view of a wafer profile according to the plasma etching apparatus of Fig. 1;

Fig. 2 is a simplified diagram of an alternative embodiment of a plasma etching apparatus according to the present invention;

Figs. 3-5 are simplified flow diagrams of plasma etching methods according to the present invention;

Fig. 5A is a plot of uniformity, temperature, pressure, and gap for an etching process according to the present invention;

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Fig. 6 is a simplified plot of 1/ash rate vs. LCD plate number according to the present invention;

Figs. 7-9 illustrate an example with regard to circular substrates according to the present invention; and

Figs. 10-12 illustrate an example with regard to rectangular substrates according to the present invention.

#### DESCRIPTION OF THE SPECIFIC EMBODIMENT

##### Plasma Etching Apparatus

Fig. 1 is a simplified diagram of a plasma etching apparatus 10 according to the present invention. The plasma etching apparatus also known as a co-axial reactor includes at least three processing zones. The three processing zones are defined as a plasma generating zone (PG) 13, a transport zone (TZ) 15, a plate stack zone (PS) 17, and others. Also shown are a chemical feed F and exhaust E. The plasma generating zone provides for reactant species in plasma form and others. Excitation is often derived from a 13.56 MHz rf discharge 8 and may use either capacitor plates or a wrapped coil, but can also be derived from other sources. The co-axial reactor 10 also includes a chemical <sup>controller</sup> flow source 14 and a temperature and pressure control 12, among other features.

Chemical effects are often enhanced over ion induced effects and other effects by way of perforated metal shields 18 to confine the discharge to a region between an outer wall 16 and shields 18. The co-axial reactor relies substantially upon diffusion to obtain the desired etching uniformity. The co-axial reactor also relies upon a chemical etch rate which is diffusion <sup>limited</sup> limiting. In particular, the chemical etch rate is generally defined as a chemical reaction rate of etchant species plus at least a diffusion rate of etchant species. When the diffusion rate of etchant species is much greater than the chemical reaction rate, the chemical etch rate is often determined by the diffusion rate. A more detailed analysis of such chemical etch rate will be described by way of the subsequent embodiments.

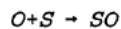
Etchant species from the plasma generating zone diffuse through the transport zone 15 of the reaction chamber,

and enter the plate stack zone space over surfaces of substrates 21. A concentration of etchant in the transport zone, which is often annular, between the plasma generating zone and the plate stack zone is defined as  $n_{o0}$ . As etchant  
 5 diffuses radially from the transport zone into the plate stack zone and over surfaces of the substrates, it is consumed by an etching reaction. A reactant concentration above the substrate can be defined as  $n_o(x, z)$ , where  $r$  is the distance from the center of the substrate and  $z$  is the distance above  
 10 the substrate. A diffusive velocity  $v_o$  of etchant species in the plate stack zone is characterized by Fick's law.

T62X

$$v_o = -D \frac{\nabla n_o}{n_o}$$

In a specific embodiment, a gap  $d_{gap}$  above the substrate is much less than the lateral extent  $d_{gap} \ll r$  and gas phase mass transfer resistance across the small axial distance  
 15 is negligible so that the axial ( $z$ -direction) term of the concentration gradient can be ignored. The embodiment can be applied without this restriction; however, numerical mesh computer solutions are then required to evaluate the reaction rate constant and uniformity. In the embodiment, the surface  
 20 etching reaction bears a first order form:



where

$S$  is a substrate atom (e.g., resist unit "mer"); and  
 $O$  is the gas-phase etchant (for example oxygen atoms) with certain etching kinetics. The first order etching  
 25 reaction can be defined as follows:

T61X

$$R_{OS} = n_o A \sqrt{T} e^{-E_{ACT}/RT}$$

where

$R_{OS}$  defines a reaction rate;  
 $n_o$  defines a concentration;  
 $A$  defines a reaction rate constant;  
 30  $T$  defines a temperature;

6

$E_{ACT}$  defines an activation energy; and  
R defines a gas constant.

An example of the first reaction is described in D.L. Flamm and D.M. Manos "Plasma Etching," (1989), which is hereby  
5 incorporated by reference for all purposes. Of course, other  
order reactions, reaction relations, and models may be applied  
depending upon the particular application.

An example of an etched substrate 21 from the plate  
stack zone is illustrated by Fig. 1A. The substrate 21 is  
10 defined in spatial coordinates such as  $z$  and  $r$ . The substrate  
includes a bottom surface 23, sides 25, and a top surface film  
27. As can be seen, the top surface film includes a convex  
region, or etching profile. The etching profile occurs by way  
of different etch rates along the  $r$ -direction of the substrate  
15 corresponding to different etchant species concentrations. A  
concentration profile  $n_o(x,z)$  is also shown where the greatest  
concentration of reactant species exists at the outer  
periphery of the top surface film. In the present invention,  
an etch rate constant may be obtained by correlation to the  
20 etching profile. By way of the etch rate constant, other  
etching parameters such as certain reactor dimensions  
including a distance between substrates, pressure,  
temperature, and the like are easily calculated.

Fig. 2 illustrates an alternative example of an  
25 etching apparatus 50 according to the present invention. The  
etching apparatus 50 is a single wafer etching apparatus with  
elements such as a chamber 53, a top electrode 55, a bottom  
electrode 57, a power source 59, a platen 64, and others. The  
bottom electrode 57 is at a ground potential, and the top  
30 electrode is operably coupled to the power source 59 at a high  
voltage potential. A plasma exists in a region 54 between the  
top electrode 55 and the bottom electrode 57, which is often a  
grid configuration or the like. Reactant species are directed  
via power source from a plasma source to a wafer substrate 61  
35 by diffusion. A temperature and pressure controller 67 and a  
flow controller 69 are also shown. The etching apparatus also  
includes a chemical source feed F and a exhaust E. Of course,

other elements may also be available based upon the particular application.

By way of a plate 63 interposed between the wafer substrate 61 and the bottom electrode 57, the reactant species do not directly bombard the wafer substrate. The plate is preferably made of an inert material appropriate for the particular etching such as pyrex or glass for resist ashing, alumina for fluorine atom etching of silicon, silicon nitride, or silicon dioxide, and the like. In an ashing reaction, the plate is placed at a distance ranging from about 5 mm to 50 mm and less from the wafer substrate 61. Of course, other dimensions may be used depending upon the particular application. The reactant species are transported via diffusion from the plasma source to the wafer substrate around the periphery of the plate 63. Accordingly, the reaction rate at the wafer substrate is controlled by a balance between chemical reaction and diffusion effects, rather than directional bombardment.

By way of the diffusion effects, an etching rate constant may be obtained for the etching apparatus 50 of Fig. 2. In particular, the etching rate constant derives from an etching profile 65, which can be measured by conventional techniques. The present invention uses the etching rate constant to select other etching rate parameters such as reactor dimensions, ~~such as~~ spacing between the substrate and its adjacent surface, temperatures, pressures, and the like. But the present invention can be used with other reactor types where etching may not be controlled by diffusion. For example, the present invention provides a reaction rate which can be used in the design of reactors where diffusion does not control such as a directional etcher and the like. The reaction rate constant may also be used in the directional etcher to predict an extent of, for example, undercutting of unprotected sidewalls while ion bombardment drives reaction in a vertical direction. Of course, the invention may be applied to other reactors such as large batch, high pressure, chemical, single wafer, and others. The invention can also be applied to different substrate materials, and the like.



Plasma Etching Method

Figs. 3-5 illustrate simplified flow diagrams of plasma etching methods according to the present invention. The present methods provide for improved etching conditions by way<sup>of</sup> a reaction rate constant derived from, for example, an etching profile. It should be noted that the present methods as illustrated should not be construed as limiting the invention as defined in the claims. One of ordinary skill in the art would easily recognize other applications<sup>of</sup> to the inventions described here.

In a specific embodiment, a method of extracting a rate constant 100 for a plasma etching step according to the present invention is illustrated by the flow diagram of Fig. 3. A substrate with an overlying film is placed into a plasma etching apparatus or the like. The overlying film is defined as an etching film. In the present embodiment, the overlying film is a photoresist film, but can also be other films such as a silicon film, a polysilicon film, silicon nitride, silicon oxide, polyimide, and the like.

A step of plasma etching the film is performed by step 101. The plasma etching step occurs at constant pressure and preferably constant plasma source characteristics. More preferably, the plasma etching step occurs isothermally at temperature  $T_1$ , but can also be performed with changing temperatures where temperature and time histories can be monitored. Plasma etching of the film stops before the endpoint (or etch stop). Alternatively, plasma etching stops at a first sign of the endpoint (or etch stop). The plasma etching step preferably stops before etching into an etch stop layer underlying the film to define a "clean" etching profile.

The substrate including etched film is removed from the chamber of the plasma etching apparatus. The etched film includes an etching profile (step 103) made by way of plasma etching (step 101). The etching profile converts into a relative etch rate, relative concentration ratio, a relative etch depth, and the like at selected spatial coordinates. The relative etch rate is defined as an etch rate at a selected spatial coordinate over an etch rate at the substrate edge.

The relative concentration ratio is defined as a concentration of etchant species at a selected spatial coordinate over a concentration of etchant at the substrate edge.

5 In x-y-z coordinates, the relative etch rate in the z-direction, and the spatial coordinates are defined in the x-y coordinates. The etching profile is thereby characterized as a relative etch rate  $u$ , a x-location, and a y-location  $u(x, y)$ . In cylindrical coordinates, the relative etch rate is also in the z-direction, and the spatial coordinates are defined in the r and  $\theta$  coordinates. The etching profile is characterized as a relative etch rate  $u$ , a r-location, and a  $\theta$ -location  $(u, r, \theta)$ . An array of data points in either the x-y coordinates or r- $\theta$  coordinates define the etching profile. The array of data points can be defined as an  $n \times 3$  array, where  $n$  represents the number of points sampled and 3 represents the etch rate and two spatial dimensions. Of course, the choice of coordinates depends upon the particular application.

20 Optionally, in a non-isothermal condition, an average etch rate is measured. By approximate integration of a time dependent etch rate, suitable starting point approximations for an etching rate constant pre-exponential and activation energy can be selected. The etch rate is integrated over time (and temperature) using measured temperature-time data (or history). An etched depth profile and the etching rate from the integration can then be compared with actual data. A rate constant is appropriately readjusted and the aforementioned method is repeated as necessary.

30 An etch constant (or a reaction rate constant) over diffusivity ( $k_{vo}/D$ ) and an etch rate at an edge is calculated at step 105. The etch constant over diffusivity correlates with data points representing the etch rate profile. In x-y coordinates, the relationship between  $k_{vo}/D$  and the relative etch rate  $u(x, y)$  is <sup>often</sup> defined as follows:

35 where

a and b define substrate lengths in, respectively, an x-direction and a y-direction.

T110X

$$u(x,y) = \sum_{m=1}^{\infty} \frac{4}{m\pi} \sin \frac{m\pi}{2} \left\{ \begin{array}{l} \frac{\cosh \left[ \sqrt{k_{vo}/D + (m\pi/b)^2} x \right]}{\cosh \left[ \sqrt{k_{vo}/D + (m\pi/b)^2} \frac{a}{2} \right]} \cos \frac{m\pi y}{b} \\ + \\ \frac{\cosh \left[ \sqrt{k_{vo}/D + (m\pi/a)^2} y \right]}{\cosh \left[ \sqrt{k_{vo}/D + (m\pi/a)^2} \frac{b}{2} \right]} \cos \frac{m\pi x}{a} \end{array} \right\}$$

In cylindrical coordinates, the relationship between the etch constant over diffusivity  $k_{vo}/D$  and the relative etch rate  $u(r)$  is defined as follows:

T111X

$$u(r) = \frac{I_0 \left( \sqrt{\frac{k_{vo}}{D}} r \right)}{I_0 \left( \sqrt{\frac{k_{vo}}{D}} a \right)}$$

where

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D1

$a$  is an outer radius (or edge) of the substrate.

In step 106, a diffusivity is calculated for the particular etchants. The binary diffusivity  $D_{AB}$  may be calculated based upon the well known Chapman-Enskog kinetic theory equation:

T112X

$$D_{AB} = 2.2646 \times 10^{-5} \frac{\sqrt{T \left( \frac{1}{M_A} + \frac{1}{M_B} \right)}}{\sigma_{AB}^2 \Omega_{D,AB} C}$$

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where

- $T$  is a temperature;
- $c$  is a total molar concentration;
- $M_A$  and  $M_B$  are molecular weights;
- $D_{AB}$  is a binary diffusivity;
- $\sigma_{AB}$  is a collision diameter; and
- $\Omega_{D,AB}$  is a collision integral.

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The Chapman-Enskog kinetic theory equation is described in detail in part III of R.B. Bird, W.E. Stewart, and E.N. Lightfoot, "Transport Phenomena," Wiley (1960) which is hereby incorporated by reference for all purposes. Of course, other techniques for calculating a diffusivity may also be used.

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The equivalent volumetric reaction rate constant  $k_{vo}$  is derived from the diffusivity as follows.

$$k_{vo} = \left(\frac{k_{vo}}{D}\right) D_{AB}$$

Once the reaction rate constant  $k_{vo}$  is extracted, the surface reaction rate constant  $k_s$  may be isolated from the previous equation as follows.

$$k_s = (k_{vo}) d_{gap}$$

Repeat steps 101-106 at different temperatures  $T_2, T_3 \dots T_n$  to calculate additional reaction rate constants  $k(T_2), k(T_3) \dots k(T_n)$ . The steps are repeated at least two times and more, and preferably at least three times and more. Each temperature is at least 5 °C greater than the previous temperature. Of course, the selection of temperatures and trial numbers depend upon the particular application.

Extract an activation energy  $E_{act}$  for a first order reaction from the data  $k(T_2), k(T_3) \dots k(T_n)$  at  $T_2, T_3 \dots T_n$  collected via step 109 by way of the following equation:

$$k_s(T) = A\sqrt{T} e^{\frac{-E_{act}}{RT}}$$

The activation energy is preferably calculated by a least square fit of data collected at step 109 or any other suitable statistical technique. By way of the same equation, the present method calculates surface reaction rate constant  $k_s$  at any temperature.

In step 111, a concentration  $n_o$  at the substrate edge is calculated. The concentration  $n_o$  deduces from the following relationship:

$$n_o = R_{os} / k_{vo,s}$$

where

$R_{os}$  is an etch rate.

From the concentration and the surface reaction rate, the particular etching step can be improved by way of adjusting selected etching parameters.

In an alternative specific embodiment, a method to "tune" a plasma source using a loading effect relationship (or equation) is illustrated by the simplified flow diagram 200 of Fig. 4. The method includes a step 201 of measuring an etch rate against an effective etchable area  $A_w$ . The effective etchable area changes by varying the number  $m$  of wafers in the reactor, varying the size of the wafer, or the like. The effective area can be changed 209 by altering a gap between a wafer and its above surface 211, changing wafer quantity in the reactor 213, and varying substrate support member dimensions 215. The method preferably occurs at constant temperature and pressure. However, the effective etchable area may also be varied by way of changing a temperature and/or a pressure.

The method calculates a uniformity value (step 217) from the measured values of etch rate vs. effective area in steps 211, 213, and 215. The uniformity is calculated by, for example:

7130X  
 7130X

$$uniformity = 100 \times \frac{R_{MAX} - R_{MIN}}{2 \sum_{i=1}^m \frac{R_i}{m}}$$

where

20  $R_{MAX}$  is a maximum etch rate;  
 $R_{MIN}$  is a minimum etch rate;  
 $m$  is a sample number;  
 $R_i$  is a general etch rate for an  $i$ th sample;  
 uniformity is a planarity measurement in  
 25 percentage.

In a specific embodiment, a uniformity of about 90% and greater or preferably 95% and greater indicates that the effective area of the substrate is substantially equal to the actual substrate area (step 221) via branch 216. Of course,  
 30 other methods of calculating a uniformity from etch rates and effective areas may also be used depending upon the particular application. Alternatively, an etching profile is measured and the effective area  $A_{eff}$  is calculated (step 219) by way of, e.g., the loading effect relationship.

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At least two and more different effective etchable areas (step 223) are measured, or preferably at least three and more different etchable areas are measured.

Alternatively, the flow diagram returns via branch 224 to step 209, and takes another etch rate measurement at a different effective area. The flow diagram then turns to step 203.

In step 203, a supply of etchant  $S^T$  in the reactor is calculated. Based upon the different etchable areas a slope  $mA_{eff}$  deduces from the loading effect relationship as follows.

$$\frac{1}{R_{os}(m)} = \frac{1}{k_s n_o} = \frac{k_r A_r + F}{k_s S^T} + \frac{mA_{eff}}{S^T}$$

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T1407  
R

where  $R_{os}(m)$  is the etching rate at the boundary between the plate stack zone and transport zone when  $m$  substrates are present in the reactor. The first term includes a recombination term proportional to the total effective area  $A_r$  which acts to catalyze loss of etchant on reactor surfaces in the reactor plus a convection term  $F$ . The second term is the loading effect relation, where the reciprocal etch rate is proportional to the amount of effective etchable substrate area  $A_{eff}$  times the number of substrates  $m$ . When the etching across a substrate is uniform,  $A_{eff}$  is the geometrical substrate area  $A_w$ . When etching is nonuniform, on the other hand,  $A_{eff}$  is a function of  $k_{vo}/D$  and geometrical reactor dimensions. The supply of etchant  $S^T$  may be calculated for a different plasma source or plasma source parameters such as temperature, pressure, or the like by repetition 207 of steps 201 and 203. By way of the supply of etchant to the reactor, other plasma source parameters may be varied to obtain desired etching rates and uniformity for the particular reactor.

Step 205 provides for the modification of chamber materials and the like to reduce slope numerator ( $k_r, A_r + F$ ) in selecting the desired etching conditions. The chamber materials can be modified to reduce, for example, the recombination rate in the reactor. The recombination rate is directly related to the effective reactor recombination area  $A_r$ . In step 205, the recombination rate can be adjusted by

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changing  $A_r$  via changing chamber material, coating chamber surfaces with, for example, a product sold under the trademark TEFLON™ or KALREZ™ and the like, among others. Alternatively, the slope numerator flow term  $F$  is reduced when  $F$  contributes as a substantial loss term. Of course, the particular materials used depend upon the application.

In step 207, the method changes plasma source parameters such as rf power, flow rate, and the like to select desired etching conditions. Once one of the aforementioned parameters is adjusted, the method returns to step 201 via branch 208. At step 201, an etch rate vs. effective etchable area is measured and the method continues through the steps until desired etching condition are achieved. Of course, other sequences of the aforementioned steps for tuning the plasma source may also exist depending upon the particular application.

Fig. 5 is a simplified flow diagram for a method of selecting a desired uniformity and desired etching parameters within selected ranges to provide a desired etch rate for a particular etching process. The etching parameters include process variables such as reactor dimensions, a pressure, a temperature, and the like for a particular substrate and reactants. Other etching parameters may also be used depending upon the particular application.

In step 301, select a uniformity for the selected substrate and the reactants. The selected uniformity becomes an upper operating limit for the reaction according to the present method. The upper operating limit ensures a "worst case" uniformity value for an etched substrate according to this method. Uniformity can be defined by, for example:

T150X  
D  
D

$$uniformity = 100 \sqrt{\frac{R_{MAX} - R_{MIN}}{2 \sum_{i=1}^m \frac{R_i}{m}}}$$

where

$R_{MAX}$  is a maximum etch rate;

$R_{MIN}$  is a minimum etch rate;

$m$  is a sample number;

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$R_i$  is a general etch rate for an  $i$ th sample;  
 uniformity is a planarity measurement in  
 percentage.

In certain embodiments, the selected uniformity ranges from  
 5 about 90 % and greater or more preferably 95 % and greater.  
 Of course, other uniformity values may be selected based upon  
 the particular application.

Based upon the selected uniformity, use the selected  
 uniformity as a starting point to extract a plurality of  
 10 reaction rate constants  $k_g$ . The reaction rate constants may  
 be also be obtained by an input activation energy for the  
 etching process, among other techniques (step 303).  
 Alternatively, calculate  $k_g$  at one or more temperatures, and  
 preferably two or more temperatures (step 303) from a  
 15 plurality of uniformity values. The uniformity values can be  
 within the selected uniformity or outside the selected  
 uniformity.

In step 307, prepare an array of etching parameters  
 including a temperature  $T$ , a pressure  $P$ , a characteristic  
 20 reactor dimension, and a uniformity value. In an embodiment,  
 the characteristic reactor dimension can be a gap  $d_{gap}$  between  
 the substrate and its adjacent surface. The array of etching  
 parameters can be illustrated by way of a three dimensional  
 plot.

An example of such array is illustrated by way of a  
 25 three dimensional plot 500 in Fig. 5A. It should be noted  
 that the illustration is merely an example of one application  
 of the specific embodiment, and other examples can readily be  
 determined by one of ordinary skill in the art. The plot  
 30 includes a temperature axis, a pressure axis, and a gap axis.  
 Each square region 501 represents a point defined by a  
 specific temperature, pressure, and gap. Each square region  
 501 also includes a gray scale. Each different gray scale  
 corresponds to a different uniformity value. In this example,  
 35 the darker gray scale values 505 represent lower uniformity  
 values than the lighter gray scale values 507.

Based upon the array, compute locus of highest  $T$ , <sup>VERSUS</sup> ~~VS~~  
 $P$  and  $d_{gap}$ , and of highest  $P$ , <sup>VERSUS</sup> ~~VS~~  $T$  and  $d_{gap}$  511 where



uniformity meets the specification, e.g., the selected uniformity from step 301. All points bounded within the highest  $T_j$  <sup>versus</sup>  $P$  and  $d_{gap}$ , and the highest  $P_j$  <sup>versus</sup>  $T$  and  $d_{gap}$  fall within the uniformity specification. Points outside the highest  $T_j$  <sup>versus</sup>  $P$  and  $d_{gap}$  and the highest  $P_j$  <sup>versus</sup>  $T$  and  $d_{gap}$  fall outside the uniformity specification. The points that fall within the uniformity specification defines the calculated uniformity limit manifold having outer boundaries at  $P_o$  and  $T_o$ .

In the calculated uniformity limit manifold, select a gap  $d_{gap}$ , and adjust a locus of  $P$  and  $T$  below the calculated uniformity limit manifold by a predetermined amount to allow for statistical and experimental error and process drift. This step defines a new uniformity limit manifold, and ensures that points defined by a temperature, a pressure, and a gap, selected during subsequent steps fall within the selected uniformity (step 301) despite any error or process drift from the calculation. The new uniformity limit manifold includes outer boundaries at  $P_i$  and  $T_i$  which are respectively less than  $P_o$  and  $T_o$ .

In step 311, a maximum edge etch rate  $R_o$ , and supply of etchant from a plasma source ( $S$ ) for a selected rf power, a reactant flow, a pressure, a temperature, and a gap within the new uniformity limit manifold is determined. The maximum edge etch rate can be used in defining a desired flow rate of source chemicals. Once the desired flow rate is determined, it should be held constant during subsequent steps in the embodiment.

A step (step 313) of locating an intersection space of  $P < P_i$ ,  $T < T_i$ , and a maximum etch rate (or an etchant supply) at selected rf power values is included. The intersection of space defines a maximum etch rate for the selected pressure  $P$ , temperature  $T$ , and gap  $d$ . Of course, other etching parameters may be adjusted depending upon the particular application.

The method provides a resulting etch rate from the etching reaction using the aforementioned parameters which is compared with a desired etch rate. If the resulting etch rate

is too low (or high), change power and/or reduce the effective etchable area, e.g., increase  $d_{gap}$ , decrease number of substrates, use smaller substrates, and the like. Of course, other sequences of steps may be used in selecting a desired temperature, pressure, gap, and other parameters to provide the desired etch rate. The embodiment provides for a desired etch rate with a selected uniformity based upon a range of temperatures, pressures, and gap values, all within the selected uniformity specification.

### Theoretical Model of Apparatus

#### 1. Plasma Generating Zone

In the specific embodiment, the plasma generating zone can be modeled as a "black box" where etchant flow of reactant species from the plasma generating source is determined from an etching rate at the plate stack zone. In particular, the etching rate is proportional to a product  $n_o k_s$  of etchant concentration  $n_o$  above an etchable material film surface and an etching reaction rate constant  $k_s$ . The etching reaction rate constant  $k_s$  can be independently determined from uniformity data previously noted. Since the relative change in  $n_o k_s$  and the absolute value of  $k_r$  (the <sup>effective</sup> surface recombination rate per unit reactor area) can be determined,  $n_o$  is easily extracted and used to study the effects of discharge and surface parameters on production of etchant species in the plasma generating zone. Accordingly, the efficiency of radical production by the plasma generating zone (the source term in a mass the mass balance of  $n_o$ ) as a function of various parameters (pressure, power, temperature, etc.) can be extracted from indirect measurements.

#### 2. Transport Zone

In the specific embodiment, etchant species concentrations in the transport space zone are approximated as "well-mixed". In the well-mixed embodiment, substantially all etchant species in the transport space zone are supplied by the plasma generating zone and are removed by at least:

- 1) etching reactions in the plate stack zone;

2) recombination; or 3) convection by flow out of the reactor. A supply  $S^T$  of etchant from the plasma generating zone is equated to the three aforementioned loss terms as follows:

$$S^T = k_r A_r n_o + mA_{eff} k_s n_o + F n_o$$

5 where  $k_r A_r$  is an effective loss term with regard to recombination effects,  $k_s$  is an etching reaction rate constant,  $A_{eff}$  is an effective etchable area of a substrate,  $n_o$  is the etchant concentration,  $m$  is the number of substrates and  $F$  is the gas flow rate out of the reactor. The equation may be rewritten in the form of a canonical loading effect  
10 relationship:

T190X

$$\frac{1}{R_o(m)} = \frac{1}{k_s n_o} = \frac{k_r A_r + F}{k_s S^T} + \frac{mA_{eff}}{S^T}$$

where  $R_o(m)$  is the etching rate at the boundary between the plate stack zone and transport zone when  $m$  substrates are present in the reactor, and the first term includes a recombination term proportional to the total effective area  $A_r$   
15 which acts to catalyze loss of etchant on reactor surfaces plus convection  $F$ . The second term is the loading relation, wherein the reciprocal etch rate is proportional to the amount of effective etchable substrate area  $A_{eff}$  times the number of substrates  $m$ . When the etching across a substrate is uniform,  
20  $A_{eff}$  is the geometrical substrate area  $A_w$ . When etching is nonuniform, on the other hand,  $A_{eff}$  is a function of  $k_{vo}/D$  and geometrical reactor dimensions. Accordingly,  $A_{eff}$  becomes a function of parameters such as temperature, pressure, reactor configuration, and the like.

25 Fig. 6 shows etch rate data vs. the number of substrates in a reactor along with a line corresponding to the loading effect relationship in the form

T191X

$$\frac{1}{\text{Ash Rate}} = C_o + C_1 m A_w$$

where

$$C_o = 0.00030171936426 \text{ min/\AA;}$$

and  $C_I A_w = 2.3003912550 \times 10^{-5}$  are best fit constants for the conditions in Fig. 6. The equation gives an etching rate at the edge of the plate stack zone as a function of the number of substrates  $m$  and etchable exposed effective surface of a substrate  $A_{eff}$ . Other variables such as the temperature, etchant generation rate, flow rate, and reactor size parameters were held constant. While  $R_o(m)$  as written strictly applies to the etch rate at the edge of a substrate, <sup>when etching uniformity is high the</sup> etching rates at any other fixed relative position on the substrates are related to  $R_o(m)$  by a constant factor of proportionality, and so they will also conform to the form of these relations.

In the general case where etching is nonuniform across a substrate, the equivalent area  $A_w$  is smaller than the geometrical substrate area by a constant factor as a function of  $k_{vo}/D$ . It turns out that  $k_g$  can be independently deduced from the profile of the etching rate in the stack zone, and in turn permits the absolute value of  $n_o$  to be computed from the etching rate  $R_o(m)$  at the edge of a substrate. If the slope of the isothermal loading effect curve

$$\frac{\partial \left[ \frac{1}{k_g n_o} \right]}{\partial m} = \frac{A_w}{S^T}$$

is measured along with etching uniformity, the rate of etchant supplied by the source  $S^T$  can be found by for substituting  $A_{eff}(k_{vo}/D)$  evaluated on the basis of etching uniformity measurements.

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### 3. Stack Zone

For etchant mass transport from the transport zone into the plate stack zone, the distance between stacked wafers  $d_{gap}$  is small compared to the lineal dimensions of a substrate in the embodiment. Consequently, it will be assumed that the concentration is substantially uniform in the axial  $z$  direction and there is equi-molal, isothermal, and isobaric counter-diffusion (e.g., no net flux,  $\Sigma n_1 = 0$ )  $x$  and  $y$  directions. Since the ashing reaction is proportional to  $n_o$ ,

and O-atom consumption is proportional to the ashing rate, the continuity equation for O-atoms in two dimensions becomes:

T211X

$$\frac{\partial n_o}{\partial t} + \nabla \cdot n_o v = -k_{vo} n_o$$

where  $k_{vo}$  is the volume equivalent surface reaction rate constant, and  $v$  is the diffusive velocity of oxygen atoms.

5 Inserting Fick's law

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$$n_o v = -D \nabla n_o$$

the diffusion equation is obtained

o T211X

$$\frac{\partial n_o}{\partial t} - \nabla \cdot (D \nabla n_o) = -k_{vo} n_o$$

And at steady-state in two dimensions and where  $D$  is not a function of spatial coordinate(s), it is rewritten as

T212X

$$\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = \frac{k_{vo}}{D} u$$

where  $u(x, y) = n_o(x, y) / n_{o0}$  and  $n_{o0}$  is the etchant concentration at the outer edges of the substrates. The boundary conditions are therefore  $u = 1$ . The equation is cast in dimensionless form as

T213X

$$\frac{\partial^2 u}{\partial^2 (x/L_x)} + \frac{\partial^2 u}{\partial^2 (y/L_y)} = \frac{k_{vo}}{D} u$$

where  $L_x$  and  $L_y$  are characteristic independent lengths and widths of substrates. From this equation, it is clear that

15  $u(x/L_x, y/L_y)$  is a function solely of  $k_{vo}/D$  and the boundary conditions. Consequently, if experimental values of  $u(x/L_x, y/L_y)$  are measured at two positions on the substrate (i.e., at the center and edge), two algebraic equations based on this measurement can be used to eliminate  $n_{o0}$  and solve for  $k_{vo}/D$ . The diffusivity  $D$  can be calculated to good accuracy with the Hirshfelder equation; hence,  $k_{vo}$  is measured with this procedure.

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For circular substrates, there is only one independent dimension (e.g., where  $r=a$  is the substrate

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radius). At steady state in one dimensional cylindrical coordinates the equation can be written:

$$\frac{1}{r} \frac{\partial (r \frac{\partial u}{\partial r})}{\partial r} + \frac{\partial u}{\partial z} = \frac{k_{vo}}{D} u$$

where  $u(r) = n_o(r)/n_{o0}$  and the boundary condition is  $u(a) = 1$  at the substrate (wafer) edge.

5 In the subsequent sections, analytic solutions to these relationships are developed for rectangular and circular substrates (e.g., for flat panel display substrates and semiconductor wafers). The framework is used to derive  
10 uniformity relationships for flat panel resist stripping equipment.

#### Examples

##### 1. Circular Substrate (Wafer) Stacked Etcher

15 To prove the principles of the aforementioned embodiments, the present method and apparatus was applied to etching of circular substrates in a stacked etcher. Of course, the present method and apparatus can be applied to other geometries and etcher types. The present example is therefore not intended to be limiting in any way. The present  
20 method and apparatus is applied to the circular substrates as illustrated by way of Fig. 7. The present method relies upon etching of substrate material  $S$  by way of oxygen using a reaction which is substantially chemical etching.

25 An illustration of a circular substrate according to the present invention is shown in Fig. 8. Assume that the distance  $d_{gap}$  between stacked wafers is relatively small compared to the wafer radius  $a$  such that  $d_{gap} \ll a$ . Based upon the assumption, the oxygen concentration will be  
30 substantially uniform in the axial direction  $z$ . Accordingly, only radial diffusion in the  $r$ -direction needs consideration. Assuming an equi-molal counterdiffusion

$$\sum_{i=1}^m n_i v_i = 0$$

and an isobaric and isothermal stack zone, the problem reduces to two dimensions and becomes

$$\frac{1}{r} \frac{\partial (r \frac{\partial u(r)}{\partial r})}{\partial r} = \frac{k_{vo}}{D} u(r)$$

where  $u(r) = n_o(r)/n_{o0}$ . The boundary condition is  $u(a) = 1$  at a wafer edge, and the solution of the equation becomes

$$u(r) = c_1 I_0 \left( \sqrt{\frac{k_{vo}}{D}} r \right) + c_2 K_0 \left( \sqrt{\frac{k_{vo}}{D}} r \right)$$

where  $I_0$  and  $K_0$  are modified Bessel functions of the first and second kind, respectively, and  $c_1$  and  $c_2$  are constants. For a finite, normalized oxygen concentration  $u(0)$  at the center of the wafer, the equation requires  $c_2 = 0$ . The remaining boundary condition of  $u(a) = 1$ , sets the solution:

$$u(r) = \frac{I_0 \left( \sqrt{\frac{k_{vo}}{D}} r \right)}{I_0 \left( \sqrt{\frac{k_{vo}}{D}} a \right)}$$

- 10 Note that the functional form  $u(r)$  describes both the relative etch rate profile  $R_o(r)/R_o(a)$  and the relative oxygen atom etchant concentration  $n_o(r)/n_o(a)$ . The relative etch rate profile can easily be obtained by measuring an etching rate profile on a circular substrate made by way of the present
- 15 method.

Fig. 9 is a simplified plot of a normalized stripping rate vs. radial distance from a wafer center for the circular substrate example. The plot shows a profile of  $u(r)$  for  $k_{vo}/D = 0.1$ , and an  $a = 150$  mm. As can be seen, the

20 normalized stripping rate is lower at a center region of the wafer, and increases to 1 at the wafer edge. Based upon a slope of the plot, a reaction rate coefficient can be extracted by way of a diffusivity.

## 2. Rectangular Substrate Stack Asher

To further provide the principle and operation of the present method and apparatus, the present method and apparatus is applied to a rectangular substrate configuration in a stack asher. Again, the present example should not be taken as limiting the scope of the claims described herein, but is merely an example. An analytical solution for etching profiles in the stack zone are derived for etching/ashing a stack of rectangular substrates as illustrated in Fig. 9. The rectangular substrate can be a flat panel display such as a liquid crystal display (LCD) plate and the like in the coordinate system of Fig. 10. To solve an equation for the present rectangular configuration where  $D$  is not dependent upon spatial coordinates, write the solution as:

$$u = u_1 + u_2$$

where  $u_1$  is satisfied by the following equation

$$\frac{\partial n_o}{\partial t} - D\nabla^2 n_o = -k_{vo}n_o$$

where  $u_1 = 0$  at  $y = \pm b/2$ ;

and  $u_2$  is a solution that is 0 at  $x = \pm a/2$ .

The solution for  $u_1(x, y) = X(x)Y(y)$  is obtained by a separation of variables as follows.

$$\frac{\partial \left[ \frac{\partial X}{\partial x} \right]}{X} + \frac{\partial \left[ \frac{\partial Y}{\partial y} \right]}{Y} = \lambda^2 = \lambda_x^2 - \lambda_y^2 = \frac{k}{D}$$

The sign of the sum decomposing  $\lambda^2$  is chosen so that  $X(x)$  and  $Y(y)$  both have real values, as shown below. Since the boundary conditions on  $Y(y)$  are:

$$Y(-b/2) = Y(b/2) = 0$$

the solution is,

$$Y = c_y \cos \lambda_y y.$$

From the boundary conditions,  $c_y = m/b$  where  $m = 1, 3, 5, \dots$

Similarly, the solution for  $X$  is

~~where  $\lambda_x$  is given by:~~



where  $\lambda_x$  is given by  $X = c_x \cosh \lambda_x x$ ,

$$\lambda_x = \sqrt{k_{vo}/D + (m\pi/b)^2}.$$

The general solution is the sum:

$$u_1 = \sum_m c_m \cosh[\sqrt{k_{vo}/D + (m\pi/b)^2} x] \cos \frac{m\pi y}{b},$$

where  $c_m = 0$  for  $m = 0, 2, 4, \dots$  to satisfy the boundary conditions. Setting  $u_1(a/2, y) = f(y)$ , where  $f(y)$  is the even-function square wave of magnitude 1, the Fourier series is obtained,

$$c_m \cosh[\sqrt{k_{vo}/D + (m\pi/b)^2} \frac{a}{2}] = \frac{2}{b} \int_0^b f(y) \cos \frac{m\pi y}{b} dy$$

and after the integration

$$c_m \cosh[\sqrt{k_{vo}/D + (m\pi/b)^2} \frac{a}{2}] = \frac{4}{m\pi} \sin \frac{m\pi}{2}$$

which is zero when  $m$  is even, as required. Thus, the  $u_1$  part of the solution can be written

$$u_1(x, y) = \sum_{m=1}^{\infty} \frac{4}{m\pi} \sin \frac{m\pi}{2} \frac{\cosh[\sqrt{k_{vo}/D + (m\pi/b)^2} x]}{\cosh[\sqrt{k_{vo}/D + (m\pi/b)^2} \frac{a}{2}]} \cos \frac{m\pi y}{b}$$

$m=1, 3, 5, \dots$

Note that  $u_1(a/2, y) = 1$  for  $(-b/2 < y < b/2)$ . The solution for  $u_2$  can be obtained in a similar way. The solution is then

$$u(x, y) = \sum_{m=1}^{\infty} \frac{4}{m\pi} \sin \frac{m\pi}{2} \left\{ \frac{\cosh[\sqrt{k_{vo}/D + (m\pi/b)^2} x]}{\cosh[\sqrt{k_{vo}/D + (m\pi/b)^2} \frac{a}{2}]} \cos \frac{m\pi y}{b} + \frac{\cosh[\sqrt{k_{vo}/D + (m\pi/a)^2} y]}{\cosh[\sqrt{k_{vo}/D + (m\pi/a)^2} \frac{b}{2}]} \cos \frac{m\pi x}{a} \right\}$$

where  $m$  is odd. As  $b \rightarrow \infty$ , this approaches the solution for 1-dimensional diffusion (corresponding to an infinitely long strip):

$$u(x) = \frac{\cosh\left[\sqrt{k_{vo}/D}x\right]}{\cosh\left[\sqrt{k_{vo}/D}\frac{a}{2}\right]}$$

Two-dimensional

The previous equation is now applied to interpret ashing uniformity data and predict uniformity and the atomic oxygen concentration profile  $n_o$  along the surface of a substrate for selected operating conditions. To use the relationship, values of  $k_{vo}$  and  $D$  are required. For atomic oxygen diffusing through  $O_2$ , diffusivity was computed as  $D(\text{cm}^2/\text{s}) = 0.044T^{3/2}$  (T is in K) <sup>using relations in</sup> ~~from~~ J.O. Hirschfelder, C.F. Curtiss, R.B. Byrd, "Molecular Theory of Gases and Liquids," pp. 538-541 and 578-582, John Wiley & Sons, 2nd Printing (1963), which is hereby incorporated by reference for all purposes. Of course, other techniques for calculating the diffusivity also exist.

In general,  $k_{vo}$  will be a function of at least gap, resist composition, temperature, and other parameters. In an example,  $k_{vo}$  is unknown, although the activation energy for resist ashing is conventionally reported to be in the 11-12 kCal range from industry literature. However, the solutions for  $u(x,y)$  depend only on  $k_{vo}/D$  and geometrical chamber dimensions such as gap (as incorporated into  $k_{vo}$ ),  $a$ ,  $b$ , and the like. Accordingly,  $k_{vo}/D$  is deduced from the etching rate profile, as previously described.

In particular,  $k_{vo}/D$  can be obtained from measurements of the amount of resist removed at two independent points (points where the theoretically predicted etch depth ratios  $u(x_1, y_1)$ ,  $u(x_2, y_2)$  are unequal by solving the appropriate equation for  $k_{vo}/D$  and <sup>substituting</sup> ~~substitute~~ for  $D(T,P)$ . But the present example used a more robust procedure: determine  $k_{vo}/D$  from a least squares fit to the entire experimental etch profile data set taken by a conventional stylus profilometer.

Fig. 1 shows an experimental etching profile data taken on a 30x30 cm resist-covered substrate spin-coated with 2.1 microns of MCPR 200 resist (Mitsubishi Chemical Corp., equivalent to Tokyo Ohka Kogyo Co. OFPR 800). A vertical axis

1201 defines an ashing rate  $R_o$  with respect to an x-direction 1203 and a y-direction 1205. A grid pattern 1207 represents a "fitted" surface region via aforementioned equation representing ashing rates. Actual data points for each ashing rate are defined as the circular points 1211, and plots representing the fitted surface region are defined as cross points 1209. Ashing rate is greater around the periphery of the substrate, than substrate center regions.

The reactor held 1.1 mm thick substrates with a 28.9 mm gap ( $d_{gap}$ ) above the wafer. A 4 kW rf power source <sup>sustained</sup> drove a plasma with pure oxygen gas flowing into the reactor at 3 liters/min. Thermocouple sensors and heaters kept the reactor chamber and substrates at  $T=220$  °C during the etch process, and a throttle valve maintained pressure at  $P=1.2$  Torr.

Etching occurred for 5 min. Resist thickness was measured before and after etching using a Nanometrics Model 210 Nanospec Auto Film Thickness Monitor. The surface of Fig. <sup>12</sup> ~~11~~ represents a least squares fit <sup>to</sup> the aforementioned equation for  $u(x,y)$  with  $k_{vo}/D$  as the only adjustable parameter. The least squares fit gives  $k_{vo}/D=0.047$ . At  $P=1.27$  Torr and  $T=493$  K into  $D(\text{cm}^2/\text{s})=0.044T^{3/2}$  yields  $D=400$   $\text{cm}^2/\text{s}$ . By way of the relationship  $k_{vo}/D=0.047$ , the etch rate constant is now  $k_{vo}=19.5$   $\text{sec}^{-1}$ . In the manner, e.g., by fitting profile data to the solution for given substrate geometry,  $k_{vo}$  can be measured under various process conditions. By way of  $k_{vo}$ , other parameters such as  $n_o$ ,  $k_s$ , and the like may also be calculated.

Once  $k_{vo}$  is known as a function of temperature, ashing rate and uniformity can be calculated as a function of reactor size parameters ( $a,b$ ) and process variables ( $p$ ,  $T$ , and  $n_o$ ). While the etching rate is proportional to  $n_{o0}$ ,  $n_{o0}$  does not affect the etch depth profile and need not be known to compute  $k_{vo}$ . However, after  $k_{vo}$  is obtained,  $n_{o0}$  can be computed from the experimentally measured etching rate per  $R_{res}=k_s n_{o0}$ . The procedure applies up to endpoint (endpoint is the time at which resist has been "stripped" and is no longer covering the region of the substrate where etching was fastest). At endpoint, resist begins to be cleared from the

substrate so that etchable area changes. Hence,  $n_{o0}$  will start to change (increase) after endpoint. The magnitude of  $n_{o0}$  during the steady-state period when resist is etching controlled by the plasma source, the number of substrates loaded into the reactor and (possibly) convective loss.

#### Predicting Etch Rate

The effect of profile uniformity on loading can be explicitly accounted for by defining a profile-average substrate area  $A_{n,eff}$

$$R_o \cdot A_{n,eff} = \iint A_{substr} k_{vo} n_o(x,y) dx dy = n_{o0} k_{vo} \iint_{substr} u(x,y) dx dy = n_{o0} k_{vo} A_{n,eff}$$

so that  $n_{o0} k_{vo} A_{n,eff}$  is the per substrate etchant consumption with nonuniformity resulting from effects of diffusion and reaction taken into account. Then for given plasma source (etchant supply), the etch rate/loading effect equation becomes:

$$\frac{1}{R_o(m)} = \frac{1}{k_g n_o} = \frac{k_r A_r + F}{k_g S^T} + \frac{m A_{eff}}{S^T}$$

All of the terms can be computed explicitly from etch rate profile data, except for the rate of etchant production by the source. The etchant production rate can be computed from two measurements of etching rate when changing  $k_{vo} A_{n,eff}$ .  $A_{n,eff}$  can be changed either by changing the number of substrates or changing the etch rate profile (with constant etchant supply).

The present invention provides a method of selecting uniformity in chemical plasma etching as a function of processing parameters. The present invention also provides for a method of measuring absolute gas-surface reaction rates in commercial processing equipment without the benefit of sophisticated diagnostic equipment.

Gas-surface radical reaction rates are often needed for the design of plasma processing equipment and for selection of desired reaction conditions. Unfortunately, few data are available on absolute reaction rates in systems of practical interest in the prior art. Most experimental data

have been taken in difficult flow tube experiments, or by related techniques which require reactant concentrations to be quantified using sophisticated methods such as gas-phase titration, laser fluorescence or mass spectrometry. These measurements require great care and specialized instrumentation. In contrast, the present invention describes a technique for measuring etching rate constants. It can be carried out in commercial processing equipment and the like, and it does not require sophisticated instrumentation, direct radical measurements, or the like. An isothermal reaction rate constant may be derived from a single measurement of etching uniformity. From this information, the etching rate uniformity as a function of substrate spacing and pressure can be computed. If experimental data on uniformity are taken at several temperatures, an intrinsic activation energy can be derived and the effects of temperature can be expressed analytically.

While the above is a full description of the specific embodiments, various modifications, alternative constructions and equivalents may be used. For example, while the description above is in terms of a plasma etching method, it would be possible to implement the present invention with other etching methods or the like.

Therefore, the above description and illustrations should not be taken as limiting the scope of the present invention which is defined by the appended claims.

WHAT IS CLAIMED IS:

1. An integrated circuit device fabrication method comprising the steps of:

providing a plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;

chemical etching said top film surface to define an etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile; and

extracting a reaction rate constant from said etch rate data, and using said reaction rate constant in adjusting said plasma etching apparatus.

Sub B1

Sub B2

~~2. The method of claim 1 wherein said chemical etching step is diffusion limiting.~~

Sub C3

3. The method of claim 1 wherein said spatial coordinates include a radius and an angle.

4. The method of claim 1 wherein said spatial coordinates include an x-direction and a y-direction.

Sub B3

5. The method of claim 1 wherein said extracting step correlates said reaction rate constant over a diffusivity with said an etching rate, said etching rate being defined by said etching profile.

Sub B4

~~6. The method of claim 1 wherein said etching rate is defined by said etching profile at selected spatial coordinates over a time.~~

~~7. The method of claim 1 wherein said chemical etching is an ashing method.~~

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~~8. The method of claim 1 wherein said ashing method comprises reactants including an oxygen and a photoresist.~~

9. A method of designing a reactor comprising the steps of:

providing a first plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;

chemical etching said top film surface to define an etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile; and

extracting a reaction rate constant from said etch rate data, and using said reaction rate constant in designing a second plasma etching apparatus.

~~10. The method of claim 9 wherein said chemical etching step is diffusion limiting.~~

11. The method of claim 9 wherein said spatial coordinates include a radius and an angle.

12. The method of claim 9 wherein said spatial coordinates include an x-direction and a y-direction.

~~13. The method of claim 9 wherein said extracting step correlates said reaction rate constant over a diffusivity with said an etching rate, said etching rate being defined by said etching profile.~~

14. The method of claim 9 wherein said etching rate is defined by said etching profile at selected spatial coordinates over a time.

~~15. The method of claim 9 wherein said chemical etching is an ashing method.~~

*By  
Amcd*

*Sub  
C5*

*Sub  
B5*

*BS  
Emell*  
~~16. The method of claim 9 wherein said ashing method comprises reactants including an oxygen and a photoresist.~~

<sup>18</sup>  
~~17. The method of claim <sup>10</sup> wherein said second plasma etching apparatus is a co-axial reactor.~~

<sup>19</sup>  
~~18. The method of claim <sup>10</sup> wherein said second plasma etching apparatus is a plasma etching apparatus.~~

*Sub.  
B6* → ~~19. A substrate fabrication method comprising:  
 providing a substrate selected from a group consisting of a semiconductor wafer, a plate, and a flat panel display, said substrate comprising a top surface;  
 forming a film overlying said top surface, said film comprising a top film surface;  
 chemical etching said top film surface to define a profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile; and  
 extracting a reaction rate constant from said etch rate data, and using said reaction rate constant in adjusting said method.~~

~~20. A method of fabricating an integrated circuit device, said method comprising:  
 providing a uniformity value for an etching reaction, said etching reaction including a substrate and etchant species;  
 defining etching parameters ranges providing said uniformity value; and  
 adjusting at least one of said etching parameters to produce a selected etching rate;  
 wherein said etching rate providing an etching condition for fabrication of an integrated circuit device.~~



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21. The method of claim 20 wherein said etching parameters can be selected from a group consisting of a temperature, a pressure, a power, a gap, and a flow rate.

Sub  
B7

~~22. The method of claim 20 wherein said uniformity ranges from 90% and greater.~~

~~23. The method of claim 20 wherein said uniformity ranges from 95% and greater.~~

add 93

Add  
B9

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## PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

## ABSTRACT OF THE DISCLOSURE

5 reactor design method includes steps of providing a first .  
plasma etching apparatus 10 having a substrate 21 therein.  
The substrate includes a top surface and a film overlying the  
top surface, and the film having a top film surface. The  
present reactor design method also includes chemical etching  
10 the top film surface to define a profile 27 on the film, and  
defining etch rate data from the profile region. A step of  
extracting a reaction rate constant from the etch rate data,  
and a step of using the reaction rate constant in designing a  
second plasma etching apparatus is also included.

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**DECLARATION AND POWER OF ATTORNEY**



As a below named inventor, I declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING** the specification of which  X  is attached hereto or   was filed on   as Application Serial No.   and was amended on   (if applicable).

I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56. I claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

**Prior Foreign Application(s)**

Country	Application No.	Date of Filing	Priority Claimed Under 35 USC 119
N/A			Yes <input type="checkbox"/> No <input type="checkbox"/>
			Yes <input type="checkbox"/> No <input type="checkbox"/>

I claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	Date of Filing	Status
N/A		<input type="checkbox"/> Patented <input type="checkbox"/> Pending <input type="checkbox"/> Abandoned
		<input type="checkbox"/> Patented <input type="checkbox"/> Pending <input type="checkbox"/> Abandoned

**POWER OF ATTORNEY:** As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

**WILLIAM J. BOHLER**, Reg. No. 31,487  
**RICHARD T. OGAWA**, Reg. No. 37,692  
**KENNETH R. ALLEN**, Reg. No. 27,301

Send Correspondence to: <b>WILLIAM J. BOHLER</b> TOWNSEND and TOWNSEND KHOURIE and CREW Steuart Street Tower One Market Plaza, 20th Floor San Francisco, CA 94105	Direct Telephone Calls to: (Name, Reg. No., Telephone No.)  Name: <b>WILLIAM J. BOHLER</b> Reg. No. 31,487 Telephone: 27,301
--	---

Full Name of Inventor 1	Last Name <b>FLAMM</b>	First Name <b>DANIEL</b>	Middle Name or Initial <b>L.</b>	
Residence & Citizenship	City <b>WALNUT CREEK</b>	State/Foreign Country <b>CALIFORNIA</b>	Country of Citizenship <b>U.S.A.</b>	
Post Office Address	Post Office Address <b>476 GREEN VIEW DRIVE</b>	City <b>WALNUT CREEK</b>	State/Country <b>CALIFORNIA</b>	Zip Code <b>94596</b>
Full Name of Inventor 2	Last Name <b>VERBONCOEUR</b>	First Name <b>JOHN</b>	Middle Name or Initial <b>.</b>	
Residence & Citizenship	City <b>HAYWARD</b>	State/Foreign Country <b>CALIFORNIA</b>	Country of Citizenship <b>U.S.A.</b>	
Post Office Address	Post Office Address <b>3350 OAKES DRIVE</b>	City <b>HAYWARD</b>	State/Country <b>CALIFORNIA</b>	Zip Code <b>94542</b>

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signature of Inventor 1	Signature of Inventor 2
<b>DANIEL L. FLAMM</b>	<b>JOHN VERBONCOEUR</b>
Date	Date

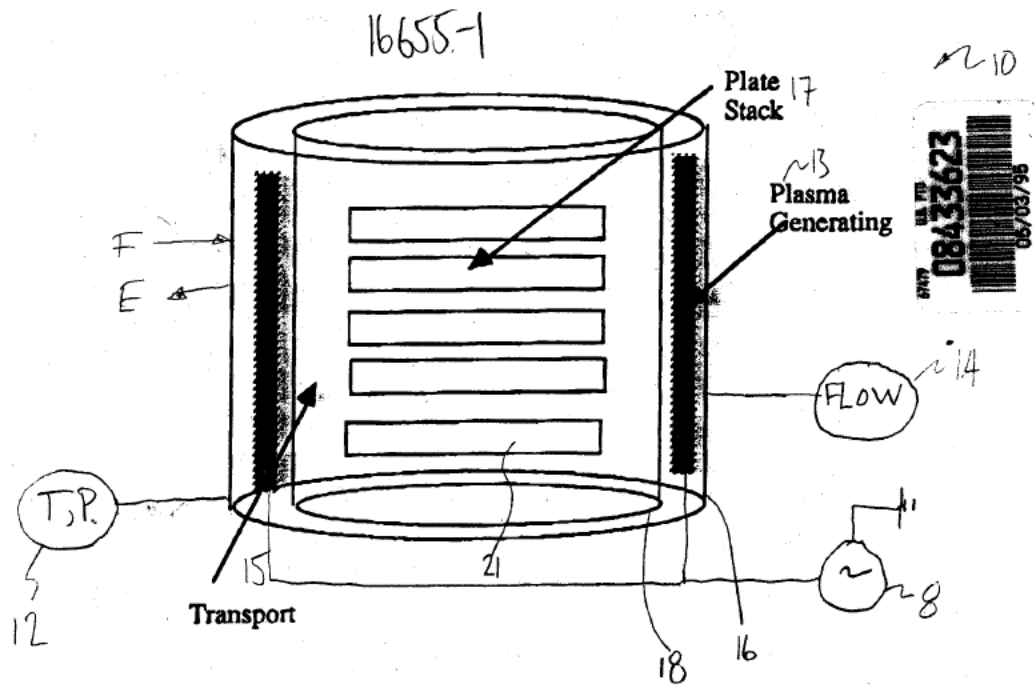


FIG. 1

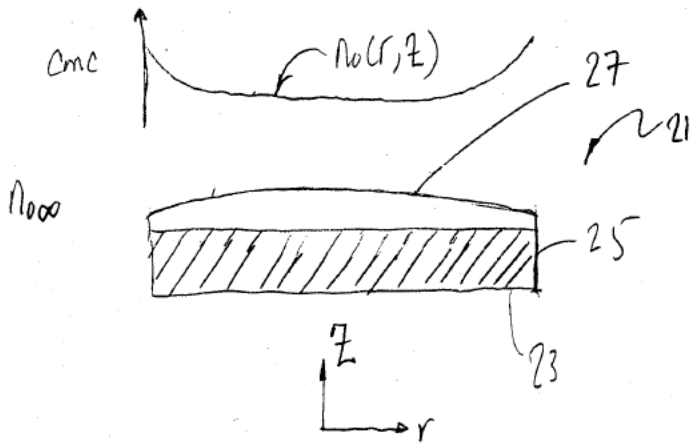


FIG. 1A

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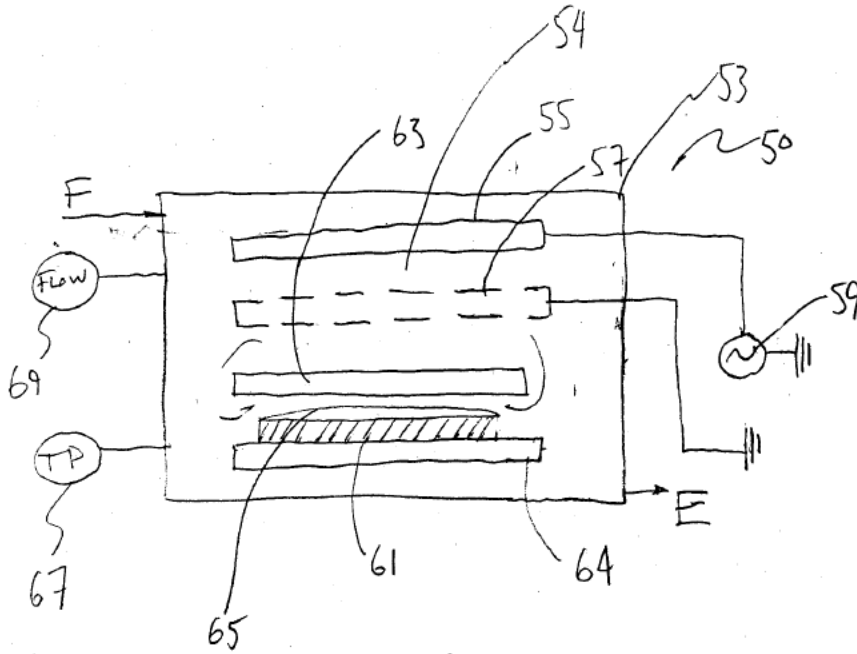


FIG. 2

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### Extract Rate Constant & Etch Rate from the Etch Rate Profile Data

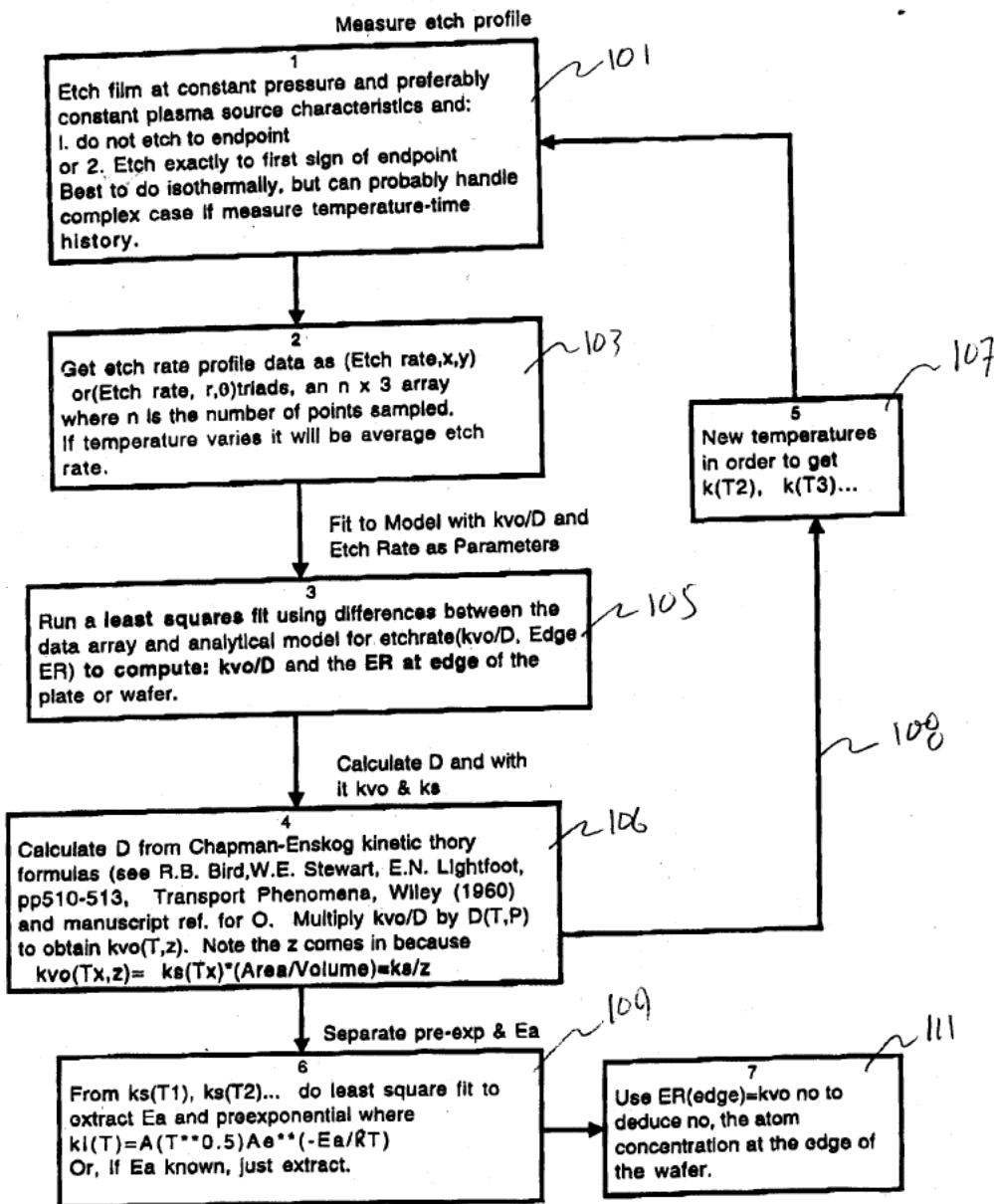


FIG. 3

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### Extract Plasma Source Intensity and "tune" the Plasma Source using Loading Effect Relationship

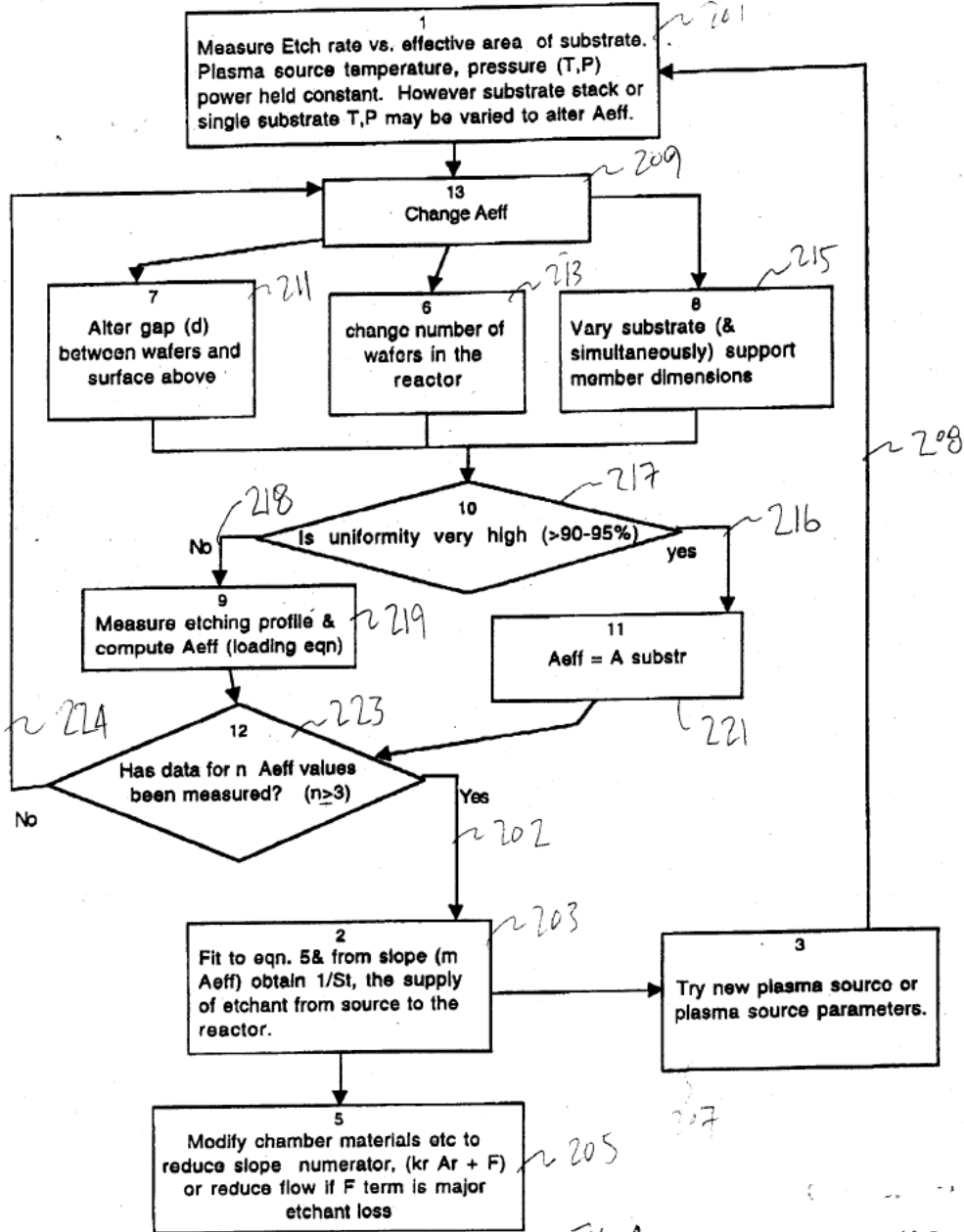


Fig 4



16655-1



### Optimize Etching Rate vs. P, T, rf Power with Uniformity Constraint

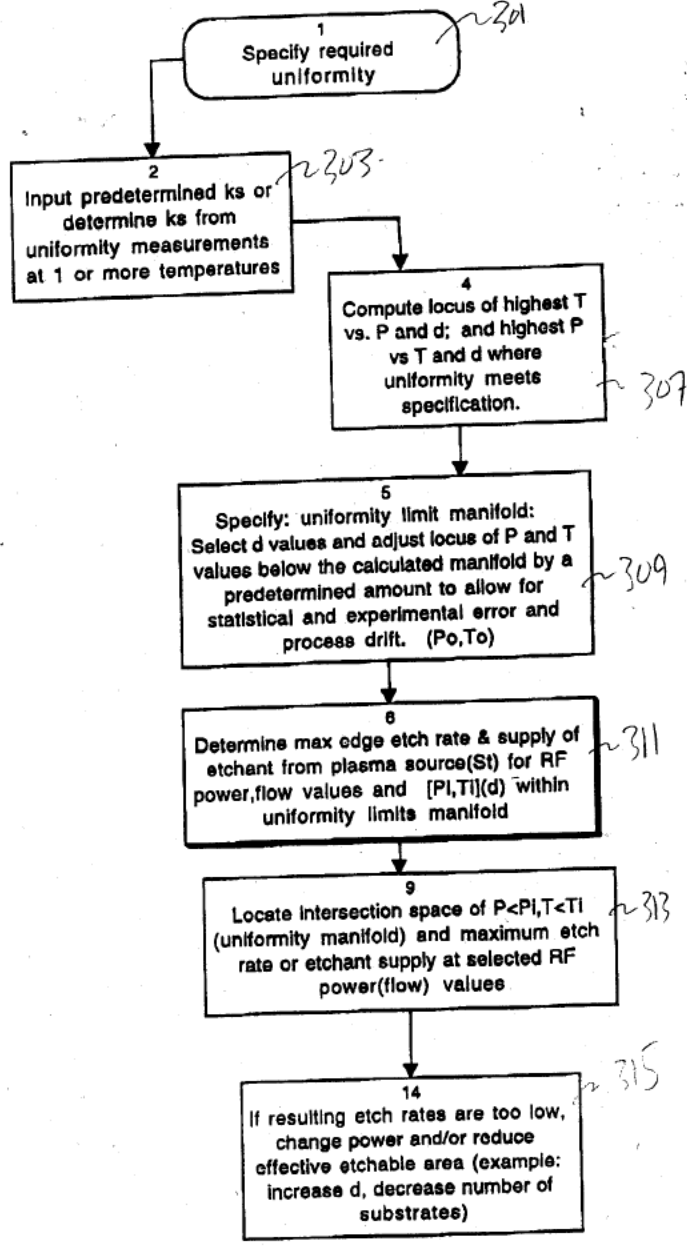


Fig. 5

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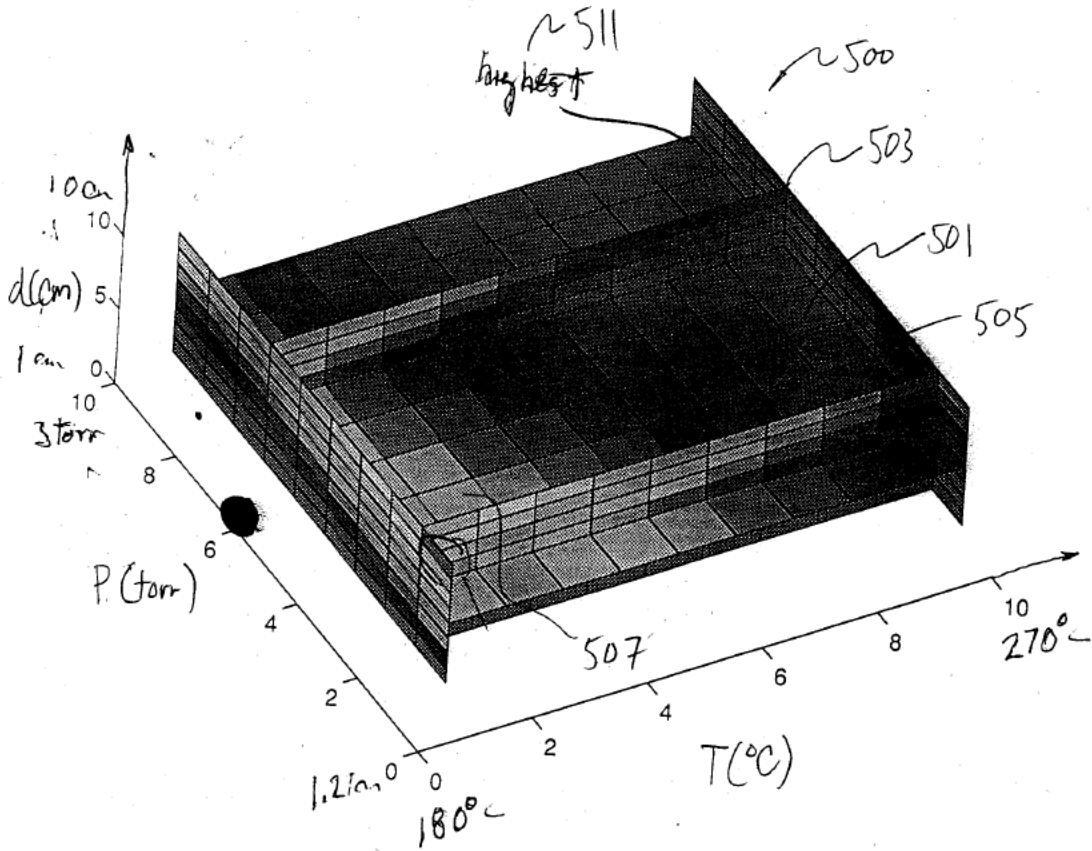


FIG. 5A

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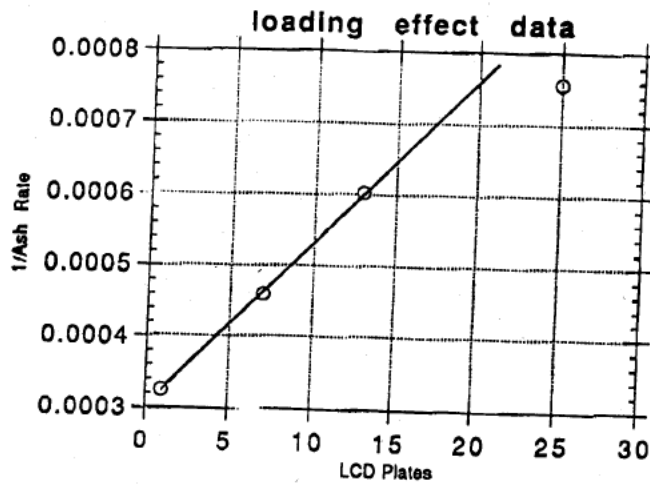


FIG. 0

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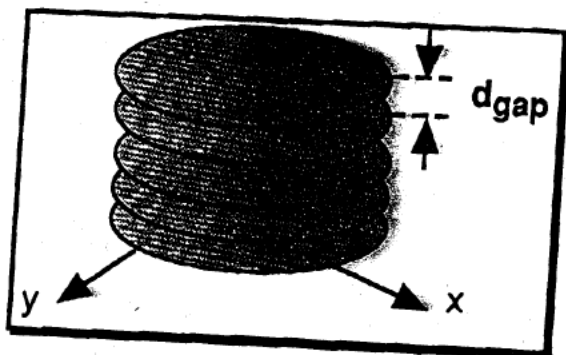


Fig. 7

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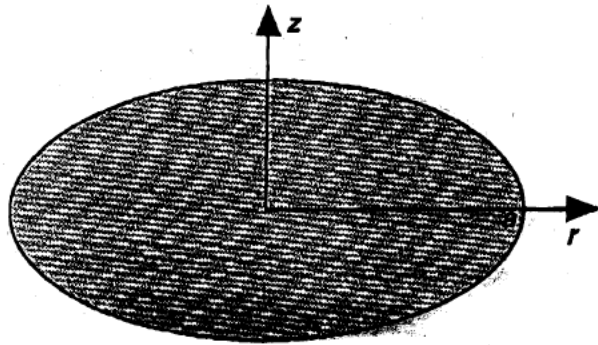


FIG. 9

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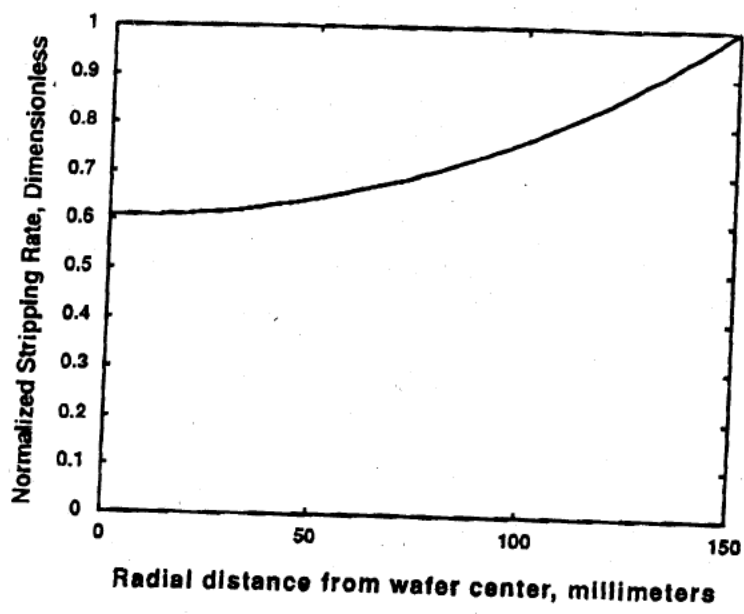


FIG. 9

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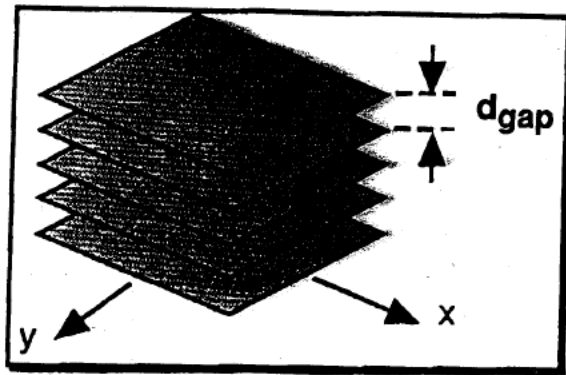


FIG. 10

16655-1

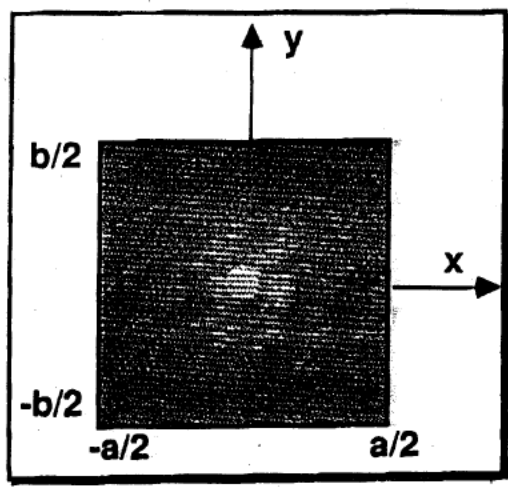


FIG. 11



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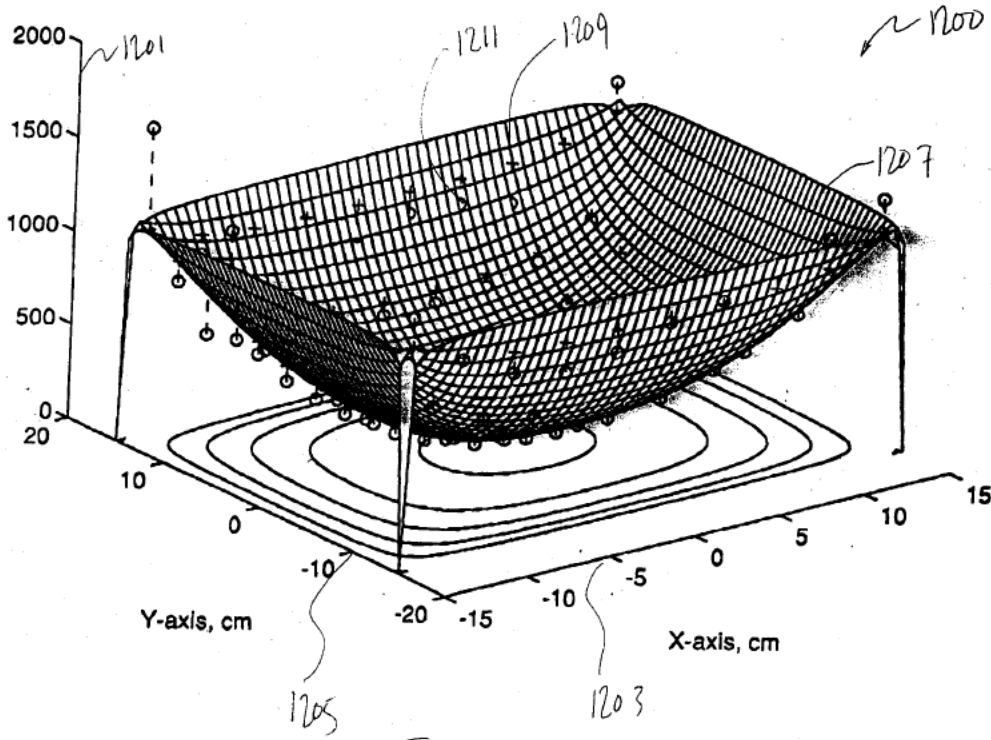


FIG. 12

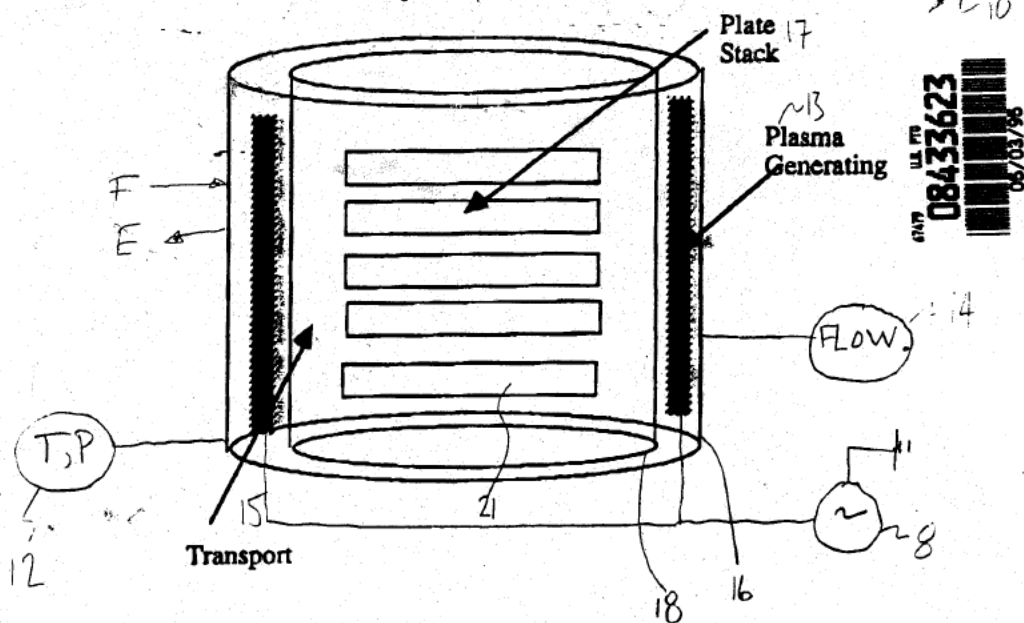


FIG. 1

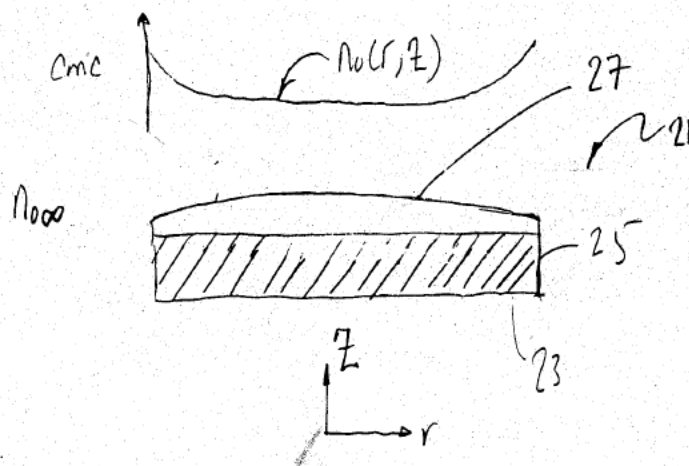


FIG. 1A

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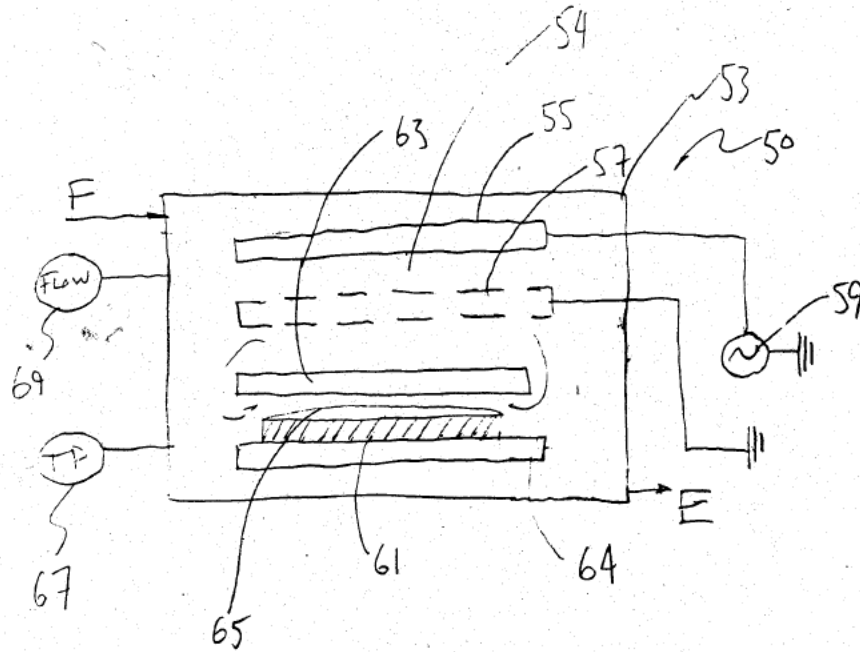


FIG. 2

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### Extract Rate Constant & Etch Rate from the Etch Rate Profile Data

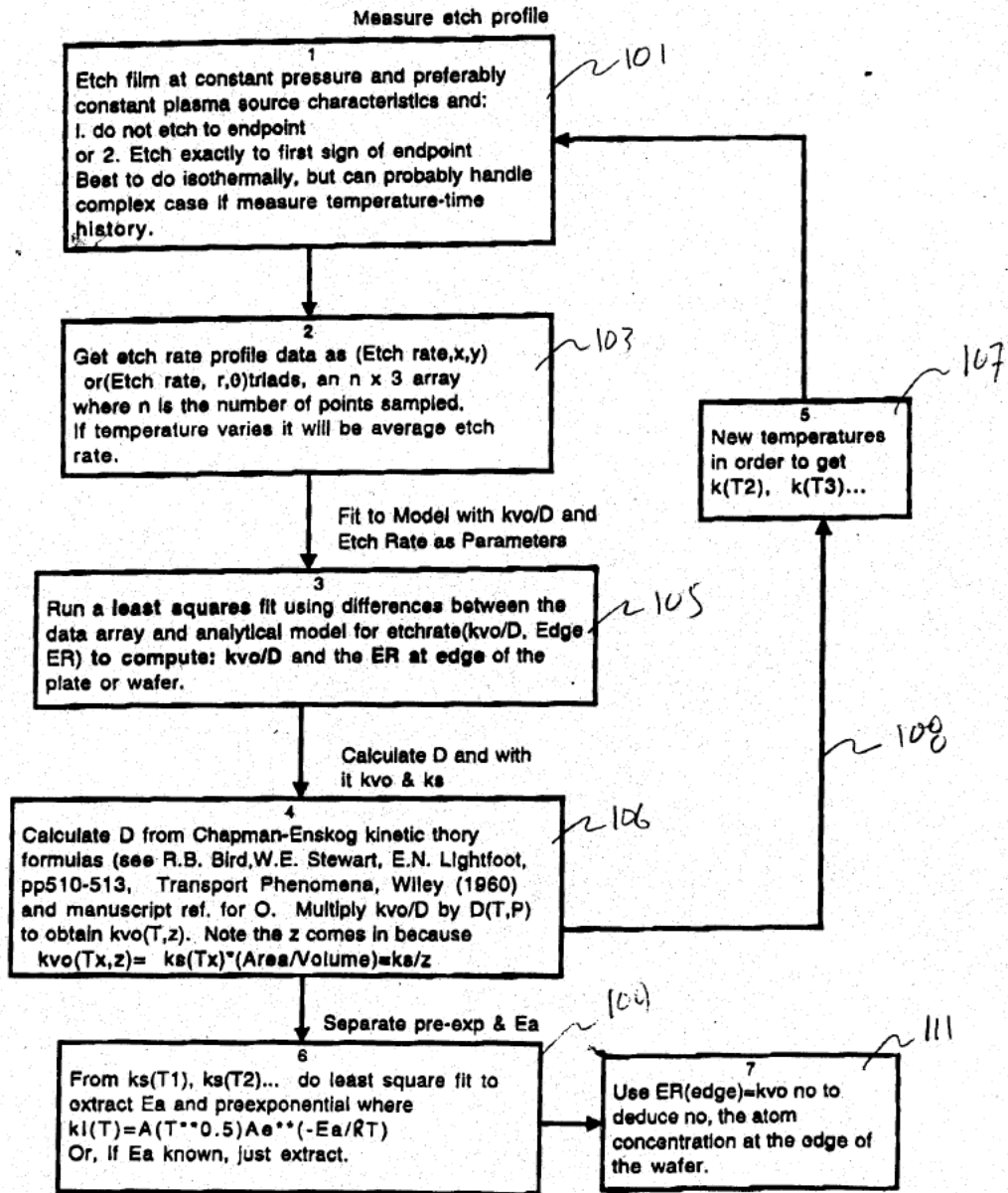


FIG. 3

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**Extract Plasma Source Intensity and "tune" the Plasma Source using Loading Effect Relationship**

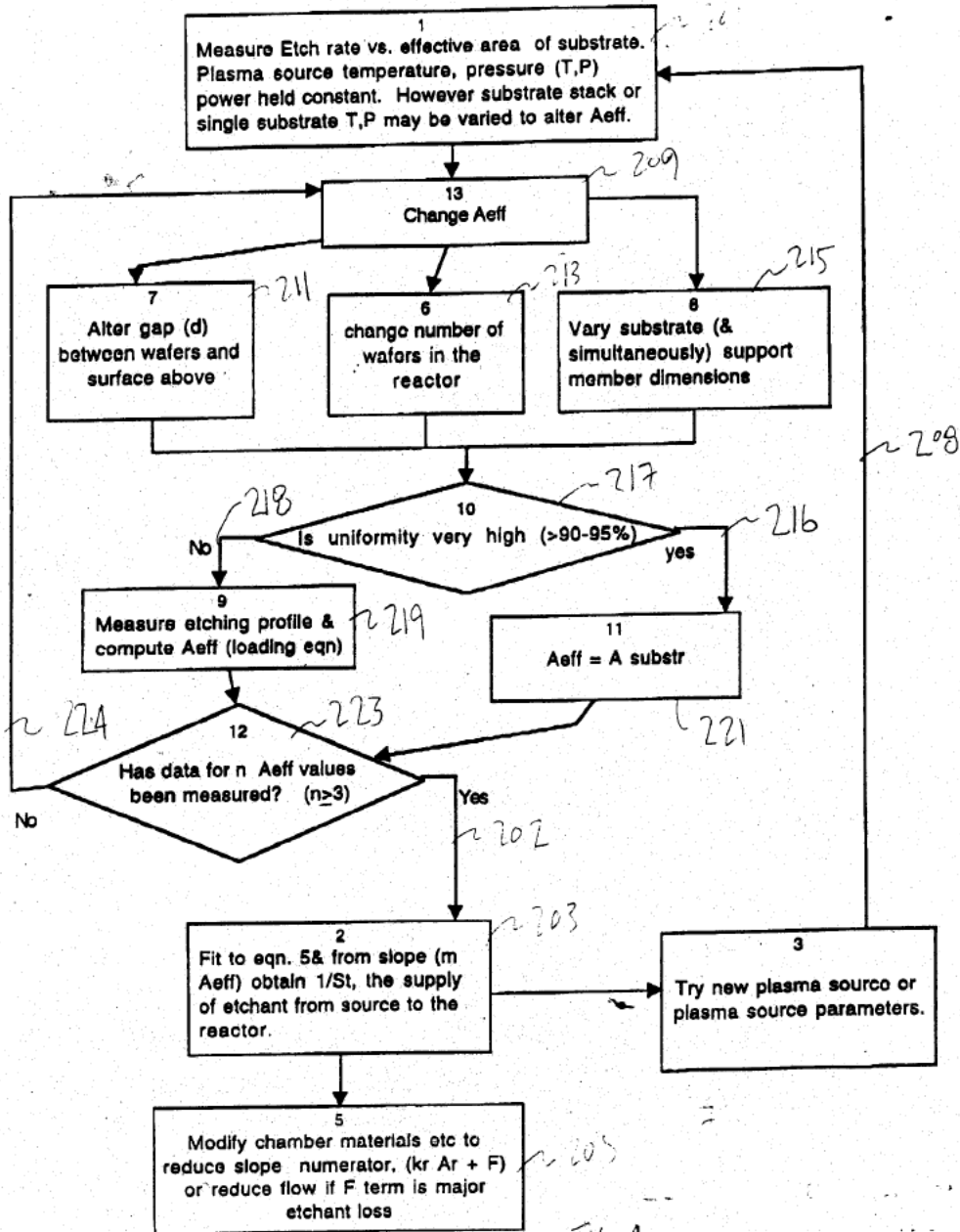


Fig. 4

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**Optimize Etching Rate vs.  
P, T, rf Power with  
Uniformity Constraint**

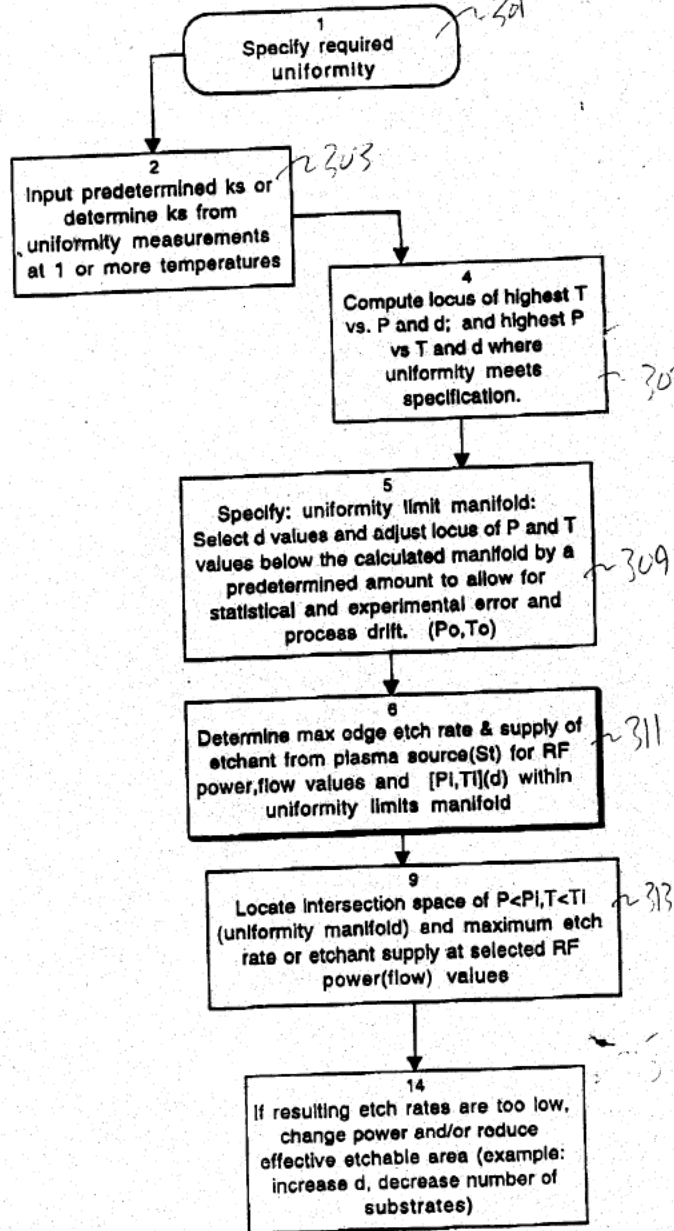


FIG 3

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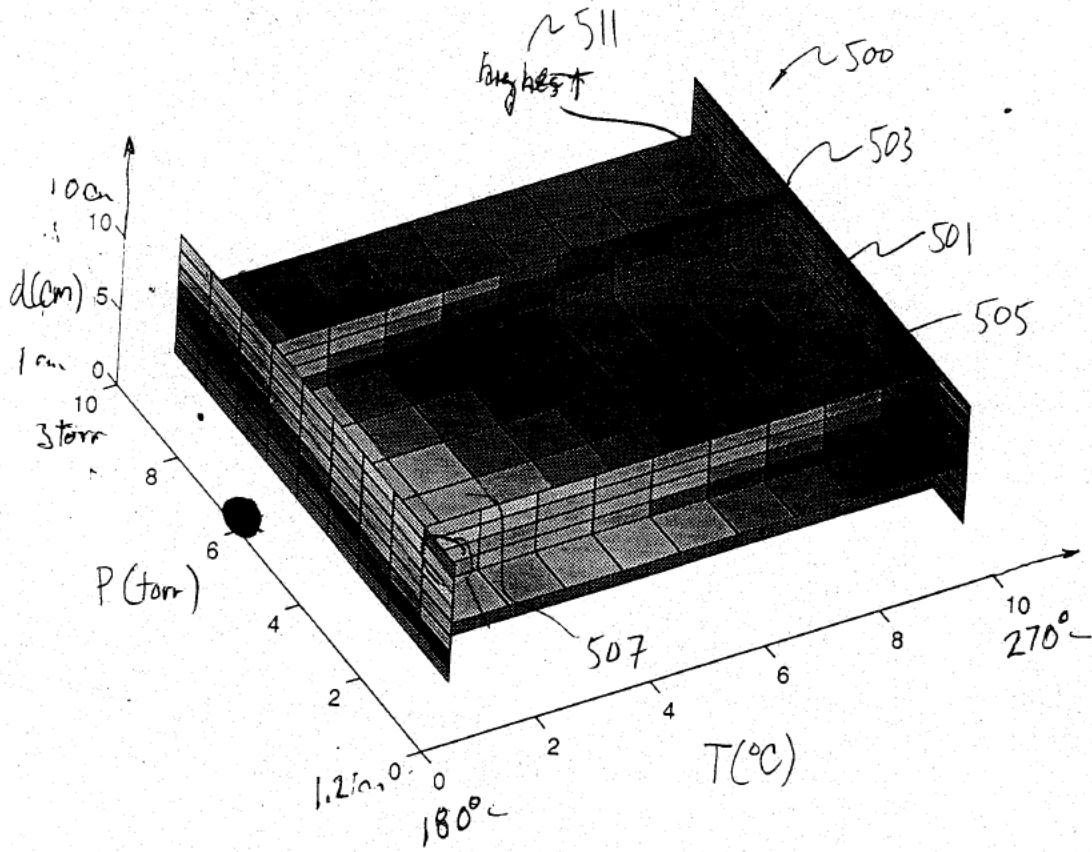


FIG. 5A

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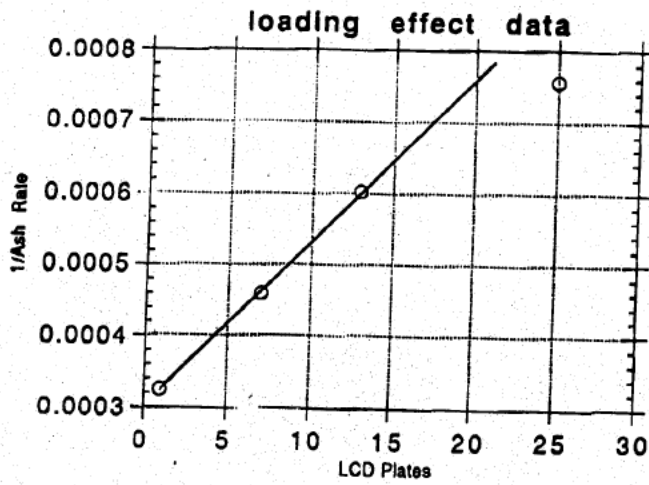


Fig. 2



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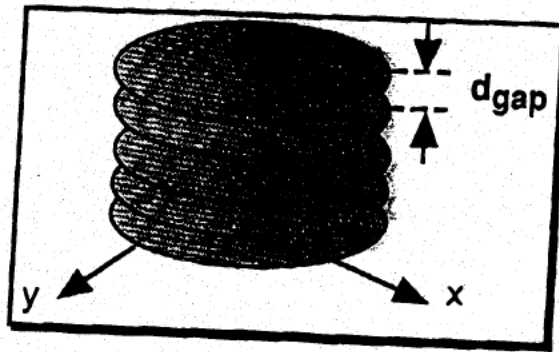


FIG. 7

16655-1

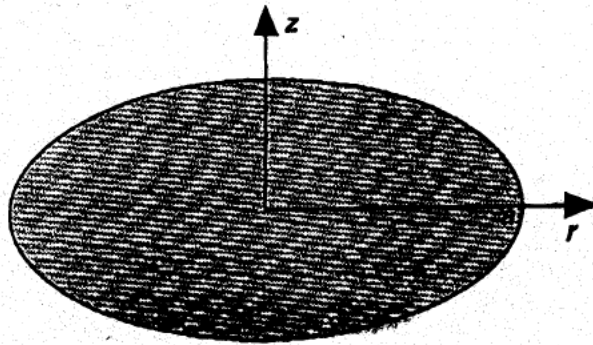


Fig. 9

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AS ORIGINAL FILED

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08/03/98

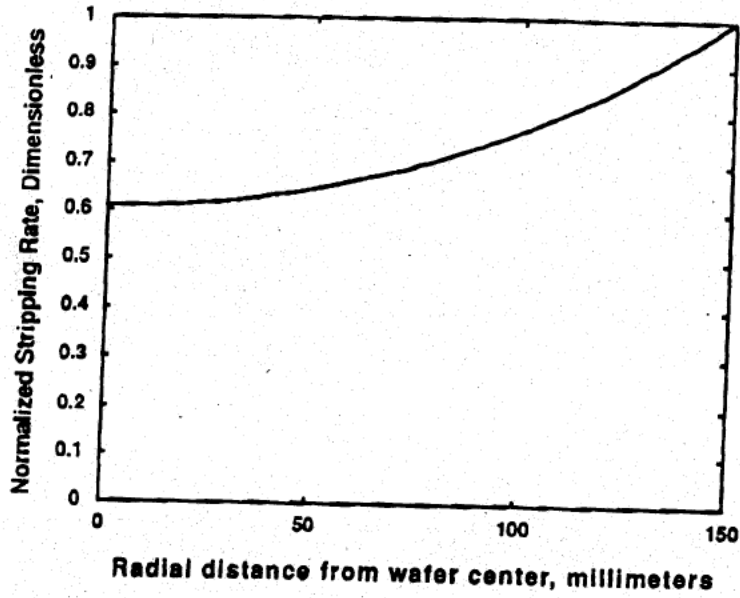


FIG. 9

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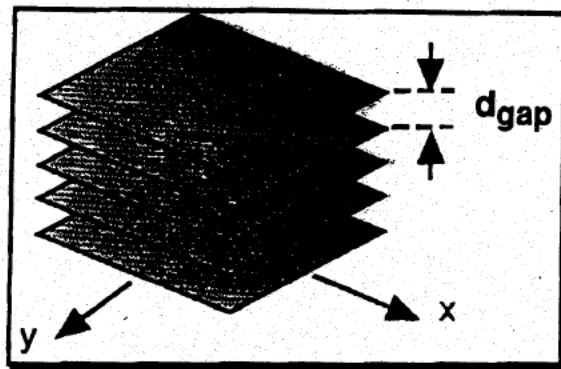


FIG. 10

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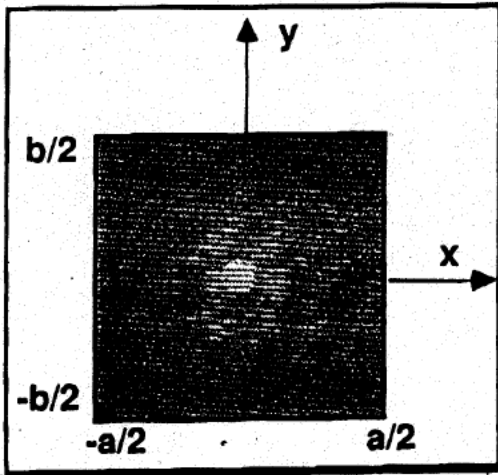


FIG. 11

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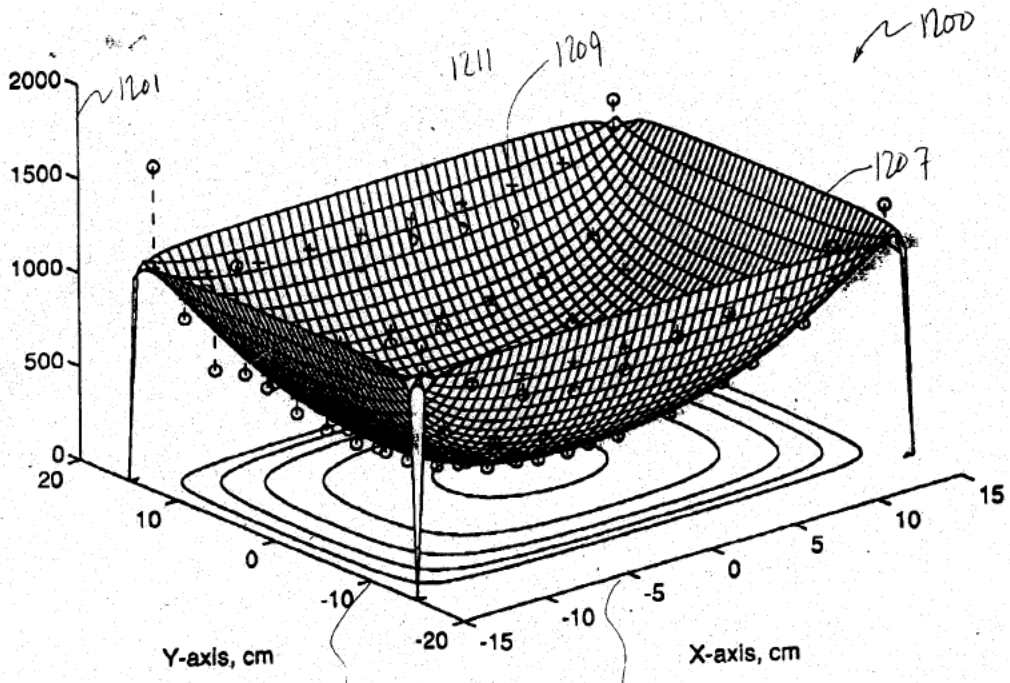


FIG. 12



UNITED STATES DEPARTMENT OF COMMERCE  
Patent and Trademark Office

Address: COMMISSIONER OF PATENTS AND TRADEMARKS #2  
Washington, D.C. 20231

APPLICATION NUMBER	FILING DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
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08/433,623 05/03/95 FLAMM D 16655000100

0212/0522

TOWNSEND AND TOWNSEND KHOURIE AND CREW  
STEUART STREET TOWER  
ONE MARKET PLAZA  
SAN FRANCISCO CA 94105

DATE MAILED: 0000

**NOTICE TO FILE MISSING PARTS OF APPLICATION  
FILING DATE GRANTED**

05/22/95

An Application Number and Filing Date have been assigned to this application. However, the items indicated below are missing. The required items and fees identified below must be timely submitted **ALONG WITH THE PAYMENT OF A SURCHARGE** for items 1 and 3-6 only of \$ 130 for large entities or \$ 65 for small entities who have filed a verified statement claiming such status. The surcharge is set forth in 37 CFR 1.16(e).

If all required items on this form are filed within the period set below, the total amount owed by applicant as a  large entity,  small entity (verified statement filed), is \$ 1002.

Applicant is given **ONE MONTH FROM THE DATE OF THIS LETTER, OR TWO MONTHS FROM THE FILING DATE** of this application, **WHICHEVER IS LATER**, within which to file all required items and pay any fees required above to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is:  missing  insufficient. Applicant as a  large entity  small entity, must submit \$ 730 to complete the basic filing fee.
- Additional claim fees of \$ 142 as a  large entity,  small entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due.
- The oath or declaration:
  - is missing.
  - does not cover the newly submitted items.

An oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date is required.
- The oath or declaration does not identify the application to which it applies. An oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
- The signature(s) to the oath or declaration is/are:  missing;  by a person other than the inventor or a person qualified under 37 CFR 1.42, 1.43, or 1.47. A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
- The signature of the following joint inventor(s) is missing from the oath or declaration:
 

\_\_\_\_\_ An oath or declaration listing the names of all inventors and signed by the omitted inventor(s), identifying this application by the above Application Number and Filing Date, is required.
- The application was filed in a language other than English. Applicant must file a verified English translation of the application and a fee of \$ \_\_\_\_\_ under 37 CFR 1.17(k), unless this fee has already been paid.
- A \$ \_\_\_\_\_ processing fee is required since your check was returned without payment. (37 CFR 1.21(m)).
- Your filing receipt was mailed in error because your check was returned without payment.
- The application does not comply with the Sequence Rules. See attached Notice to Comply with Sequence Rules 37 CFR 1.821-1.825.
- Other.

Direct the response to Box Missing Part and refer any questions to the Customer Service Center at (703) 308-1202.

**A copy of this notice MUST be returned with the response.**

OFFICE COPY



I hereby certify that this correspondence is being deposited with the United States Postal Service as airmail in an envelope addressed to:  
Assistant Commissioner for Patents,  
Application Processing Division,  
Special Processing and Correspondence Branch  
Washington, D.C. 20231, on 6/20/95

By: *[Signature]*

-PATENT

Attorney Docket No. 16655-1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	)	
Daniel L. Flamm et al.	)	Examiner: Unassigned
Serial No.: 08/433,623	)	Art Unit: Unassigned
Filed: May 3, 1995	)	<u>TRANSMITTAL LETTER</u>
For: PROCESS OPTIMIZATION IN GAS	)	
PHASE DRY ETCHING	)	

Attn: Application Processing Division  
Special Processing and Correspondence Branch  
Assistant Commissioner for Patents  
Washington, D.C. 20231

Sir:

Pursuant to the Notice to File Missing Parts of Application - Filing Date Granted dated May 3, 1995, enclosed are the following to be made of record in the above-identified application:

- 1) Executed Declaration and Power of Attorney;
- 2) Verified Statement Claiming Small Entity Status;
- 3) Copy of Notice of Missing Parts;
- 4) Assignment; and
- 4) Recordation Form PTO-1595.

Please charge the statutory basic filing fee of \$436.00 (total claims, 23 and 4 independent claims), \$40.00 for Recordation of the Assignment, and the surcharge of \$65.00 - Total \$541.00 to Deposit Account No. 20-1430 of the undersigned. The Assistant Commissioner is hereby authorized to charge any additional fees associated with this paper or during the pendency of this application, or credit any overpayment to Deposit Account

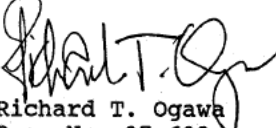


Daniel L. Flamm  
Serial No.: 08/433,623  
Page 2

PATENT

No. 20-1430 for this paper and during the prosecution of this application. This Transmittal Letter is submitted in triplicate.

Respectfully submitted,



Richard T. Ogawa  
Reg. No. 37,692

TOWNSEND and TOWNSEND and CREW  
One Market Plaza  
Steuart Street Tower, 20th Floor  
San Francisco, California 94105  
(415) 326-2400

RTO/ka

K:\16655\1-MIS.PTS



DECLARATION AND POWER OF ATTORNEY

As a below named inventor, I declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING the specification of which \_\_\_ is attached hereto or X was filed on May 3, 1995 as Application Serial No. 08/433,623 and was amended on \_\_\_ (if applicable).

I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56. I claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)

Country	Application No.	Date of Filing	Priority Claimed Under 35 USC 119
			Yes ___ No ___
			Yes ___ No ___

I claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	Date of Filing	Status
		___ Patented ___ Pending ___ Abandoned
		___ Patented ___ Pending ___ Abandoned

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

Richard T. Ogawa, Reg. No. 37,692  
William J. Bohler, Reg. No. 31,487  
Kenneth R. Allen, Reg. No. 27,301

Send Correspondence to: <u>Richard T. Ogawa</u> <u>TOWNSEND and TOWNSEND KHOURIE and CREW</u> Steuart Street Tower <u>One Market Plaza, 20th Floor</u> <u>San Francisco, CA 94105</u>	Direct Telephone Calls to: (Name, Reg. No., Telephone No.)  Name: Richard T. Ogawa Reg. No. 37,692 Telephone: 415 326-2400
--	---

Full Name of Inventor 1	Last Name <u>Flamm</u> <i>Jo</i>	First Name <u>Daniel</u>	Middle Name or Initial <u>L.</u>	
Residence & Citizenship	City <u>Walnut Creek</u> <i>CA</i>	State/Foreign Country <u>California</u>	Country of Citizenship <u>U.S.A.</u>	
Post Office Address	Post Office Address <u>476 Green View Drive</u>	City <u>Walnut Creek</u>	State/Country <u>California</u>	Zip Code <u>94596</u>
Full Name of Inventor 2	Last Name <u>Verboncoeur</u> <i>2-o</i>	First Name <u>John</u>	Middle Name or Initial <u>P.</u>	
Residence & Citizenship	City <u>Hayward</u> <i>CA</i>	State/Foreign Country <u>California</u>	Country of Citizenship <u>U.S.A.</u>	
Post Office Address	Post Office Address <u>3350 Oakes Drive</u>	City <u>Hayward</u>	State/Country <u>California</u>	Zip Code <u>94542</u>
Full Name of Inventor 3	Last Name	First Name	Middle Name or Initial	
Residence & Citizenship	City	State/Foreign Country	Country of Citizenship	
Post Office Address	Post Office Address	City	State/Country	Zip Code

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signature of Inventor 1 <i>Daniel L. Flamm</i> Daniel L. Flamm	Signature of Inventor 2 <i>John P. Verboncoeur</i> John P. Verboncoeur	Signature of Inventor 3
Date <u>June 9, 1995</u>	Date <u>06-12-95</u>	Date

**DECLARATION AND POWER OF ATTORNEY**

As a below named inventor, I declare that:

My residence, post office address and citizenship are as stated below next to my name; I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled: **PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING** the specification of which  is attached hereto or  was filed on May 3, 1995 as Application Serial No. 08/433,623 and was amended on      (if applicable).

I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above. I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56. I claim foreign priority benefits under Title 35, United States Code, Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

**Prior Foreign Application(s)**

Country	Application No.	Date of Filing	Priority Claimed Under 35 USC 119
			Yes <input type="checkbox"/> No <input type="checkbox"/>
			Yes <input type="checkbox"/> No <input type="checkbox"/>

I claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56 which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Application Serial No.	Date of Filing	Status
		<input type="checkbox"/> Patented <input type="checkbox"/> Pending <input type="checkbox"/> Abandoned
		<input type="checkbox"/> Patented <input type="checkbox"/> Pending <input type="checkbox"/> Abandoned

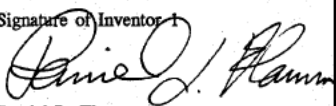
**POWER OF ATTORNEY:** As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

Richard T. Ogawa, Reg. No. 37,692  
 William J. Bohler, Reg. No. 31,487  
 Kenneth R. Allen, Reg. No. 27,301

Send Correspondence to: Richard T. Ogawa TOWNSEND and TOWNSEND KHOURIE and CREW Steuart Street Tower One Market Plaza, 20th Floor San Francisco, CA 94105	Direct Telephone Calls to: (Name, Reg. No., Telephone No.)  Name: Richard T. Ogawa Reg. No. 37,692 Telephone: 415 326-2400
--	---

Full Name of Inventor 1	Last Name <b>Flamm</b>	First Name <b>Daniel</b>	Middle Name or Initial <b>L.</b>	
Residence & Citizenship	City <b>Walnut Creek</b>	State/Foreign Country <b>California</b>	Country of Citizenship <b>U.S.A.</b>	
Post Office Address	Post Office Address <b>476 Green View Drive</b>	City <b>Walnut Creek</b>	State/Country <b>California</b>	Zip Code <b>94596</b>
Full Name of Inventor 2	Last Name <b>Verboncoeur</b>	First Name <b>John</b>	Middle Name or Initial <b>P.</b>	
Residence & Citizenship	City <b>Hayward</b>	State/Foreign Country <b>California</b>	Country of Citizenship <b>U.S.A.</b>	
Post Office Address	Post Office Address <b>3350 Oakes Drive</b>	City <b>Hayward</b>	State/Country <b>California</b>	Zip Code <b>94542</b>
Full Name of Inventor 3	Last Name	First Name	Middle Name or Initial	
Residence & Citizenship	City	State/Foreign Country	Country of Citizenship	
Post Office Address	Post Office Address	City	State/Country	Zip Code

I further declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

Signature of Inventor 1 	Signature of Inventor 2	Signature of Inventor 3
<b>Daniel L. Flamm</b>	<b>John P. Verboncoeur</b>	
Date <i>June 9, 1995</i>	Date	Date



Atty. Docket No. 16655-1

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) and 1.27(b)) - INDEPENDENT INVENTOR

Applicant: Daniel L. Flamm and John P. Verboncoeur
Serial or Patent No.: 08/433,623
Filed or Issued: May 3, 1995
Title: PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees to the Patent and Trademark Office regarding the invention entitled PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING described in:

- [ ] the specification herewith.
[X] application Serial No. 08/433,623, filed May 3, 1995
[ ] Patent No. \_\_\_\_\_, issued \_\_\_\_\_

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey or license any rights in the invention is listed below:\*

- [X] No such person, concern, or organization
[ ] Persons, concerns or organizations listed below\*

\*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

NAME
ADDRESS

- [ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

NAME
ADDRESS

- [ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

NAME
ADDRESS

- [ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Table with 3 columns: NAME OF INVENTOR, SIGNATURE OF INVENTOR, DATE. Row 1: DANIEL L. FLAMM, [Signature], Date June 9, 1995.

K:\166551-ent2.ent



Atty. Docket No. 16655-1

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) and 1.27(b)) - INDEPENDENT INVENTOR

Applicant or Patentee: Daniel L. Flamm and John P. Verboncoeur
Serial or Patent No.: 08/433,623
Filed or Issued: May 3, 1995
Title: PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

As a below named inventor, I hereby declare that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees to the Patent and Trademark Office regarding the invention entitled PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING described in:

- [ ] the specification herewith.
[X] application Serial No. 08/433,623, filed May 3, 1995
[ ] Patent No. , issued

I have not assigned, granted, conveyed or licensed and am under no obligation under contract or law to assign, grant, convey or license, any rights in the invention to any person who would not qualify as an independent inventor under 37 CFR 1.9(c) if that person had made the invention, or to any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

Each person, concern or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey or license any rights in the invention is listed below:\*

- [ ] No such person, concern, or organization
[X] Persons, concerns or organizations listed below\*

\*NOTE: Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27)

NAME DANIEL L. FLAMM
ADDRESS 476 Green View Drive, Walnut Creek, California 94596

- [X] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

NAME
ADDRESS

- [ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

NAME
ADDRESS

- [ ] INDIVIDUAL [ ] SMALL BUSINESS CONCERN [ ] NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

Table with 3 columns: NAME OF INVENTOR, SIGNATURE OF INVENTOR, DATE. Row 1: JOHN P. VERBONCOEUR, [Signature], 06-12-95. Row 2: [Signature], [Signature], [Signature]. Row 3: Date, Date, Date.

K:\16655-1-mfl.exe



UNITED STATES DEPARTMENT OF COMMERCE  
 Patent and Trademark Office  
 Address: COMMISSIONER OF PATENTS AND TRADEMARKS  
 Washington, D.C. 20231

H/M

APPLICATION NUMBER	FILING DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
08/433,623	05/03/95	FLAMM	D 16655000100

0212/0522  
 TOWNSEND AND TOWNSEND KHOURIE AND CREW  
 STEUART STREET TOWER  
 ONE MARKET PLAZA  
 SAN FRANCISCO CA 94105

DATE MAILED: 0000

#3

**NOTICE TO FILE MISSING PARTS OF APPLICATION  
 FILING DATE GRANTED**

05/22/95

An Application Number and Filing Date have been assigned to this application. However, the items indicated below are missing. The required items and fees identified below must be timely submitted **ALONG WITH THE PAYMENT OF A SURCHARGE** for items 1 and 3-6 only of \$ 130 for large entities or \$ 65 for small entities who have filed a verified statement claiming such status. The surcharge is set forth in 37 CFR 1.16(e).

If all required items on this form are filed within the period set below, the total amount owed by applicant as a  large entity,  small entity (verified statement filed), is \$ 1002.

Applicant is given **ONE MONTH FROM THE DATE OF THIS LETTER, OR TWO MONTHS FROM THE FILING DATE** of this application, **WHICHEVER IS LATER**, within which to file all required items and pay any fees required above to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is:  missing  insufficient. Applicant as a  large entity  small entity, must submit \$ 730 to complete the basic filing fee.
- Additional claim fees of \$ 112 as a  large entity,  small entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due.
- The oath or declaration:
  - is missing.
  - does not cover the newly submitted items.

An oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date is required.
- The oath or declaration does not identify the application to which it applies. An oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
- The signature(s) to the oath or declaration is/are:  missing;  by a person other than the inventor or a person qualified under 37 CFR 1.42, 1.43, or 1.47. A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.

P 30125 The signature of 07/24/95 08433623 joint inventor(s) is missing from the oath or declaration: 20-1430 030 201 365.00CH

P 30126 07/24/95 08433623 An oath or declaration listing the names of all inventors and signed by the omitted inventor(s), identifying this application by the above Application Number and Filing Date, is required. 20-1430 030 205 56.00CH

- The application was filed in a language other than English. Applicant must file a verified English translation of the application and a fee of \$ \_\_\_\_\_ under 37 CFR 1.17(k), unless this fee has already been paid.
- A \$ \_\_\_\_\_ processing fee is required since your check was returned without payment. (37 CFR 1.21(m)).
- Your filing receipt was mailed in error because your check was returned without payment.
- The application does not comply with the Sequence Rules. See attached Notice to Comply with Sequence Rules 37 CFR 1.821-1.825.
- Other.

260 SC 20-1430 08/08/95 08433623  
 26073 203 15.00CH

Direct the response to Box Missing Part and refer any questions to the Customer Service Center at (703) 308-1202.

**A copy of this notice MUST be returned with the response.**



TOWNSEND and TOWNSEND and CREW  
 Stuart Street Tower  
 One Market Plaza  
 San Francisco, CA 94105  
 (415) 543-9600



Preliminary Amendment

Angel indt

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 Au 113

Atty. Docket No. 16655-000100

Date November 9, 1995

In re application of Daniel L. Flamm, et al.

I hereby certify that this is being deposited with the United States Postal Service as first class mail in an envelope addressed to:

Serial No: 08/433,623

Assistant Commissioner for Patents  
 Washington, D. C. 20231.

Filed: May 3, 1995

Date: November 9, 1995

Group Art Unit:

*Alise Elzingre*

For: PROCESS OPTIMIZATION IN GAS  
 PHASE DRY ETCHING

ASSISTANT COMMISSIONER FOR PATENTS  
 Washington, D.C. 20231

Sir:

Transmitted herewith is a preliminary amendment in the above-identified application.

Amendment.

Small entity status of this application under 37 CFR 1.9 and 1.27 has been established by a verified statement previously submitted.

Postcard.

The filing fee has been calculated as shown below:

(Col. 1)		(Col. 2)		(Col. 3)	SMALL ENTITY		OTHER THAN A SMALL ENTITY		
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NO. PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE	ADDIT. FEE	RATE	ADDIT. FEE	
TOTAL	*25	MINUS	**23	=2	2 x11=	\$22.00	x22=	\$	
INDEP.	*5	MINUS	***4	=1	1 x39=	\$39.00	x78=	\$	
<input type="checkbox"/> FIRST PRESENTATION OF MULTIPLE DEP. CLAIM					+125=	\$	+250=	\$	
					TOTAL	\$61.00	OR	TOTAL	\$

\* If the entry in Col. 1 is less than the entry in Col. 2, write "0" in Col. 3.

\*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, write "20" in this space.

\*\*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, write "3" in this space. The "Highest Number Previously Paid For" (Total or Independent) is the highest number found from the equivalent box in Col. 1 of a prior amendment or the number of claims originally filed.

No fee is due.

Please charge Deposit Account No. 20-1430 as follows:

Claims fee \$61.00  
 Any additional fees associated with this paper or during the pendency of this application.

2 extra copies of this sheet are enclosed.

TOWNSEND and TOWNSEND and CREW

*Richard T. Ogawa*  
 Richard T. Ogawa  
 Reg. No.: 37,692  
 Attorneys for Applicant

rtolwork1665511-pam.tn



GP 110

8113

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to:

Assistant Commissioner for Patents  
Washington, D.C. 20231, on November 9, 1995

Date: 11/9/95 By: Neil Elgin

PATENT  
16655-000100US

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	)	
Daniel L. Flamm, et al.	)	Examiner: Unassigned
Serial No. 08/433,623	)	Art Unit: Unassigned
Filed: May 3, 1995	)	
For: PROCESS OPTIMIZATION IN	)	<u>PRELIMINARY AMENDMENT</u>
GAS PHASE DRY ETCHING	)	

*Y/A*

RECEIVED  
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GROUP 100  
11 33 PM '95

ASSISTANT COMMISSIONER FOR PATENTS  
Washington, D.C. 20231

Sir:

Before action on the merits, please amend the above-identified application as follows:

IN THE CLAIMS:

Please amend claims 1 and 5 and add new claims 24 and 25 as follows. The pending claims, including the presently amended claims, are presented in Appendix A for ease of reference:

*[Handwritten scribble]*

Sub B  
1. (Amended) ~~[An integrated circuit] A device fabrication method comprising the steps of:~~

providing a plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;

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30079	202			22.00CH
30080	203			

*A*

~~chemical etching said top film surface to define an etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile; and~~

~~extracting a reaction rate [constant] from said etch rate data[, and using said reaction rate constant in adjusting said plasma etching apparatus].~~

Sub 33  
5. (Amended) ~~The method of claim 1 wherein said extracting step correlates said reaction rate [constant] over a diffusivity with said etching rate, said etching rate being defined by said etching profile.~~

9 24. (New) The method of claim 1 further comprising a step of using said reaction rate constant in adjusting said plasma etch apparatus.

Sub B4  
25. (New) ~~A process for fabricating a device, said device being fabricated by use of a reaction rate constant, said reaction rate constant being derived from a method comprising:~~

~~providing a plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;~~

~~etching said top surface at a temperature to define an etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile; and~~

~~extracting from said etching rate data a reaction rate for said temperature.~~

#### REMARKS

Applicant adds new claims 24 and 25 to the subject application for examination. No new matter has been introduced thereby.

If the Examiner believes a telephone conference would expedite prosecution of

this application, please telephone the undersigned at (415) 326-2400. 261

Respectfully submitted,  
TOWNSEND and TOWNSEND and CREW

Date: 11/9/95

By: 

Richard T. Ogawa  
Reg. No. 37,692

RTO:de

*rto\work\1665511-prem.amd*

## APPENDIX A

1. (Amended) A device fabrication method comprising the steps of:  
providing a plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;  
chemical etching said top film surface to define an etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile; and  
extracting a reaction rate [constant] from said etch rate data[, and using said reaction rate constant in adjusting said plasma etching apparatus].
2. The method of claim 1 wherein said chemical etching step is diffusion limiting.
3. The method of claim 1 wherein said spatial coordinates include a radius and an angle.
4. The method of claim 1 wherein said spatial coordinates include an x-direction and a y-direction.
5. (Amended) The method of claim 1 wherein said extracting step correlates said reaction rate over a diffusivity with said etching rate, said etching rate being defined by said etching profile.
6. The method of claim 1 wherein said etching rate is defined by said etching profile at selected spatial coordinates over a time.
7. The method of claim 1 wherein said chemical etching is an ashing method.
8. The method of claim 1 wherein said ashing method comprises reactants including an oxygen and a photoresist.
9. A method of designing a reactor comprising the steps of:  
providing a first plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;  
chemical etching said top film surface to define an etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile; and  
extracting a reaction rate constant from said etch rate data, and using said reaction rate constant in designing a second plasma etching apparatus.

10. The method of claim 9 wherein said chemical etching step is diffusion limiting.

11. The method of claim 9 wherein said spatial coordinates include a radius and an angle.

12. The method of claim 9 wherein said spatial coordinates include an x-direction and a y-direction.

13. The method of claim 9 wherein said extracting step correlates said reaction rate constant over a diffusivity with said an etching rate, said etching rate being defined by said etching profile.

14. The method of claim 9 wherein said etching rate is defined by said etching profile at selected spatial coordinates over a time.

15. The method of claim 9 wherein said chemical etching is an ashing method.

16. The method of claim 9 wherein said ashing method comprises reactants including an oxygen and a photoresist.

17. The method of claim 9 wherein said second plasma etching apparatus is a co-axial reactor.

18. The method of claim 9 wherein said second plasma etching apparatus is a plasma etching apparatus.

19. A substrate fabrication method comprising:  
providing a substrate selected from a group consisting of a semiconductor wafer, a plate, and a flat panel display, said substrate comprising a top surface;  
forming a film overlying said top surface, said film comprising a top film surface;  
chemical etching said top film surface to define a profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile; and  
extracting a reaction rate constant from said etch rate data, and using said reaction rate constant in adjusting said method.

20. A method of fabricating an integrated circuit device, said method comprising:  
providing a uniformity value for an etching reaction, said etching reaction including a substrate and etchant species;  
defining etching parameters ranges providing said uniformity value; and  
adjusting at least one of said etching parameters to produce a selected etching rate;

wherein said etching rate providing an etching condition for fabrication of an integrated circuit device.

21. The method of claim 20 wherein said etching parameters can be selected from a group consisting of a temperature, a pressure, a power, a gap, and a flow rate.

22. The method of claim 20 wherein said uniformity ranges from 90% and greater.

23. The method of claim 20 wherein said uniformity ranges from 95% and greater.

24. (New) The method of claim 1 further comprising a step of using said reaction rate constant in adjusting said plasma etch apparatus.

25. (New) A process for fabricating a device, said device being fabricated by use of a reaction rate constant, said reaction rate constant being derived from a method comprising:

providing a plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;

etching said top surface at a temperature to define an etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile; and

extracting from said etching rate data a reaction rate for said temperature.



UNITED STATES DEPARTMENT OF COMMERCE  
Patent and Trademark Office

Address: COMMISSIONER OF PATENTS AND TRADEMARKS  
Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.
---------------	-------------	----------------------	---------------------

08/433,623 05/03/95 FLAMM

D 16655-000100

EXAMINER  
ANGEBRANN, J.M.

11M1/0306

RICHARD T OGAWA  
TOWNSEND AND TOWNSEND KHOURIE AND CREW  
STEWART STREET TOWER  
ONE MARKET PLAZA 20TH FLOOR  
SAN FRANCISCO CA 94105

ART UNIT PAPER NUMBER

1113

5

DATE MAILED: 03/06/96

This is a communication from the examiner in charge of your application.  
COMMISSIONER OF PATENTS AND TRADEMARKS

This application has been examined  Responsive to communication filed on 11/13/95  This action is made final.

A shortened statutory period for response to this action is set to expire 3 month(s),      days from the date of this letter.  
Failure to respond within the period for response will cause the application to become abandoned. 35 U.S.C. 133

Part I THE FOLLOWING ATTACHMENT(S) ARE PART OF THIS ACTION:

- 1.  Notice of References Cited by Examiner, PTO-892.
- 2.  Notice of Draftsman's Patent Drawing Review, PTO-948.
- 3.  Notice of Art Cited by Applicant, PTO-1449.
- 4.  Notice of Informal Patent Application, PTO-152.
- 5.  Information on How to Effect Drawing Changes, PTO-1474.
- 6.  \_\_\_\_\_

Part II SUMMARY OF ACTION

1.  Claims 1-25 are pending in the application.

Of the above, claims \_\_\_\_\_ are withdrawn from consideration.

2.  Claims \_\_\_\_\_ have been cancelled.

3.  Claims \_\_\_\_\_ are allowed.

4.  Claims 1-25 are rejected.

5.  Claims \_\_\_\_\_ are objected to.

6.  Claims \_\_\_\_\_ are subject to restriction or election requirement.

7.  This application has been filed with informal drawings under 37 C.F.R. 1.85 which are acceptable for examination purposes.

8.  Formal drawings are required in response to this Office action.

9.  The corrected or substitute drawings have been received on \_\_\_\_\_. Under 37 C.F.R. 1.84 these drawings are  acceptable;  not acceptable (see explanation or Notice of Draftsman's Patent Drawing Review, PTO-948).

10.  The proposed additional or substitute sheet(s) of drawings, filed on \_\_\_\_\_, has (have) been  approved by the examiner;  disapproved by the examiner (see explanation).

11.  The proposed drawing correction, filed \_\_\_\_\_, has been  approved;  disapproved (see explanation).

12.  Acknowledgement is made of the claim for priority under 35 U.S.C. 119. The certified copy has  been received  not been received  been filed in parent application, serial no. \_\_\_\_\_; filed on \_\_\_\_\_.

13.  Since this application appears to be in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under Ex parte Quayle, 1935 C.D. 11; 453 O.G. 213.

14.  Other

EXAMINER'S ACTION



Art Unit: 1113

15 Claims 1-25 are rejected under 35 U.S.C. § 112, second paragraph, as being indefinite, for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

The claims should clearly indicate that this is a localized etching rate constant, since it combines the effects and rates of diffusion from the etching source to the surface of the thin film, the diffusion of the resulting products away from the surface of the thin film, adsorption and desorption as well as the rate of the actual etching process to make it clear what parameter is being used to evaluate and optimize uniformity.

Also please note that the applicant optimizes the same parameters (ie "temperature pressure, reactor configuration, and the like" (page 18 lines 21-24) and changing the chamber material or coating the chamber surfaces ... rf power, flow rate and the like (page 14/lines 1-16 and 2/14-20) which are commonly optimized as part of the process. Some of these parameters are not disclosed as affecting the rate constants.

16 The following is a quotation of the appropriate paragraphs of 35 U.S.C. § 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless --

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

(e) the invention was described in a patent granted on an application for patent by another filed in the United States before the invention thereof by the applicant for patent, or on an international application by another who has fulfilled the requirements of paragraphs (1), (2), and (4) of section 371(c) of this title before the invention thereof by the applicant for patent.

Art Unit: 1113

17 The following is a quotation of 35 U.S.C. § 103 which forms the basis for all obviousness rejections set forth in this Office action:

A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

Subject matter developed by another person, which qualifies as prior art only under subsection (f) or (g) of section 102 of this title, shall not preclude patentability under this section where the subject matter and the claimed invention were, at the time the invention was made, owned by the same person or subject to an obligation of assignment to the same person.

18 Claims 1-6,9-14 and 18-25 are rejected under 35 U.S.C. § 102(b) as anticipated by or, in the alternative, under 35 U.S.C. § 103 as obvious over Bobbio '520.

Bobbio '520 describes a prior art apparatus in which the barriers are placed parallel to each other the inherent etch rates as a function of position are determined in figures 4a and 4b. These are corrected to produce an etch which is relatively uniform over the entire wafer. Typically no more than three positioning steps are required to achieve uniformity deviations of less than 2% (col 8/lines 43-50, hereinafter 8/43-50).

The examiner holds that the relative etch rates disclosed are equivalent to the combined etch rate constant and that the observations and varying of the position of the barriers results in a new etching apparatus. Alternatively, it would have been obvious to vary known etch parameters including reactive gas composition, temperature, pressure, reactor configuration, rf power, flow rate and the like as is known in the art to produce a more

Serial Number: 08/433623

-4-

Art Unit: 1113

uniform etch in the course of routine optimization. Please note that one skilled in the art would also be expected to either know or be able to find references teaching in general what conditions are suitable for etching the desired material.

19 Claims 1-25 are rejected under 35 U.S.C. § 102(b) as anticipated by or, in the alternative, under 35 U.S.C. § 103 as obvious over Horiike '706.

The examiner holds that the relative etch rates as a function of distance disclosed are equivalent to the combined etch rate constant and that the observations and varying of the position of the etch target results in a new etching apparatus (see figures 9 and 10). Alternatively, it would have been obvious to vary known etch parameters including reactive gas composition, temperature, pressure, reactor configuration, rf power, flow rate and the like as is known in the art to produce a more uniform etch in the course of routine optimization. Please note that one skilled in the art would also be expected to either know or be able to find references teaching in general what conditions are suitable for etching the desired material.

20 Claims 1-6,9-14 and 18-25 are rejected under 35 U.S.C. § 102(b) as anticipated by or, in the alternative, under 35 U.S.C. § 103 as obvious over Mogab '665.

Mogab '665 teaches that loading is known in the art to result in inter or intra wafer non-uniformity. Reactor design is known to increase etch uniformity. (2/15-22) The routine optimization to decrease the effects of loading on the system is disclosed. (2/63+) These changes are disclosed as reducing non-uniformity of the etch. (3/11-17) The use of a radial

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flow apparatus to determine experimentally the optimum conditions for an etch process is disclosed (5/8-14).

The examiner holds that the relative etch rates as a function of loading disclosed are equivalent to the combined etch rate constant and that the observations and varying of the etch conditions results in a new etching apparatus, since the composition of the etchant, which makes it an etching apparatus is changed. Alternatively, it would have been obvious to vary known etch parameters including reactive gas composition, temperature, pressure, reactor configuration, rf power, flow rate and the like as is known in the art to produce a more uniform etch in the course of routine optimization. Please note that one skilled in the art would also be expected to either know or be able to find references teaching in general what conditions are suitable for etching the desired material.

21 Claims 1-6,9-14 and 18-25 are rejected under 35 U.S.C. § 102(b) as anticipated by or, in the alternative, under 35 U.S.C. § 103 as obvious over Mundt et al. '162.

Mundt et al. '162 teaches the relative etch rates as a function of position for both flat and convex electrodes in figures 2 and 3.

The examiner holds that the relative etch rates disclosed are equivalent to the combined etch rate constant and that the observations and changing the electrode results in a new etching apparatus. Alternatively, it would have been obvious to vary known etch parameters including reactive gas composition, temperature, pressure, reactor configuration, rf power, flow rate and the like as is known in the art to produce a more uniform etch in the

Serial Number: 08/433623

-6-

Art Unit: 1113

course of routine optimization. Please note that one skilled in the art would also be expected to either know or be able to find references teaching in general what conditions are suitable for etching the desired material.

22 Claims 1-6,9-14 and 18-25 are rejected under 35 U.S.C. § 102(b) as anticipated by or, in the alternative, under 35 U.S.C. § 103 as obvious over Stefani et al. '229.

Stefani et al. '229 teaches the use of ellisometry to determine the localized etch rates over the wafer surface and/or over a plurality of wafer surfaces in the same etch chamber. (2/34-38) a model is developed to describe the relative non-uniformity of the etch. (4/49-56) This data allows the operator to change parameters and evaluate the effects of doing so. (6/39-60)

The examiner holds that the relative etch rates as a function of position as equivalent to the combined etch rate constant recited and that the observations and varying of the etch conditions results in a new etching apparatus, since the composition of the etchant, which makes it an etching apparatus is changed. Alternatively, it would have been obvious to vary known etch parameters including reactive gas composition, temperature, pressure, reactor configuration, rf power, flow rate and the like as is known in the art to produce a more uniform etch in the course of routine optimization. Please note that one skilled in the art would also be expected to either know or be able to find references teaching in general what conditions are suitable for etching the desired material.

Serial Number: 08/433623

-7-

Art Unit: 1113

23 Claims 1-25 are rejected under 35 U.S.C. § 103 as obvious over Thompson "Introduction to Microlithography".

Thompson "Introduction to Microlithography" teaches the relationship between the loading effect and the etch rate, including the etching rate constant. (page 234) The use of "large volume reactors" to reduce loading effects is disclosed. (page 234) The cases of diffusion limited processes is disclosed. (page 234) The reduction of localized depletion (non-uniformity of the etch) of the etchant may be pressure and flow rates. (page 235) Several examples of etching chambers appear on page 230..

The examiner holds that it would have been obvious to vary known etch parameters including reactive gas composition, temperature, pressure, reactor configuration, rf power, flow rate and the like as is known in the art to produce a more uniform etch in the course of routine optimization in known etching processes including ashing processes which are commonly used to remove resists. Please note that one skilled in the art would also be expected to either know or be able to find references teaching in general what conditions are suitable for etching the desired material.

24 Claims 1-25 are rejected under 35 U.S.C. § 103 as obvious over Mogab '665 and Thompson "Introduction to Microlithography".

It would have been obvious to one skilled in the art to preform the calculations disclosed by Thompson "Introduction to Microlithography" in the process disclosed by Mogab

Art Unit: 1113

'665 for the different etching apparatus/conditions to optimize the parameters for a particular etch process with a reasonable expectation of success.

25 Claims 1-25 are rejected under 35 U.S.C. § 103 as being unpatentable over either Stefani et al. '229, Mundt et al. '162, Horiike '706 or Bobbio '520, in view of Babanov et al. Plasma Chemistry and Plasma Processing and Thompson "Introduction to Microlithography".

It would have been obvious to one skilled in the art to determine the parameters including the etch rate constants in a manner similar to that disclosed by Babanov et al. Plasma Chemistry and Plasma Processing and Thompson "Introduction to Microlithography" with each of the etch processes taught by either Stefani et al. '229, Mundt et al. '162, Horiike '706 or Bobbio '520 to further optimize known parameters including reactive gas composition, temperature, pressure, reactor configuration, rf power, flow rate and the like as is known in the art to produce a more uniform etch in the course of routine optimization in known etching processes based upon the teachings of Thompson "Introduction to Microlithography" to do so to improve the uniformity of the etch process.

This includes ashing processes which are commonly used to remove resists.

26 The prior art made of record and not relied upon is considered pertinent to applicant's disclosure.

Elliott "Integrated Circuit Fabrication Technology" teaches types of etching apparatus and processes for their use.

Art Unit: 1113

Giapis et al. Appl. Phys. Lett., Ha et al. Plasma Chemistry and Plasma Processing and Gregus et al. Plasma Chemistry and Plasma Processing teach the effects of temperature of etch uniformity.

Hendricks et al. '461 and Ikeda et al. '506 teach the use of a baffle plate to increase etch uniformity. (see figure 6)

Kubota et al. '606 teaches the use of rf fields to control the movement of the electrons in the plasma and increase etch uniformity. (see figures 7c and 8b)

Kojima et al. '709 teaches cooling the support and using a baffle plate to increase the uniformity of the etch process across the wafer.

Ryan et al. Plasma Chemistry and Plasma Processing teach the process of determining etch rates

27 The applicants are reminded of thier duty of disclosure..

28 Any inquiry concerning this communication or earlier communications from the examiner should be directed to Martin Angebranntd whose telephone number is (703) 308-4397.

I am normally available between 7:30 AM and 5:00 PM, Monday through Thursday and 7:30 AM and 4:00 PM on alternate Fridays.

If repeated attempts to reach me are unsuccessful, my supervisor may be reached at (703) 308-2417.

Facsimile correspondence should be directed to (703) 305-3599.

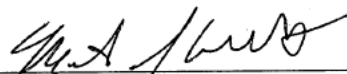


Serial Number: 08/433623

-10-

Art Unit: 1113

Any inquiry of a general nature or relating to the status of this application should be directed to the Group receptionist whose telephone number is (703) 308-0661.



---

Martin J. Angebrannt  
Patent Examiner, Group 1100  
March 4, 1996

SUBSTITUTE PTO-892		U. S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		SERIAL NO. <b>08/433623</b>	GROUP ART UNIT <b>1113</b>	ATTACHMENT TO PAPER NUMBER <b>5</b>		
<b>NOTICE OF REFERENCES CITED</b>				APPLICANT(S) <b>Flamm et al.</b>				
<b>U.S. PATENT DOCUMENTS</b>								
	DOCUMENT NO.	DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE		
A	5,445,709	8/1995	Kojima et al.	156	662.1	11/1993		
B	4,243,506	1/1981	Ikeda et al.	156	345P			
C	5,330,606	7/1994	Kubota et al.	156	345P	10/1991		
D	4,340,461	7/1982	Hendricks et al.	156	345P			
E	5,399,229	3/1995	Stefani et al.	156	626.1	5/1993		
F	4,297,162	10/1981	Mundt et al.	156	345P			
G	4,226,665	10/1980	Mogab	156	643.1			
H	4,192,706	3/1980	Horiike	156	643.1			
I	5,147,520	9/1992	Bobbio	204	298.32			
J								
K								
<b>FOREIGN PATENT DOCUMENTS</b>								
	DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. PP. DWG. SPEC.	
L								
M								
N								
O								
P								
Q								
<b>OTHER REFERENCES (Including Author, Title, Date, Pertinent Pages, Etc.)</b>								
R	Thompson et al. "Introduction to Microlithography" © 1983 ACS pp 228-235.							
	Giapis et al. Appl. Phys Lett 57(10) 983-985 (9/1990)							
	Gregus et al. Plasma Chem. Plasma Process. 13(3) 521-537 (1993)							
S	Babanov et al. Plasma Chem. Plasma Process. 13(1) 37-59 (1993)							
	Ha et al. Plasma Chem. Plasma Process. 11(2) 311-321 (1991)							
T	Rayn et al. Plasma Chem. Plasma Process. 10(2) 207-229 (1990)							
U	Elliott "Integrated Circuit Fabrication Technology" © 1982 pp 242-243 and 258-271.							
EXAMINER <i>M. W. A.</i>			DATE <b>3/4/96</b>		SHEET 1 OF 1			
* A copy of this reference is not being furnished with this office action. (See Manual of Patent Examining Procedure, section 707.05(a).)								

Transmittal Letter

TOWNSEND and TOWNSEND and CREW  
Steuart Street Tower  
One Market Plaza  
San Francisco, CA 94105  
(415) 326-2400

Atty. Docket No. 16655-000100

Date February 16, 1996

In re application of: DANIEL L. FLAMM et al.


Serial No.: 08/433,623

Filed: May 3, 1995

For: PROCESS OPTIMIZATION IN A GAS  
PHASE DRY ETCHING

I hereby certify that this is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D. C. 20231.

Date: February 16, 1996

  
Michael A. Miranda

BOX IDS  
ASSISTANT COMMISSIONER FOR PATENTS  
Washington, D.C. 20231

Sir:


Transmitted herewith are the following documents:

- 1) Information Disclosure Statement Under 37 CFR §1.97 and §1.98;
- 2) Form PTO-1449 (including 37 references);
- 3) Postcard.

Please charge Deposit Account No. 20-1430 as follows:

Any additional fees associated with this paper or during the pendency of this application.

2 copies of this sheet are enclosed. TOWNSEND and TOWNSEND and CREW

  
Richard T. Ogawa  
Reg. No.: 37,692

Attorneys for Applicant

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I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231,

1113 C  
3-7-96  
#20106  
PATENT



February 16, '96

Attorney Docket No. 16655-000100

TOWNSEND and TOWNSEND and CREW

By *Michael A. Miranda*  
Michael A. Miranda

GROUP 1100

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

DANIEL L. FLAMM et al.

Examiner: T. Lee

Application No.: 08/433,623

Art Unit: ~~1100~~

Filed: May 3, 1995

INFORMATION DISCLOSURE STATEMENT UNDER

For: PROCESS OPTIMIZATION IN A GAS PHASE DRY ETCHING

37 CFR §1.97 and §1.98

Assistant Commissioner for Patents  
Washington, D.C. 20231

RECEIVED  
MAR 4 1996

Sir:

GROUP 1100

The references cited on attached form PTO-1449 are being called to the attention of the Examiner. A copy of each is enclosed.

It is respectfully requested that the cited information be expressly considered during the prosecution of this application, and the references be made of record therein and appear among the "references cited" on any patent to issue therefrom.

Applicant believes that no fee is required for submission of this statement, since it is being submitted prior to the first Office Action. However, if a fee is required, the Commissioner is authorized to charge such fee to Deposit Account

DANIEL L. FLANN et al.  
Application No.: 08/433,623  
Page 2

PATENT

No. 20-1430. Please charge any additional fees or credit any overpayment to the above-noted Deposit Account.

Respectfully submitted,



Richard T. Ogawa  
Reg. No. 37,692

TOWNSEND and TOWNSEND and CREW  
One Market Plaza  
Steuart Street Tower, 20th Floor  
San Francisco, California 94105

(415) 326-2400  
Fax (415) 326-2422

RTO:mam

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FORM PTO-1449 (Modified)		Attorney Docket No. 16655-000100	Serial No.: 08/433,623			
LIST OF PATENTS AND PUBLICATIONS FOR APPLICANT'S INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)		Applicant: DANIEL L. FLAMM et al.				
		Filing Date: 05/03/95	Group: <del>1409</del> 1113			
Reference Designation		U.S. PATENT DOCUMENTS				
Examiner Initial	Document No.	Date	Name	Class	Sub-class	Filing Date (If Appropriate)
___ AA						
___ AB						
___ AC						
___ AD						
___ AE						
___ AF						
___ AG						
___ AH						
___ AI						
___ AJ						
___ AK						
___ AL						
		FOREIGN PATENT DOCUMENTS				
	Document No.	Date	Country	Class	Sub-class	Translation (yes/no)
___ AM						
___ AN						
___ AO						
___ AP						
___ AQ						
OTHER ART (Including Author, Title, Date, Pertinent Pages, Etc.)						
<del>AR</del>	Bird et al., <u>Transport Phenomena</u> , 1960, John Wiley & Sons, pg. 510.					
<del>AS</del>	Manos, D. M. and Flamm, D. L., <u>Plasma Etchings, An Introduction</u> , 1989, Academic Press, (title page and table of contents. <i>only</i> )					
___ AT						
EXAMINER	<i>W. N. B.</i>		DATE CONSIDERED <i>1/4/93</i>			

EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

TOWNSEND and TOWNSEND and C...W LLP  
 Two Embarcadero Center, 8th Floor  
 San Francisco, CA 94111-3834  
 (415) 326-2400



In re application of Daniel L. Fleming et al.

Serial No: 08/433,623

Filed: May 3, 1995

Group Art Unit: 1113

For: PROCESS OPTIMIZATION IN GAS  
 PHASE DRY ETCHING

ASSISTANT COMMISSIONER FOR PATENTS  
 Washington, D.C. 20231

Sir:

Transmitted herewith is an amendment in the above-identified application.

- Amendment.
- Petition to Extend Time.
- Small entity status of this application under 37 CFR 1.9 and 1.27 has been established by a verified statement previously submitted.
- Postcard.

The filing fee has been calculated as shown below:

		(Col. 1)	(Col. 2)	(Col. 3)	SMALL ENTITY		OR	OTHER THAN A SMALL ENTITY	
		CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NO. PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE	ADDIT. FEE		RATE	ADDIT. FEE
TOTAL	*31	MINUS	**25	=6	6 x11=	\$ 66.00		x22=	\$
INDEP.	*6	MINUS	***5	=1	1 x39=	\$ 39.00		x78=	\$
[X] FIRST PRESENTATION OF MULTIPLE DEP. CLAIM: See claim 28, which is counted as three claims					+125=	\$125.00		+250=	\$
					TOTAL	\$230.00	OR	TOTAL	\$

- \* If the entry in Col. 1 is less than the entry in Col. 2, write "0" in Col. 3.
  - \*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, write "20" in this space.
  - \*\*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, write "3" in this space.
- The "Highest Number Previously Paid For" (Total or Independent) is the highest number found from the equivalent box in Col. 1 of a prior amendment or the number of claims originally filed.

[ ] No fee is due.

Please charge Deposit Account No. 20-1430 as follows:

- Claims fee \$230.00
- Any additional fees associated with this paper or during the pendency of this application.

2 extra copies of this sheet are enclosed.

Amendment Transmittal  
 Atty. Docket No. 55-000100  
 Date 9/6/96

I hereby certify that this is being deposited with the United States Postal Service as first class mail in an envelope addressed to:

Assistant Commissioner for Patents  
 Washington, D. C. 20231.

Date: 9/6/96  
 RECEIVED  
 OCT 8 1996  
 GROUP 1100

36199-203  
 36200-202  
 36201-204  
 TOWNSEND and TOWNSEND and CREW LLP  
 Richard T. Ogawa  
 Reg. No.: 37,692  
 Attorneys for Applicant

I hereby certify that this correspondence being deposited with the United States Postal Service as first class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231, on

9/6/96



TOWNSEND and TOWNSEND and CREW LLP

By Richard T. Ogawa

1113  
# 7/Ext. 1  
75ms  
3 ms. PATENT

Attorney Docket No. 16655-000100

M. WATTS  
9/6/96

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: )  
Daniel L. Flamm, et al. )  
Application No.: 08/433,623 )  
Filed: May 3, 1995 )  
For: PROCESS OPTIMIZATION IN GAS )  
PHASE DRY ETCHING )

RECEIVED  
Examiner: OC Angebrann  
8 1996  
Art Unit GROUP 1100  
PETITION TO EXTEND TIME UNDER  
37 CFR §1.136(a)

Assistant Commissioner for Patents  
Washington, D.C. 20231

Sir:

Applicants petition the Assistant Commissioner of Patents to extend the time for response to the Office Action, dated March 6, 1996 for three months, from June 6, 1996 to September 6, 1996. An appropriate response to the Office Action in the form of an Amendment is enclosed herewith.

Please charge \$450.00, pursuant to 37 CFR §1.17, to the Deposit Account No. 20-1430. Please charge any additional fees or credit overpayment to the above Deposit Account. This Petition is submitted in triplicate.

Respectfully submitted,

Dated: 9/6/96

Richard T. Ogawa  
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36198 217 450.00CH 16655-000100



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I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to Assistant Commissioner for Patents, Washington, D.C. 20231, on

TOWNSEND and TOWNSEND and CREW LLP

By [Signature]



PATENT

Attorney Docket No. 16655-000100

#8/Amend B  
M. W. HATS  
11/9/96

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	)	
Daniel L. Flamm	)	Examiner: M. Angebrandt
Application No.: 08/433,623	)	Art Unit: 1113
Filed: May 3, 1995	)	<u>AMENDMENT UNDER 37 CFR §1.115</u>
For: PROCESS OPTIMIZATION IN GAS	)	
PHASE DRY ETCHING	)	

Assistant Commissioner for Patents  
Washington, D.C. 20231

Dear Sirs:

In response to the Office Action mailed March 6, 1996, the period for response being extended as a result of the enclosed Petition for Extension of Time and requisite fee, please amend the above-cited application as follows.

IN THE CLAIMS:

Please amend claims 1, 2, 5-10, 13-16, 19, 20, 22, 23, and 25; and add new claims 27-29 as follows. For the convenience of the Examiner, all claims subject to examination are shown, even if not being amended.

1. (Twice Amended) A device fabrication method comprising the steps of: providing a plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;

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B1  
C1

~~[chemical] etching said top film surface to define [an] a relatively non-uniform etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said relatively non-uniform etching profile, said etching comprising a reaction between a gas phase etchant and said film; and~~  
extracting a surface reaction rate constant [reaction rate] from said etch rate data, and using said surface reaction rate constant in the fabrication of a device.

B2  
Sub  
C2

2. (Amended) The method of claim 1 wherein said [chemical] etching step is diffusion limiting.

3. The method of claim 1 wherein said spatial coordinates include a radius and an angle.

4. The method of claim 1 wherein said spatial coordinates include an x-direction and a y-direction.

B3

5. (Amended) The method of claim 1 wherein said extracting step correlates said surface reaction rate constant [reaction rate] over a diffusivity with said etch[ing] rate, said etch[ing] rate being defined by said relatively non-uniform etching profile.

B4

6. (Amended) The method of claim 1 wherein said etch[ing] rate is defined by said relatively non-uniform etching profile at selected spatial coordinates over a time.

7. (Amended) The method of claim 1 wherein said [chemical] etching is an ashing method.

34

8. (Amended) The method of claim [1] 7 wherein said ashing method comprises reactants including an oxygen and a photoresist.

Sub 4  
B4

9. (Amended) A method of designing a reactor comprising the steps of:  
providing a first plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;

[chemical] etching said top film surface to define [an] a relatively non-uniform etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile, said etching comprising a reaction between a gas phase etchant and said film; and

extracting a surface reaction rate constant [reaction rate constant] from said etch rate data, and using said [reaction rate constant] surface reaction rate constant in designing a second plasma etching apparatus.

10. (Amended) The method of claim 9 wherein said **[chemical]** etching step is diffusion limiting.

11. The method of claim 9 wherein said spatial coordinates include a radius and an angle.

12. The method of claim 9 wherein said spatial coordinates include an x-direction and a y-direction.

B5

~~13~~<sup>14</sup>. (Amended) The method of claim ~~9~~<sup>10</sup> wherein said extracting step correlates said surface reaction rate constant [reaction rate constant] over a diffusivity with said **[an] etch[ing] rate**, said etch[ing] rate being defined by said relatively non-uniform etching profile.

~~14~~<sup>15</sup>. (Amended) The method of claim ~~9~~<sup>10</sup> wherein said etch[ing] rate is defined by said relatively non-uniform etching profile at selected spatial coordinates over a time.

35

~~15~~<sup>16</sup>. (Amended) The method of claim ~~9~~<sup>10</sup> wherein said **[chemical]** etching is an ashing method.

B5

<sup>17</sup>  
16. (Amended) The method of claim [9] <sup>16</sup>~~15~~ wherein said ashing method comprises reactants including an oxygen and a photoresist.

17. The method of claim 9 wherein said second plasma etching apparatus is a co-axial reactor.

18. The method of claim 9 wherein said second plasma etching apparatus is a plasma etching apparatus.

Sub  
C6  
B6

19. (Amended) A substrate fabrication method comprising:  
providing a substrate selected from a group consisting of a semiconductor wafer, a plate, and a flat panel display, said substrate comprising a top surface;  
forming a film overlying said top surface, said film comprising a top film surface;  
**[chemical]** etching said top film surface to define a relatively non-uniform profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile, said etching comprising a reaction between a gas phase etchant and said film; and  
extracting a surface reaction rate constant **[reaction rate constant]** from said etch rate data, and using said **[reaction rate constant]** surface reaction rate constant in adjusting said method.

20. (Amended) A method of fabricating an integrated circuit device, said method comprising:  
providing a uniformity value and a surface reaction rate constant for an etching reaction, said etching reaction including a substrate and etchant species;  
defining etching parameters **[ranges]** providing said uniformity value; and  
adjusting at least one of said etching parameters using said surface reaction rate constant to produce a selected etching rate;  
wherein said etching rate providing an etching condition for fabrication of an integrated circuit device.

36

21. The method of claim 20 wherein said etching parameters can be selected from a group consisting of a temperature, a pressure, a power, a gap, and a flow rate.

B7

<sup>24</sup>22. (Amended) The method of claim <sup>22</sup>20 wherein said uniformity value ranges from 90% and greater.

<sup>25</sup>23. (Amended) The method of claim <sup>22</sup>20 wherein said uniformity value ranges from 95% and greater.

24. The method of claim 1 further comprising a step of using said reaction rate constant in adjusting said plasma etch apparatus.

B8  
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C7

25. (Amended) A process for fabricating a device, said device being fabricated by use of a surface reaction rate constant [reaction rate constant], said surface reaction rate constant [reaction rate constant] being derived from a method comprising:  
providing a plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;

etching said top surface at a temperature to define [an] a relatively non-uniform etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate from said etching profile, said etching comprising a reaction between a gas phase etchant and said film; and

extracting from said etching rate data a surface reaction rate constant [reaction rate] for said temperature.

Sub  
C8

26. (New) The process of claim 25 wherein said surface reaction rate constant is derived from at least a diffusivity.

B9

<sup>28</sup>27. (New) The process of claim <sup>26</sup>25 wherein said etching is provided whereupon chemical effects are enhanced over ion bombardment effects.

37

21  
28. (New) The method of claims 1, ~~8~~<sup>10</sup>, or ~~19~~<sup>20</sup> wherein said etching is provided whereupon chemical effects are enhanced over ion bombardment effects.

29. (New) A method of fabricating a device or designing a reactor using a surface reaction rate constant, said surface reaction rate constant is provided by at least a diffusivity value.

REMARKS

Reconsideration of these claims, as amended, is respectfully requested.  
Claims 1-29 are now pending in this application.

35 U.S.C. §112

Claims 1-25 were rejected under 35 U.S.C. §112, second paragraph, for failing to particularly point out and distinctly claim the subject matter which Applicants regard as the invention. In particular, the Examiner indicates that the "claims should clearly indicate that this is a localized etching rate constant." Office Action mailed 3/6/96, page 2, first paragraph. As described by the Examiner, the localized etching rate constant combines the effects and rates of diffusion, adsorption and desorption, and the actual etching rate.

Applicants, however, intended the "reaction rate constant" as recited by the claims to be a "surface reaction rate constant," which is described throughout the present patent specification and notably at page 17, lines 15-20 as  $k_s$ . This surface reaction rate constant, commonly termed  $k_s$ , is not the so-called localized etching rate constant according to the Examiner's description. As indicated by the Examiner, the localized etching rate constant is believed to be what is commonly termed as a phenomenological or an overall etching rate constant, which includes influences of substantially all the etching variables.

The surface reaction rate constant, however, depends predominantly upon temperature, as defined throughout the present patent specification, but most notably by the equation at page 11 line 16. The surface reaction rate constant is also generally for the chemical reaction between a gas phase etchant and the film, which is not the overall etching process. Unlike the phenomenological reaction rate constant, the surface reaction rate constant can be used to derive process certain variables for device fabrication and reactor design, for example. These variables include temperature, flow rate, gap, reactor

dimensions, and others. This allows a user of such surface reaction rate to adjust these process or reactor variables without undue "trial and error" as disclosed by the patent specification.

Based upon the above description of the various types of reaction rate constants, it is believed that any claim indefiniteness perceived by the Examiner has been resolved. This should also clarify those variables which could be calculated by the use of the surface reaction rate constant, which are clearly defined throughout the specification. Accordingly, these rejections to claims 1-25 under 35 U.S.C. §112, second paragraph, are now moot.

35 U.S.C. §§102/103

The Examiner has rejected claims 1-6, 9-14, and 18-25 under 35 U.S.C. §102(b) as being anticipated by, or in alternative, under 35 U.S.C. §103 as being obvious over Bobbio. In particular, it is asserted that Bobbio discloses an apparatus and relative etch rates, which were believed similar to those in the claims.

Bobbio, however, fails to show or suggest the combination of etching and extracting a surface reaction rate constant, as recited by claims 1, 9, 19, and 25. In particular, Bobbio fails to show or suggest etching a top film surface to define a relatively non-uniform etching profile on the film and defining etch rate data comprising an etch rate and a spatial coordinate from the relatively non-uniform etching profile. Bobbio also fails to show or suggest a further combination of extracting a surface reaction rate constant from the etch rate data, which is provided by a non-uniform etching profile from etching using a gas phase etchant and the film. This surface reaction rate constant can be used to derive other etching parameters such as a temperature, a gap, a flow rate, reactor dimensions, and others, as shown by the present specification.

In fact, Bobbio does not even suggest any surface reaction rate constant to define these parameters, but merely uses the same "trial and error" process described in the background of invention section of the present patent specification. Clearly, Bobbio "found that typically no more than three positioning steps, including the initial positioning, are required to achieve acceptable uniformity for the split cathode magnetron," which is simply the conventional technique of 'trial and error.' [Emphasis added.] Bobbio, col. 8 lines 43-50. Bobbio also fails to show or suggest a later step of using the surface reaction rate

constant for the fabrication of a device such as those recited by claims 1, 19, or 25, or for designing a reactor as recited by claim 9. Accordingly, claims 1-6, 9-14, and 18-25 are patentable over Bobbio.

The Examiner also rejected claims 1-25 under 35 U.S.C. §102(b) as being anticipated by or, in the alternative, under 35 U.S.C. §103 as being obvious over Horiike. Horiike supposedly disclosed etch rates as a function of distance. Horiike, however, also fails to show or suggest the combination of etching and extracting a surface reaction rate constant, as claimed.

In particular, Horiike does not show or suggest a step of etching a top film surface to define a relatively non-uniform etching profile on the film and defining etch rate data comprising an etch rate and a spatial coordinate from the relatively non-uniform etching profile. Horiike also fails to show or suggest any further step of extracting a surface reaction rate constant from the etch rate data. As noted above, this surface reaction rate constant can be used to derive other etching parameters such as a temperature, a gap, a flow rate, reactor dimensions, and others, as shown by the present specification. At best, the etch rate data of Fig. 9 in Horiike may provide a phenomenological etch rate constant, which appears to vary with position. In contrast, the surface reaction rate constant is generally independent of most variables including position, but is dependent predominantly on temperature, as noted above and described throughout the present patent specification. Furthermore, Horiike does not show or suggest using the surface reaction rate constant for fabricating a device such as those in claims 1, 19, and 25, or for designing the reactor of claim 9. Accordingly, claims 1-25 are patentable over Horiike.

Claims 1-6, 9-14, and 18-25 were rejected under 35 U.S.C. §102(b) as being anticipated by or, in the alternative, under 35 U.S.C. §103 as being obvious over Mogab. Mogab generally taught adjusting the reactor design to reduce the influences of loading. Mogab, however, clearly fails to show or suggest the further combination of etching a top film surface to define a relatively non-uniform etching profile on the film and defining etch rate data comprising an etch rate and a spatial coordinate from the relatively non-uniform etching profile, as claimed.

Furthermore, Mogab fails to show or suggest any further step of extracting a surface reaction rate constant from the etch rate data, which can be used to derive other etching parameters such as a temperature, a gap, a flow rate, reactor dimensions, and others.



At best, the etching taught by Mogab is an overall etching rate, where a phenomenological etch rate constant might be derived. As noted above and further emphasized herein, this phenomenological etch rate constant is not a surface reaction rate constant, which is predominately dependent upon temperature. Moreover, Mogab does not show or suggest using the surface reaction rate constant for device fabrication or using the reaction rate constant for designing a reactor, as claimed. Accordingly, claims 1-6, 9-14, and 18-25 are patentable over Mogab.

Claims 1-6, 9-14, and 18-25 were rejected under 35 U.S.C. §102(b) as being anticipated by or, in the alternative, under 35 U.S.C. §103 as being obvious over Mundt et al. This references supposedly taught relative etch rates as a function of position for both flat and convex electrodes in Figs. 2 and 3. Mundt et al., however, clearly fails to show or suggest the further combination of etching a top film surface to define a relatively non-uniform etching profile on the film and defining etch rate data comprising an etch rate and a spatial coordinate from the relatively non-uniform etching profile, as claimed.

Mundt et al. also fails to show or suggest any further step of extracting a surface reaction rate constant from the etch rate data, which can be used to derive other etching parameters such as a temperature, a gap, a flow rate, reactor dimensions, and others. Similar to those previous references, Mundt et al. merely discloses relative etching rates, which may produce a phenomenological rate constant. This phenomenological rate constant is not the same as the present surface reaction rate constant. Thus, Mundt et al. is no more relevant than any of the above references and clearly does not show or suggest using such surface reaction rate constant in fabricating a device or designing a reactor, as claimed. Accordingly, claims 1-6, 9-14, and 18-25 are patentable over Mundt et al.

Claims 1-6, 9-14, and 18-25 were rejected under 35 U.S.C. 102(b) as being anticipated by or, in the alternative, under 35 U.S.C. §103 as being obvious over Stefani. In particular, Stefani supposedly taught an ellipsometer to determine the localized etch rates over the wafer surface, which generally has nothing to do with the invention recited by the pending claims.

Clearly, Stefani did not show or suggest a combination of etching a top film surface to define a relatively non-uniform etching profile on the film, which defines an etch rate and a spatial coordinate, as recited by the claims. Stefani also fails to further show or suggest a step of extracting a surface reaction rate constant from the etch rate data. This

surface reaction rate constant can be used to derive other etching parameters such as those noted above. Accordingly, claims 1-6, 9-14, and 18-25 are patentable over Stefani.

The Examiner rejected claims 1-25 under 35 U.S.C. §103 as being obvious over Thompson, "Introduction to Microlithography." In particular, the Examiner indicated that Thompson taught a relationship between the loading effect and the etch rate, including the etching rate constant.

Thompson, however, fails to show or suggest the claimed combination of etching a top-film surface to define a relatively non-uniform etching profile on the film, which defines an etch rate and a spatial coordinate and extracting a surface reaction rate constant from the etch rate data. At best, Thompson merely taught the same "trial and error" technique of adjusting a reactor as disclosed by the present patent specification. Accordingly, claims 1-25 are patentable over Thompson.

Claims 1-25 were also rejected under 35 U.S.C. §103 as obvious over Mogab and Thompson, "Introduction to Microlithography". As shown above, neither of these references show or suggest the combination of etching a film to provide etch rate data and extracting a surface reaction rate constant. This surface reaction rate constant can be used in adjusting variables for reactor design or fabricating a device, as claimed. Accordingly, these claims should be patentable over the combination of these references.

Claims 1-25 were rejected under 35 U.S.C. §103 as being unpatentable over either Stefani *et al.*, Mundt *et al.*, Horiike, or Bobbio, in view of Babanov *et al.*, Plasma Chemistry and Plasma Processing and Thompson, "Introduction to Microlithography". Neither of these references show or suggest the further combination of etching a film to provide etch rate data and extracting a surface reaction rate constant from the data, as recited by the above claims. Furthermore, these references, alone or in combination, further fail to show or suggest the claimed step of using the surface reaction rate constant in fabricating a device or designing a reactor. Clearly, claims 1-25 are patentable over these references under 35 U.S.C. §102 and §103.

The above-cited references, alone or in combination, also fail to show or suggest the method of fabricating an integrated circuit device of claim 20, as amended. In particular, they fail to show or suggest steps of providing a uniformity value and a surface reaction rate constant for an etching reaction, which was discussed in detail above. These references also fail to show or suggest defining etching parameters, which provide the

uniformity value, and adjusting at least one of the etching parameters using the surface reaction rate constant to produce a selected etching rate. This etching rate provides an etching condition for fabrication of an integrated circuit device. By way of the surface reaction rate constant and the etching parameters, a user can adjust at least one of the etching rate parameters and determine its influence on the other parameters by way of this claim. Otherwise, the user would need to resort to "trial and error" as disclosed in the background of invention section of the present patent specification. Accordingly, claim 20 is patentable over the cited references under 35 U.S.C. §102 and §103.

Dependent claims 2-8, 10-18, and 21-24 are also patentable over the cited references for at least the same reasons noted above. In addition, these claims provide further patentable features to their dependent claims. In fact, since the Examiner does not appear to specifically point out the non-patentability of these claims directly, they must be patentable. Accordingly, the dependent claims should be patentable under 35 U.S.C. §102 and §103.

Applicants have also added new claims 27-29. No new matter has been introduced thereby. Accordingly, claims 27-28 should be entered by way of this amendment for examination.

Applicants have reviewed the other art cited by the Examiner and believe that they are no more relevant. In particular, Elliott, Giapis et al., Hendricks et al., Kubota et al., Kojima et al., and Ryan et al. appear to be no more relevant than any of the other references cited above. These references seem to disclose the same concepts as disclosed in the background of invention section of the present patent specification. Accordingly, claims 1-25 are clearly patentable over these references.

Daniel L. Flamm  
Application No.: 08/433,623  
Page 12

PATENT

CONCLUSION

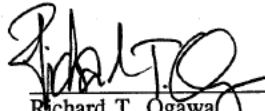
Therefore, in view of the remarks above, Applicant respectfully requests that the rejections be removed, that claims 1-29 be allowed, and the case passed to issue. The issuance of a formal Notice of Allowance at an early date is respectfully requested.

If the Examiner believes a telephone conference would expedite prosecution of this application, please telephone the undersigned at (415) 326-2400.

Respectfully submitted,

Date:

9/6/96

  
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UNITED STATES DEPARTMENT OF COMMERCE  
Patent and Trademark Office

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APPLICATION NUMBER	FLING DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NO.
08/433,623	05/03/95	FLAMM	D 16655-000100

11M1/0124  
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ANGEBRANDT, M	
ART UNIT	PAPER NUMBER
1113	9
DATE MAILED:	01/24/97

This is a communication from the examiner in charge of your application.  
COMMISSIONER OF PATENTS AND TRADEMARKS

OFFICE ACTION SUMMARY

Responsive to communication(s) filed on 4/24/96 & 9/10/96

This action is FINAL.

Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 D.C. 11; 453 O.G. 213.

A shortened statutory period for response to this action is set to expire 3 month(s), or thirty days, whichever is longer, from the mailing date of this communication. Failure to respond within the period for response will cause the application to become abandoned. (35 U.S.C. § 133). Extensions of time may be obtained under the provisions of 37 CFR 1.136(a).

Disposition of Claims

Claim(s) 1-29 is/are pending in the application.

Of the above, claim(s) \_\_\_\_\_ is/are withdrawn from consideration.

Claim(s) \_\_\_\_\_ is/are allowed.

Claim(s) 1-29 is/are rejected.

Claim(s) \_\_\_\_\_ is/are objected to.

Claims \_\_\_\_\_ are subject to restriction or election requirement.

Application Papers

See the attached Notice of Draftsperson's Patent Drawing Review, PTO-948.

The drawing(s) filed on \_\_\_\_\_ is/are objected to by the Examiner.

The proposed drawing correction, filed on \_\_\_\_\_ is  approved  disapproved.

The specification is objected to by the Examiner.

The oath or declaration is objected to by the Examiner.

Priority under 35 U.S.C. § 119

Acknowledgement is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d).

All  Some\*  None of the CERTIFIED copies of the priority documents have been

received.

received in Application No. (Series Code/Serial Number) \_\_\_\_\_.

received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

\*Certified copies not received: \_\_\_\_\_

Acknowledgement is made of a claim for domestic priority under 35 U.S.C. § 119(e).

Attachment(s)

Notice of Reference Cited, PTO-892

Information Disclosure Statement(s), PTO-1449, Paper No.(s) 6

Interview Summary, PTO-413

Notice of Draftsperson's Patent Drawing Review, PTO-948

Notice of Informal Patent Application, PTO-152

-- SEE OFFICE ACTION ON THE FOLLOWING PAGES --

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Art Unit: 1113

15 The responses provided by the applicant has been read and given careful consideration. The applicant generally argues that the surface reaction rate constant can be used to determine or optimize a host of parameters of the etching conditions, including temperature, the gap (between the source and the surface), the flow rate, reactor dimensions, etc. Of these only the plasma temperature could reasonably be expected to have a small impact on the transport rate constants as it is related most closely with the energy of the etchant species. Additionally, the applicant appears to neglect in the arguments that many of these parameters are not disclosed as affecting the rate constants. Also please note that the applicant optimizes the same parameters (ie "temperature pressure, reactor configuration, and the like" (page 18 lines 21-24) and changing the chamber material or coating the chamber surfaces ... rf power, flow rate and the like (page 14/lines 1-16 and 2/14-20) which are commonly optimized as part of the process and represent the only parameters available for optimization.

The examiner also notes that the applicant sent only a single page of the Bird et al. reference and the table of contents of the Manos and Flamm reference and hopes that the applicant recognizes that this means that only those portions of the references have been considered in determining patentability and that this cannot in any way be interpreted in mean that any other portion of these references has been considered.

16 Claims 26 and 29 are objected to under 37 CFR 1.75(c), as being of improper dependent form for failing to further limit the subject matter of a previous claim. Applicant

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is required to cancel the claim(s), or amend the claim(s) to place the claim(s) in proper dependent form, or rewrite the claim(s) in independent form.

The applicant argues that the surface reaction rate constant is the etching rate constant without contributions from transport phenomena. The claim seems to indicate otherwise. The diffusivity measurement is used to isolate or determine the actual surface reaction rate constant from the volumetric reaction rate constant which includes transport phenomena, but it cannot be said that the surface reaction rate is **derived** from the diffusivity as the former specifically excludes contributions from the latter.

17 Claim 29 is rejected under 35 U.S.C. 112, second paragraph, as failing to set forth the subject matter which applicant(s) regard as their invention.

The preamble of the claim recites two dissimilar processes rendering the scope interminable. If the applicant intends to present separate new claims at this point in the prosecution directed purely to reactor design, these will be restricted and withdrawn from consideration.

18 Claim 19-23 and 29 are rejected under 35 U.S.C. § 112, first paragraph, as the disclosure is enabling only for claims limited to plasma etching processes. See M.P.E.P. §§ 706.03(n) and 706.03(z).

19 The following is a quotation of 35 U.S.C. § 103 which forms the basis for all obviousness rejections set forth in this Office action:

A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a

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whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negated by the manner in which the invention was made.

Subject matter developed by another person, which qualifies as prior art only under subsection (f) or (g) of section 102 of this title, shall not preclude patentability under this section where the subject matter and the claimed invention were, at the time the invention was made, owned by the same person or subject to an obligation of assignment to the same person.

20 Claims 1-29 are rejected under 35 U.S.C. § 103 as obvious over Thompson

"Introduction to Microlithography".

Thompson "Introduction to Microlithography" teaches the relationship between the loading effect and the etch rate, including the etching rate constant. (page 234) The use of "large volume reactors" to reduce loading effects is disclosed. (page 234) The cases of diffusion limited processes is disclosed. (page 234) The reduction of localized depletion (non-uniformity of the etch) of the etchant may be pressure and flow rates. (page 235) Several examples of etching chambers appear on page 230..

The examiner holds that it would have been obvious to vary known etch parameters including reactive gas composition, temperature, pressure, reactor configuration, rf power, flow rate and the like as is known in the art to produce a more uniform etch in the course of routine optimization in known etching processes including ashing processes which are commonly used to remove resists. Please note that one skilled in the art would also be expected to either know or be able to find references teaching in general what conditions are suitable for etching the desired material.



Art Unit: 1113

In response to the arguments raised by the applicant, the equations shown on page 234 of the reference would allow one skilled in the art to determine if the etching conditions were affected by the loading effect, thereby presenting useful information for diagnostic purposes.

**Note that without accounting for the transport phenomena, no optimization of the uniformity of the etch process can be performed.** The rejection is maintained.

21 Claims 1-29 are rejected under 35 U.S.C. § 103 as obvious over Mogab '665 and Thompson "Introduction to Microlithography".

Mogab '665 teaches that loading is known in the art to result in inter or intra wafer non-uniformity. Reactor design is known to increase etch uniformity. (2/15-22) The routine optimization to decrease the effects of loading on the system is disclosed. (2/63+) These changes are disclosed as reducing non-uniformity of the etch. (3/11-17) The use of a radial flow apparatus to determine experimentally the optimum conditions for an etch process is disclosed (5/8-14).

It would have been obvious to one skilled in the art to perform the calculations disclosed by Thompson "Introduction to Microlithography" in the process disclosed by Mogab '665 for the different etching apparatus/conditions to perform diagnostics which describe the physical processes occurring within the plasma etching apparatus thereby allowing for optimization of the parameters for a particular etch process with a reasonable expectation of success.

Art Unit: 1113

The response provided above is relied upon here without further comment. The rejection is maintained.

22 Claims 1-29 are rejected under 35 U.S.C. § 103 as being unpatentable over either Stefani et al. '229, Mundt et al. '162, Horiike '706 or Bobbio '520, in view of Babanov et al. Plasma Chemistry and Plasma Processing and Thompson "Introduction to Microlithography".

Stefani et al. '229 teaches the use of ellisometry to determine the localized etch rates over the wafer surface and/or over a plurality of wafer surfaces in the same etch chamber. (2/34-38) am model is developed to describe the relative non-uniformity of the etch. (4/49-56) This data allows the operator to change parameters and evaluate the effects of doing so. (6/39-60)

Mundt et al. '162 teaches the relative etch rates as a function of position for both flat and convex electrodes in figures 2 and 3.

Horiike '706 teaches that the relative etch rates as a function of distance disclosed are equivalent to the combined etch rate constant and that the observations and varying of the position of the etch target results in a new etching apparatus (see figures 9 and 10).

Bobbio '520 describes a prior art apparatus in which the barriers are placed parallel to each other the inherent etch rates as a function of position are determined in figures 4a and 4b. These are corrected to produce an etch which is relatively uniform over the entire wafer. Typically no more than three positioning steps are required to achieve uniformity deviations of less than 2% (col 8/lines 43-50, hereinafter 8/43-50).

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Art Unit: 1113

It would have been obvious to one skilled in the art to determine the parameters including the etch rate constants in a manner similar to that disclosed by Babanov et al. Plasma Chemistry and Plasma Processing and Thompson "Introduction to Microlithography with each of the etch processes taught by either Stefani et al. '229, Mundt et al. '162, Horiike '706 or Bobbio '520 to further optimize known parameters including reactive gas composition, temperature, pressure, reactor configuration, rf power, flow rate and the like as is known in the art to produce a more uniform etch in the course of routine optimization in known etching processes based upon the teachings of Thompson "Introduction to Microlithography" to do so to improve the uniformity of the etch process. This includes ashing processes which are commonly used to remove resists.

The examiner notes that all of the primary reference teach increasing uniformity and therefore would be held to be optimizing the "uniformity value" irrespective of whether this is actually calculated or not. The response provided above is relied upon here as well without further comment.

23 Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for response to this final action is set to expire **THREE MONTHS** from the date of this action. In the event a first response is filed within **TWO MONTHS** of the mailing date of this final action and the advisory action is not mailed until

Serial Number: 08/433623

-8-

Art Unit: 1113

after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event will the statutory period for response expire later than SIX MONTHS from the date of this final action. *New Claims*

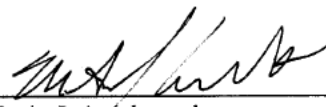
24 Any inquiry concerning this communication or earlier communications from the examiner should be directed to Martin Angebrannt whose telephone number is (703) 308-4397.

I am normally available between 7:30 AM and 5:00 PM, Monday through Thursday and 7:30 AM and 4:00 PM on alternate Fridays.

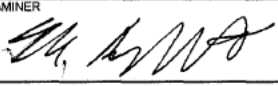
If repeated attempts to reach me are unsuccessful, my supervisor may be reached at (703) 308-2303.

Facsimile correspondence should be directed to (703) 305-3599.

Any inquiry of a general nature or relating to the status of this application should be directed to the Group receptionist whose telephone number is (703) 308-0661.



Martin J. Angebrannt  
Primary Examiner, Group 1100  
January 21, 1997

SUBSTITUTE PTO-892		U. S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE		SERIAL NO. <b>08/433623</b>	GROUP ART UNIT <b>1113</b>	ATTACHMENT TO PAPER NUMBER <b>9</b>		
<b>NOTICE OF REFERENCES CITED</b>				APPLICANT(S) <b>Flamm et al.</b>				
<b>U.S. PATENT DOCUMENTS</b>								
	DOCUMENT NO.	DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE		
A								
B								
C								
D								
E								
F								
G								
H								
I								
J								
K								
<b>FOREIGN PATENT DOCUMENTS</b>								
	DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. DWG	PP. SPEC.
L								
M								
N								
O								
P								
Q								
<b>OTHER REFERENCES (Including Author, Title, Date, Pertinent Pages, Etc.)</b>								
	<b>Manos et al. "Plasma Etching, An Introduction", © 1989, Academic Press, pp 91-183.</b>							
R								
S								
T								
U								
EXAMINER 			DATE <b>1/19/97</b>		<b>SHEET 1 OF 1</b>			
* A copy of this reference is not being furnished with this office action. (See Manual of Patent Examining Procedure, section 707.05(a).)								

Amendment Transmittal

TOWNSEND and TOWNSEND and CREW LLP  
 Two Embarcadero Center, 8th Floor  
 San Francisco, CA 94111-3834  
 (415) 326-2400

Atty. Docket No. 16655-000100

Date May 13, 1997

In re application of Daniel L. Flamm, et al.

I hereby certify that this is being deposited with the United States Postal Service as first class mail in an envelope addressed to:

Serial No: 08/433,623

Filed: May 3, 1995

Group Art Unit: 1113

For: PROCESS OPTIMIZATION IN GAS  
 PHASE DRY ETCHING

Assistant Commissioner for Patents  
 Washington, D. C. 20231.

Date: 5/13/97  
Kristina Alvarez  
 Kristina Alvarez



BOX FEE AMENDMENT  
 ASSISTANT COMMISSIONER FOR PATENTS  
 Washington, D.C. 20231

Sir:

Transmitted herewith are the following documents in response to the Final Office Action dated January 24, 1997 **GROUP 1100**

- 1) Amendment Under 37 CFR §1.116;
- 2) Petition for Extension of Time (1-mo); and
- 3) Postcard.

The filing fee has been calculated as shown below:

(Col. 1)		(Col. 2)		(Col. 3)		SMALL ENTITY		OTHER THAN A SMALL ENTITY		
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NO. PREVIOUSLY PAID FOR		PRESENT EXTRA	RATE	ADDIT. FEE	OR	RATE	ADDIT. FEE
TOTAL	*29	MINUS	**31		=0	x11=	\$		x22=	\$
INDEP.	*5	MINUS	***6		=0	x39=	\$		x78=	\$
[X] FIRST PRESENTATION OF MULTIPLE DEP. CLAIM: See claim 28, which is counted as three claims						+125=	\$		+250=	\$
						TOTAL	\$	OR	TOTAL	\$
						ADDIT. FEE				

- \* If the entry in Col. 1 is less than the entry in Col. 2, write "0" in Col. 3.
  - \*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, write "20" in this space.
  - \*\*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, write "3" in this space.
- The "Highest Number Previously Paid For" (Total or Independent) is the highest number found from the equivalent box in Col. 1 of a prior amendment or the number of claims originally filed.

Please charge Deposit Account No. 20-1430 as follows:

Petition to Extend Time (1-mo) \$55.00  
 Any additional fees associated with this paper or during the pendency of this application.

2 extra copies of this sheet are enclosed.

TOWNSEND and TOWNSEND and CREW LLP  
Richard T. Ogawa  
 Richard T. Ogawa  
 Reg. No.: 37,692  
 Attorneys for Applicant

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231



on 5/13/97 TOWNSEND and TOWNSEND and CREW LLP

By *Rachina Chan*

*10/1/97*  
*6/6/97*

PATENT  
Attorney Docket No. 16655-000100

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: )  
Daniel L. Flamm, et al. )  
Application No.: 08/433,623 )  
Filed: May 3, 1995 )  
For: PROCESS OPTIMIZATION IN GAS )  
PHASE DRY ETCHING )

Examiner: M. Angebranndt

Art Unit: 1113

PETITION TO EXTEND TIME UNDER  
37 CFR §1.136(a)

BOX FEE AMENDMENT  
Assistant Commissioner for Patents  
Washington, D.C. 20231

RECEIVED  
JUN 4 1997  
GROUP 1100

Sir:

Applicants petition the Assistant Commissioner of Patents to extend the time for response to the Office Action, dated January 24, 1997 for one month, from April 24, 1997 to May 24, 1997. An appropriate response to the Office Action in the form of an Amendment Under 37 CFR §1.116 is enclosed herewith.

Please charge \$55.00, pursuant to 37 CFR §1.17, to the Deposit Account No. 20-1430. Please charge any additional fees or credit overpayment to the above Deposit Account. This Petition is submitted in triplicate.

Respectfully submitted,

Dated: 5/13/97

*Richard T. Ogawa*  
Richard T. Ogawa  
Reg. No. 37,692

TOWNSEND and TOWNSEND and CREW LLP  
Two Embarcadero Center, 8th Floor  
San Francisco, California 94111-3834  
(415) 326-2400  
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06/03/1997 LCHLMEK 00000023 DAI#201430 08433623  
Sale Ref: 00000023 DAI# 201430 08433623  
01 Ft:215 55.00 CH

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Assistant Commissioner for Patents, Washington, D.C. 20231, on

5/13/97

TOWNSEND and TOWNSEND and CREW LLP

By *[Signature]*



Attorney Docket No. 16655-000100

PATENT

*[Handwritten initials]*

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: )  
)  
Daniel L. Flamm )  
)  
Application No.: 08/433,623 )  
)  
Filed: May 3, 1995 )  
)  
For: PROCESS OPTIMIZATION IN GAS )  
PHASE DRY ETCHING )  
)  
)

Examiner: M. Angebranndt

Art Unit: 1113

AMENDMENT UNDER 37 CFR §1.116

Assistant Commissioner for Patents  
Washington, D.C. 20231

RECEIVED

JUN 4 1997

GROUP 1100

Dear Sirs:

In response to the Office Action mailed January 24, 1997, please amend the above-cited application as follows.

IN THE CLAIMS:

Please amend claims 1-4, 9-12, 19, 20, 25, 26, and 29 as follows. For the convenience of the Examiner, all claims subject to examination are shown, even if not being amended.

*OK to  
Enter  
WJF  
6/3/97*

*[Handwritten mark]*

1. (Amended) A device fabrication method comprising the steps of:  
providing a plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;  
etching said top film surface to define a relatively non-uniform etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate

*39*



C1

which defines a position within [from] said relatively non-uniform etching profile on said substrate, said etching comprising a reaction between a gas phase etchant and said film; and extracting a surface reaction rate constant from said etch rate data, and using said surface reaction rate constant in the fabrication of a device.

C2

2. (Amended) The method of claim 1 wherein said etching step is diffusion limited [limiting].

C3

3. (Amended) The method of claim 1 wherein said spatial coordinate[s] includes a radius and an angle.

4. (Amended) The method of claim 1 wherein said spatial coordinate[s] includes an x-direction and a y-direction.

5. The method of claim 1 wherein said extracting step correlates said surface reaction rate constant over a diffusivity with said etch rate, said etch rate being defined by said relatively non-uniform etching profile.

6. The method of claim 1 wherein said etch rate is defined by said relatively non-uniform etching profile at selected spatial coordinates over a time.

7. The method of claim 1 wherein said etching is an ashing method.

8. The method of claim 7 wherein said ashing method comprises reactants including an oxygen and a photoresist.

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<sup>10</sup>/~~9~~ (Amended) A method of designing a reactor comprising the steps of:  
providing a first plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;

etching said top film surface to define a relatively non-uniform etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate which defines a position within [from] said relatively non-uniform etching profile on said film of said substrate, said etching comprising a reaction between a gas phase etchant and said film; and

extracting a surface reaction rate constant from said etch rate data, and using said surface reaction rate constant in designing a second plasma etching apparatus.

<sup>11</sup>/~~10~~ (Amended) The method of claim <sup>10</sup>/~~9~~ wherein said etching step at a position on said relatively non-uniform etching profile is diffusion limited [limiting].

25

<sup>12</sup>/~~11~~ (Amended) The method of claim <sup>10</sup>/~~9~~ wherein said spatial coordinate[s] which defines said position along said relatively non-uniform etching profile includes a radius and an angle.

<sup>13</sup>/~~12~~ (Amended) The method of claim <sup>10</sup>/~~9~~ wherein said spatial coordinate[s] which defines said position within said relatively non-uniform etching profile includes an x-direction and a y-direction.

13. The method of claim 9 wherein said extracting step correlates said surface reaction rate constant over a diffusivity with said etch rate, said etch rate being defined by said relatively non-uniform etching profile.

14. The method of claim 9 wherein said etch rate is defined by said relatively non-uniform etching profile at selected spatial coordinates over a time.

15. The method of claim 9 wherein said etching is an ashing method.

41

16. The method of claim 15 wherein said ashing method comprises reactants including an oxygen and a photoresist.

17. The method of claim 9 wherein said second plasma etching apparatus is a co-axial reactor.

18. The method of claim 9 wherein said second plasma etching apparatus is a plasma etching apparatus.

C6

20

19. (Amended) A substrate fabrication method, using a plasma etching apparatus, said method comprising:

providing a substrate selected from a group consisting of a semiconductor wafer, a plate, and a flat panel display, said substrate comprising a top surface;

forming a film overlying said top surface, said film comprising a top film surface;

etching said top film surface to define a relatively non-uniform profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate which defines a position within [from] said relatively non-uniform etching profile of said film on said substrate, said etching comprising a reaction between a gas phase etchant and said film; and

extracting a surface reaction rate constant from said etch rate data, and using said surface reaction rate constant [in adjusting said method].

20

20. (Amended) A method of fabricating an integrated circuit device, using a plasma etching apparatus, said method comprising:

providing a uniformity value and a surface reaction rate constant for an etching reaction, said etching reaction including a substrate and etchant species;

defining etching parameters providing said uniformity value; and

adjusting at least one of said etching parameters using said surface reaction rate constant to produce a selected etching rate;

wherein said etching rate providing an etching condition for fabrication of an integrated circuit device.

12

21. The method of claim 20 wherein said etching parameters can be selected from a group consisting of a temperature, a pressure, a power, a gap, and a flow rate.

22. The method of claim 20 wherein said uniformity value ranges from 90% and greater.

23. The method of claim 20 wherein said uniformity value ranges from 95% and greater.

24. The method of claim 1 further comprising a step of using said reaction rate constant in adjusting said plasma etch apparatus.

25. (Amended) A process for fabricating a device using a plasma etching apparatus, said device being fabricated by use of a surface reaction rate constant, said surface reaction rate constant being derived from a method comprising:

providing a plasma etching apparatus comprising a substrate therein, said substrate comprising a top surface and a film overlying said top surface, said film comprising a top film surface;

etching said top surface at a temperature to define a relatively non-uniform etching profile on said film, and defining etch rate data comprising an etch rate and a spatial coordinate which defined a position from said relatively non-uniform etching profile on said film of said substrate, said etching comprising a reaction between a gas phase etchant and said film; and

extracting from said etching rate data a surface reaction rate constant for said temperature.

26. (Amended) The process of claim ~~25~~<sup>26</sup> wherein said surface reaction rate constant is derived **[from]** using at least a diffusivity value that is determined by an equation.

27. The process of claim 25 wherein said etching is provided whereupon chemical effects are enhanced over ion bombardment effects.

28. The method of claims 1, 9, or 19 wherein said etching is provided whereupon chemical effects are enhanced over ion bombardment effects.

19  
29. (Amended) The method of claim <sup>24</sup>25 further comprising [A method of fabricating a device or designing a reactor] using [a] said surface reaction rate constant in a method selected from a group consisting of a fabrication of a device or of designing a reactor, said surface reaction rate constant [is] being provided by at least a diffusivity value.

REMARKS

Applicant would like to thank Examiner Angebrannt for his time and cooperation in interviewing this subject patent application. Reconsideration of these claims, as amended, is respectfully requested. Claims 1-29 are now pending in this application.

35 U.S.C. §112

Claim 29 was rejected under 35 U.S.C. §112, second paragraph as failing to set forth the subject matter which applicants regard as their invention. As shown, claim 29 has been amended to be dependent upon independent claim 25. Accordingly, the rejection should now be moot.

Claims 19-23 and 29 were rejected under 35 U.S.C. §112, first paragraph, since the disclosure is indicated as enabling only for claims limited to plasma etching processes. As shown above and explained to the Examiner, claims 19-23 and 29 generally use, for example, directly or indirectly, an apparatus for plasma etching and have been amended, as shown above. Accordingly, claims 19-23 and 29 are patentable under 35 U.S.C. §112, first paragraph.


35 U.S.C. §103

44  
The Examiner has rejected claims 1-29 under 35 U.S.C. §103(b) as being obvious over Thompson "Introduction to Microlithography". In particular, the Examiner indicated that Thompson taught a relationship between the loading effect and the etch rate, including the etching rate constant. Thompson generally discloses an equation for loading effect. Thompson, however, fails to show or suggest the invention of claims 1-29, as

amendment, which was suggested by the Examiner. These claims should be patentable over Thompson for the reasons discussed herein using claim 1 as merely an example.

In particular, claim 1 recites a device fabrication method which includes novel aspects of extracting a chemical reaction rate constant from an etching profile. The method includes providing a plasma etching apparatus having a substrate therein. The substrate has a top surface and a film overlying the top surface. The top film surface is etched to define a relatively non-uniform etching profile on the film, which defines etch rate data comprising an etch rate and a spatial coordinate. The spatial coordinate defines a position within the relatively non-uniform etching profile on the substrate. A step of extracting a surface reaction rate constant from the etch rate data is included. The surface reaction rate constant is used in the fabrication of a device. Accordingly, claim 1 provides a sequence of steps for extracting a chemical reaction rate constant from an etching profile in a relatively easy manner. At best, Thompson suggested a loading effect equation, which cannot derive the claimed surface reaction rate constant from an etching profile. Additionally, the loading effect equation includes a term "G" defined as "the generation rate of the active species" which is not available. Furthermore, the term  $k_{\text{loss}}$  is generally not known, and is likely to be difficult to obtain. Moreover, the etching rate constant  $K_{\text{etch}}$  is also not known. Accordingly, the loading effect equation has at least three variables including  $k_{\text{etch}}$ ,  $k_{\text{loss}}$ , and G, which are not known and cannot easily be solved for.

Thompson also suggests away from the invention of claim 1, as amended. Thompson taught a loading effect equation that requires a uniform reactant species density, i.e., a uniform etching profile. The uniform etching profile is required or is an assumed condition for applying the loading effect equation. Now, Thompson does not mention this assumption with the loading effect equation, but accordingly to Applicant Dr. Daniel Flamm, the loading effect equation uses the underlying assumption that the reactant species overlying the film to be etched is uniform, which leads to a constant etching rate over all portions of the film to be etched. This constant etching rate provides a uniform etching profile. In contrast, the present invention takes advantage of a relatively non-uniform etching profile to extract a surface reaction rate constant as recited by claim 1, for example. Accordingly, Thompson clearly suggests away from these novel aspects of the present invention, which are recited by claim 1.



Claims 1-29 were also rejected under 35 U.S.C. §103 as obvious over Mogab and Thompson, "Introduction to Microlithography". Mogab may have taught certain aspects of the loading effect but still fails to show or suggest extracting a chemical reaction rate constant from an etching profile. Accordingly, claims 1-29 are patentable over Mogab and Thompson.

Claims 1-25 were rejected under 35 U.S.C. §103 as being unpatentable over either Stefani et al., Mundt et al., Horiike or Bobbio, in view of Babanov et al., Plasma Chemistry and Plasma Processing and Thompson, "Introduction to Microlithography". As noted above, it is clear that claim 1 is patentable and non-obvious over Thompson. Accordingly, claims 1-29 are at least patentable under 35 U.S.C. §103 for the reasons noted above. Additionally, any combination of Stefani et al., Mundt et al., Horiike or Bobbio, and even Babanov et al., further fail to show or suggest the claimed combination including extracting a chemical reaction rate constant from an etching profile. In particular, Stefani et al. appeared to suggest a system for monitoring and evaluating uniformity of a semiconductor wafer, which has nothing to do with extracting a chemical reaction rate constant from an etching profile within a wafer surface. Mundt et al. seems to suggest using curved electrodes for the manufacturing of semiconductor devices. Thus, Mundt et al. does not show or suggest extracting a chemical reaction rate constant from an etching profile. Horiike generally taught a reaction vessel for plasma etching, but fails to show or suggest the claimed combination including extracting a chemical reaction rate constant from an etching profile within a wafer surface. Bobbio seems to suggest a magnetron plasma processing apparatus for producing "a uniform processing rate over an entire substrate surface." Bobbio, Col. 2, lines 54-58. In contrast, the present invention takes advantage of a non-uniform processing rate or etching profile to extract a chemical reaction rate constant therefrom. As for Babanov et al., it merely describes some etching mechanisms, which do not have a thing to do with the present invention, which includes extracting a chemical reaction rate constant from an etching profile. Accordingly, claims 1-29 are clearly non-obvious and patentable over these references under 35 U.S.C. §103.

Numerous advantages are achieved by way of the invention of claim 1, for example. In the semiconductor industry, the surface reaction rate constant can be used to design a reactor such as a plasma etching reactor or even a chemical vapor deposition reactor. Additionally, the invention of claim 1 can be used for designing other types of

Daniel L. Flamm  
Application No.: 08/433,623  
Page 9

PATENT

reactors which are generally know. Furthermore, the invention of claim 1 will generally provide more uniform films from the selection of plasma etching parameters or operating conditions without undue experimentation or "trial and error," which is often required using pre-existing or conventional techniques, i.e., Stefani et al., Mundt et al., Horiike, Bobbio, Babanov et al., Thompson, and others. Applicant can provide further details and examples of these advantages, and others, by way of a declaration by Dr. Daniel L. Flamm, as the request of the Examiner.

CONCLUSION

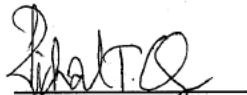
Therefore, in view of the remarks above, Applicant respectfully requests that the rejections be removed, that claims 1-29 be allowed, and the case passed to issue. The issuance of a formal Notice of Allowance at an early date is respectfully requested.

If the Examiner believes a telephone conference would expedite prosecution of this application, please telephone the undersigned at (415) 326-2400.

Respectfully submitted,

Date:

5/13/97

  
Richard T. Ogawa  
Reg. No. 37,692

TOWNSEND and TOWNSEND and CREW LLP  
Two Embarcadero Center, 8th Floor  
San Francisco, California 94111-3834  
(415) 326-2400  
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UNITED STATES DEPARTMENT OF COMMERCE  
 Patent and Trademark Office  
 Address: COMMISSIONER OF PATENTS AND TRADEMARKS  
 Washington, D.C. 20231

SERIAL NUMBER	FILING DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NO.
08/433,623	05/03/95	FLAMM	D 16655-000100

11M1/0610

RICHARD T OGAWA  
 TOWNSEND AND TOWNSEND KHOURIE AND CREW  
 STEUART STREET TOWER  
 ONE MARKET PLAZA 20TH FLOOR  
 SAN FRANCISCO CA 94105

EXAMINER

ANGEBRANNDT, M

ART UNIT	PAPER NUMBER
1113	12

06/10/97

DATE MAILED:

**NOTICE OF ALLOWABILITY**

**PART I.**

1.  This communication is responsive to 5/19/97
2.  All the claims being allowable, PROSECUTION ON THE MERITS IS ~~(OR REMAINS)~~ CLOSED in this application. If not included herewith (or previously mailed), a Notice Of Allowance And Issue Fee Due or other appropriate communication will be sent in due course.
3.  The allowed claims are 1-29
4.  The drawings filed on \_\_\_\_\_ are acceptable.
5.  Acknowledgment is made of the claim for priority under 35 U.S.C. 119. The certified copy has  been received.  not been received.  been filed in parent application Serial No. \_\_\_\_\_, filed on \_\_\_\_\_.
6.  Note the attached Examiner's Amendment.
7.  Note the attached Examiner Interview Summary Record, PTOL-413.
8.  Note the attached Examiner's Statement of Reasons for Allowance.
9.  Note the attached NOTICE OF REFERENCES CITED, PTO-892.
10.  Note the attached INFORMATION DISCLOSURE CITATION, PTO-1449.

**PART II.**

A SHORTENED STATUTORY PERIOD FOR RESPONSE to comply with the requirements noted below is set to EXPIRE THREE MONTHS FROM THE "DATE MAILED" indicated on this form. Failure to timely comply will result in the ABANDONMENT of this application. Extensions of time may be obtained under the provisions of 37 CFR 1.136(a).

1.  Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL APPLICATION, PTO-152, which discloses that the oath or declaration is deficient. A SUBSTITUTE OATH OR DECLARATION IS REQUIRED.
2.  APPLICANT MUST MAKE THE DRAWING CHANGES INDICATED BELOW IN THE MANNER SET FORTH ON THE REVERSE SIDE OF THIS PAPER.
  - a.  Drawing informalities are indicated on the NOTICE RE PATENT DRAWINGS, PTO-948, attached hereto or to Paper No. \_\_\_\_\_. CORRECTION IS REQUIRED.
  - b.  The proposed drawing correction filed on \_\_\_\_\_ has been approved by the examiner. CORRECTION IS REQUIRED.
  - c.  Approved drawing corrections are described by the examiner in the attached EXAMINER'S AMENDMENT. CORRECTION IS REQUIRED.
  - d.  Formal drawings are now REQUIRED.

Any response to this letter should include in the upper right hand corner, the following information from the NOTICE OF ALLOWANCE AND ISSUE FEE DUE: ISSUE BATCH NUMBER, DATE OF THE NOTICE OF ALLOWANCE, AND SERIAL NUMBER.

**Attachments:**

- Examiner's Amendment
- Examiner Interview Summary Record, PTOL-413
- Reasons for Allowance
- Notice of References Cited, PTO-892
- Information Disclosure Citation, PTO-1449
- Notice of Informal Application, PTO-152
- Notice re Patent Drawings, PTO-948
- Listing of Bonded Draftsmen
- Other

MARTIN ANGEBRANNDT  
 PRIMARY EXAMINER  
 GROUP 1100

Serial Number: 08/433623

-2-

Art Unit: 1113

3 The following is an Examiner's Statement of Reasons for Allowance: The arguments forwarded by the applicant have been found persuasive when combined with the amendments to the claims tying the data concerning the non-uniformity of the etch directly to an individual substrate rather than merely a location within the reactor which was more addressable by the loading description of Thompson.

Any comments considered necessary by applicant must be submitted no later than the payment of the Issue Fee and, to avoid processing delays, should preferably **accompany** the Issue Fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

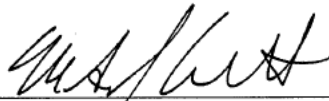
4 Any inquiry concerning this communication or earlier communications from the examiner should be directed to Martin Angebranndt whose telephone number is (703) 308-4397.

I am normally available between 7:30 AM and 5:00 PM, Monday through Thursday and 7:30 AM and 4:00 PM on alternate Fridays.

If repeated attempts to reach me are unsuccessful, my supervisor may be reached at (703) 308-2303.

Facsimile correspondence should be directed to (703) 305-3599.

Any inquiry of a general nature or relating to the status of this application should be directed to the Group receptionist whose telephone number is (703) 308-0661.



---

Martin J. Angebranndt  
Primary Examiner, Group 1100  
June 9, 1997

**The drawings submitted with this application were declared informal by the applicant. Accordingly they have not been reviewed by a draftsperson at this time. When formal drawings are submitted, the draftsperson will perform a review.**

**Direct any inquires concerning drawing review to the Drawing Review Branch (703) 305-8404.**

SUBSTITUTE PTO-948

**The drawings submitted with this application were declared informal by the applicant. Accordingly they have not been reviewed by a draftsman at this time. When formal drawings are submitted, the draftsman will perform a review.**

**Direct any inquires concerning drawing review to the Drawing Review Branch (703) 305-8404.**



UNITED STATES DEPARTMENT OF COMMERCE  
Patent and Trademark Office

Address: Box ISSUE FEE  
ASSISTANT COMMISSIONER FOR PATENTS  
WASHINGTON, D.C. 20231

**NOTICE OF ALLOWANCE AND ISSUE FEE DUE**

11M1/0610

RICHARD T OGAWA  
TOWNSEND AND TOWNSEND KHOURIE AND CREW  
STEUART STREET TOWER  
ONE MARKET PLAZA 20TH FLOOR  
SAN FRANCISCO CA 94105

APPLICATION NO.	FILING DATE	TOTAL CLAIMS	EXAMINER AND GROUP ART UNIT	DATE MAILED
08/433,623	05/03/95	029	ANGEBRANNDT, M	1113 06/10/97
First Named Applicant	FLAMM, DANIEL L.			

TITLE OF PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING INVENTION

ATTY'S DOCKET NO.	CLASS-SUBCLASS	BATCH NO.	APPLN. TYPE	SMALL ENTITY	FEE DUE	DATE DUE
1	16655-000100	156-643.100	N95 UTILITY	YES	\$645.00	09/10/97

**THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED.**

**THE ISSUE FEE MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED.**

**HOW TO RESPOND TO THIS NOTICE:**

- |  |  |
|--|--|
| <p>I. Review the SMALL ENTITY status shown above. If the SMALL ENTITY is shown as yes, verify your current SMALL ENTITY status:</p> <p>A. If the status is changed, pay twice the amount of the FEE DUE shown and notify the Patent and Trademark Office of the change in status, or</p> <p>B. If the status is the same, pay the FEE DUE shown above.</p> <p>II. Part B of this notice should be completed and returned to the Patent and Trademark Office (PTO) with your ISSUE FEE. Even if the ISSUE FEE has already been paid by charge to deposit account, Part B should be completed and returned. If you are charging the ISSUE FEE to your deposit account, section "6b" of Part B should be completed.</p> <p>III. All communications regarding this application must give application number and batch number. Please direct all communication prior to issuance to Box ISSUE FEE unless advised to the contrary.</p> | <p>If the SMALL ENTITY is shown as NO:</p> <p>A. Pay FEE DUE shown above, or</p> <p>B. File verified statement of Small Entity Status before, or with, payment of 1/2 the FEE DUE shown above.</p> |
|--|--|

**IMPORTANT REMINDER: Patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.**

3. PATENT AND TRADEMARK OFFICE COPY

TRANSMITTAL LETTER

TOWNSEND and TOWNSEND and CREW LLP  
Two Embarcadero Center, 8th Floor  
San Francisco, CA 94105  
(650) 326-2400

RECEIVED  
Publishing Division  
SEP 09 1997

Atty. Docket No. 16655-000100  
Date September 9, 1997

In re application of: Daniel L. Flamm, et al.  
Serial No.: 08/433,623  
Filed: May 3, 1995  
Group Art Unit: 1113  
For: PROCESS OPTIMIZATION IN GAS PHASE DRY  
ETCHING

09

I hereby certify that this is being deposited with the United States Postal Service as first class mail in an envelope addressed to: Box Issue Fee, Assistant Commissioner for Patents, Washington, D. C. 20231.

Date: September 9, 1997  
Debra Edginger

BOX ISSUE FEE  
ASSISTANT COMMISSIONER FOR PATENTS  
Washington, D.C. 20231

Sir:

Transmitted herewith are the documents in response to the Notice of Allowance and Issue Fee Transmittal dated June 10, 1997:

- 1) Transmittal Letter (in trip.);
- 2) Issue Fee Transmittal (Part B);
- 3) Letter to Official Draftsman;
- 4) Formal Drawings (8 sheets); and
- 5) Postcard.

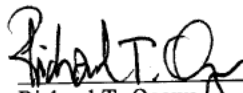
A fee in the amount of \$645.00 is due.

Please charge Deposit Account No. 20-1430 as follows:

- Issue Fee \$645.00
- Any additional fees associated with this paper or during the pendency of this application.

2 copies of this sheet are enclosed.

TOWNSEND and TOWNSEND and CREW LLP



Richard T. Ogawa  
Reg. No.: 37,692  
Attorneys for Applicant

1665511-issfee.trn

#13  
Boyd

I hereby certify that this correspondence is being deposited with the United States Postal Service as first class mail in an envelope addressed to:

Box Issue Fee  
Assistant Commissioner of Patents and Trademarks,  
Washington, D.C. 20231, on September 7, 1997

PATENT

By Neville Elzinga

Attorney Docket No. 16655-000100

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

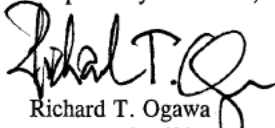
In re application of:	)		
	)	Examiner: M. Angebrannt	
Daniel L. Flamm, et al.	)		
	)	Art Unit: 1113	RECEIVED
Serial No.: 08/433,623	)		Publishing Division
	)	Batch No.: N95	SEP 09 1997
Filed: May 3, 1995	)		
	)	LETTER TO OFFICIAL	
For: PROCESS OPTIMIZATION IN GAS	)	<u>DRAFTSPERSON</u>	09
PHASE DRY ETCHING	)		
	)		
	)		
	)		

Assistant Commissioner of Patents  
Washington, D.C. 20231

Sir:

Pursuant to the Notice of Allowability dated June 10, 1997, applicants submit eight sheets of formal drawings to be made of record in the above-identified case.

Respectfully submitted,

  
Richard T. Ogawa  
Reg. No. 37,692

TOWNSEND and TOWNSEND and CREW LLP  
Two Embarcadero Center, 8th Floor  
San Francisco, California 94111-3834

(650) 326-2400

RTO:de

no1work\16655\1-fm1drw.ltr

APPROVED	O.G. FIG. 8
BY	CLASS. SUBJECT
DRAFTSMAN	150 6/3/1

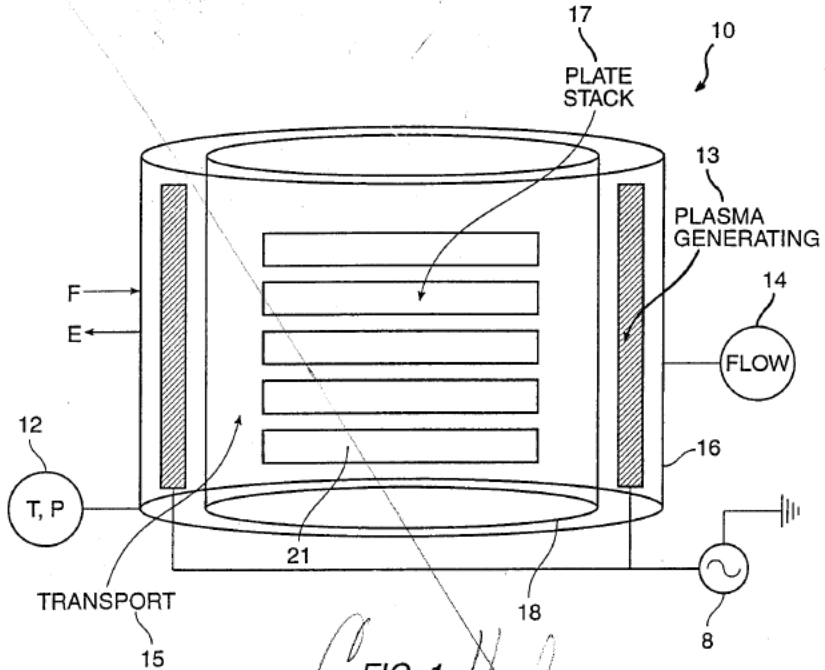


FIG. 1  
*Cancelled*

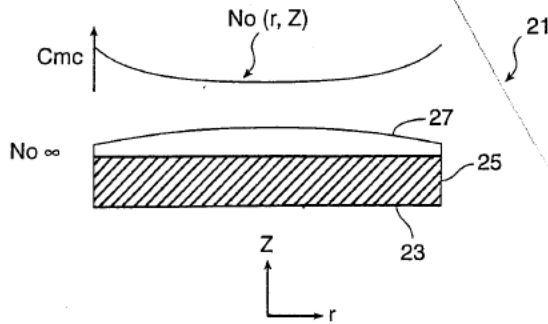


FIG. 1A



2/8

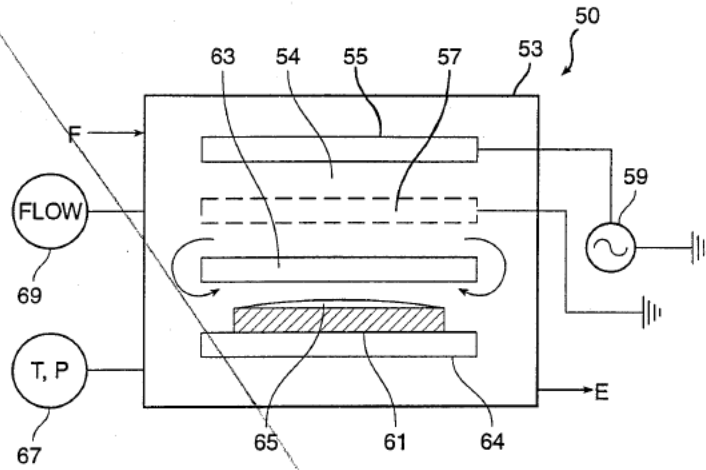


FIG. 2

*Cancelled*

APPROVED O.G. FIG.  
BY CLASS SURCLASS  
DRAFTSMAN

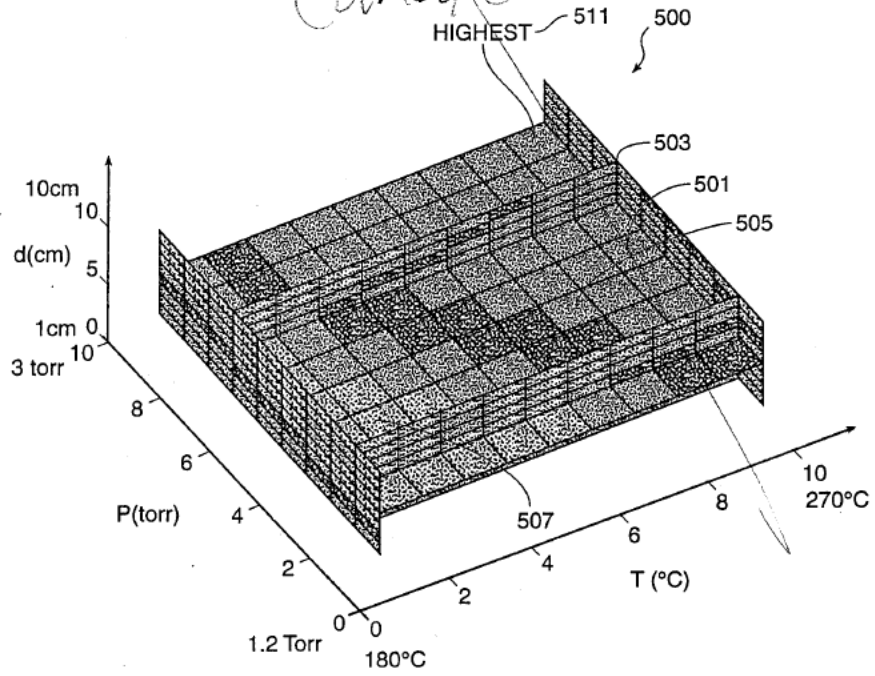


FIG. 5A

APPROVED	OG FIG
BY	CLASS SUBCLASS
DRAFTSMAN	

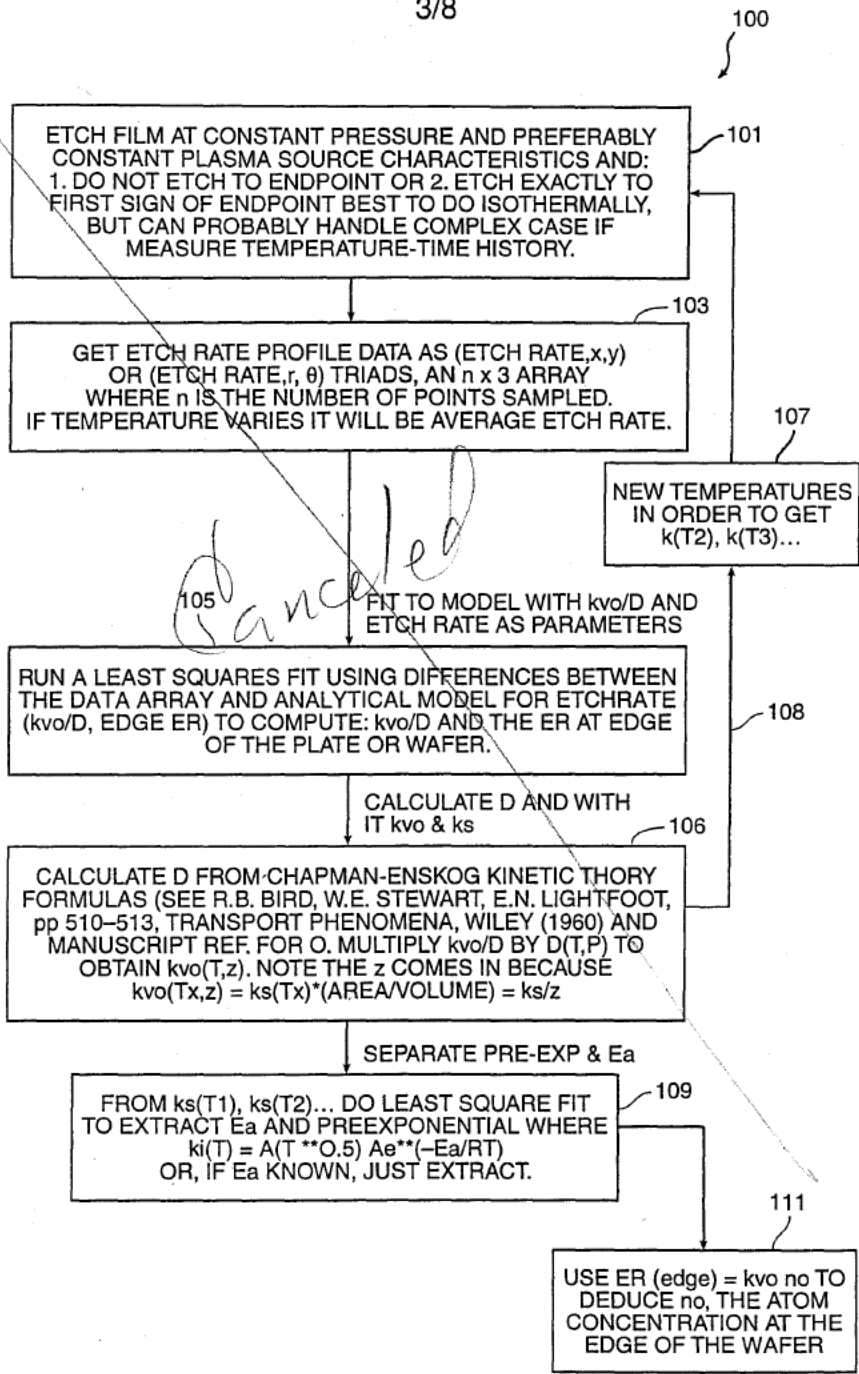


FIG. 3

APPROVED	OG FIG.
BY	CLASS SUBCLASS
DRAFTSMAN	

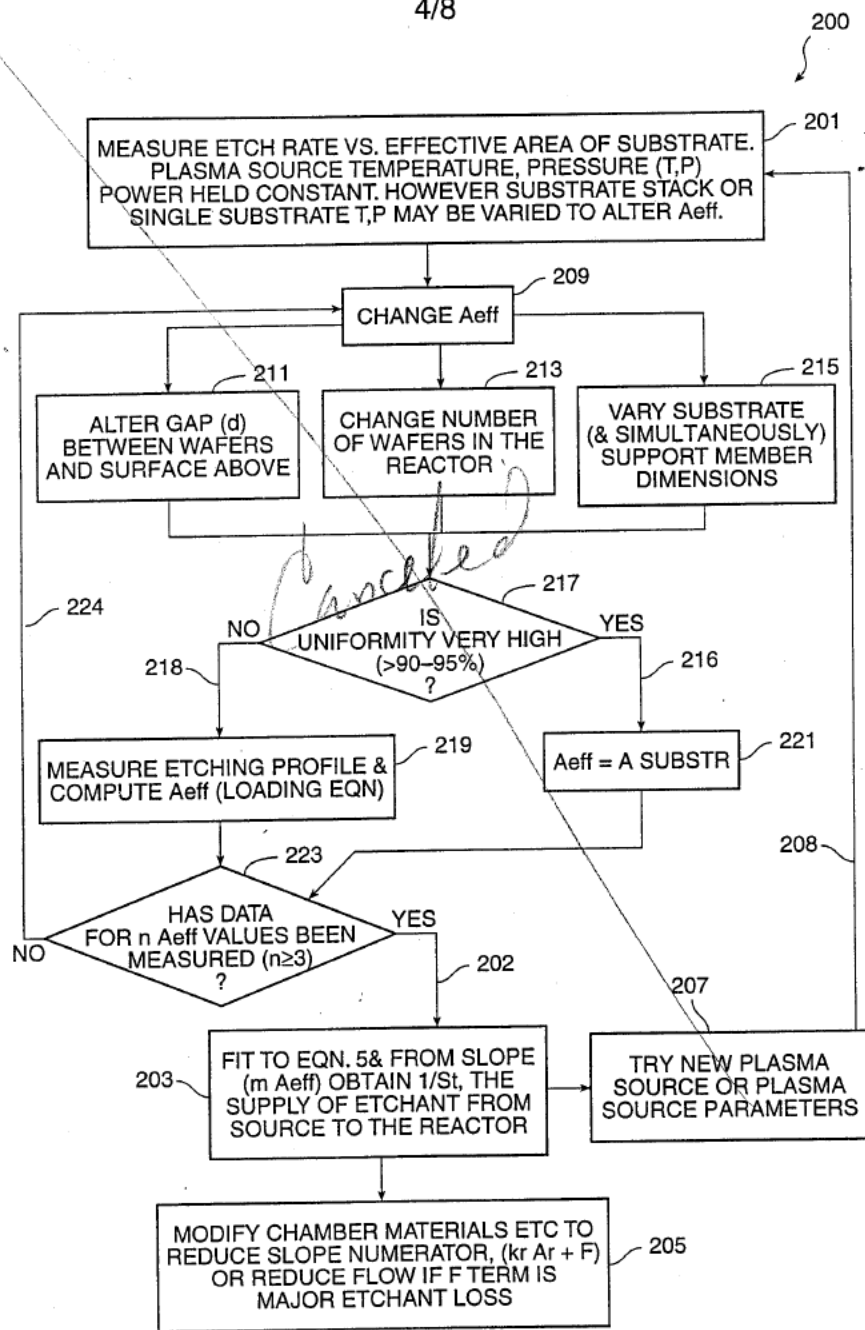


FIG. 4

APPROVED	O.G. FIG.	
	CLASS	SUBCLASS
BY	DRAFTSMAN	

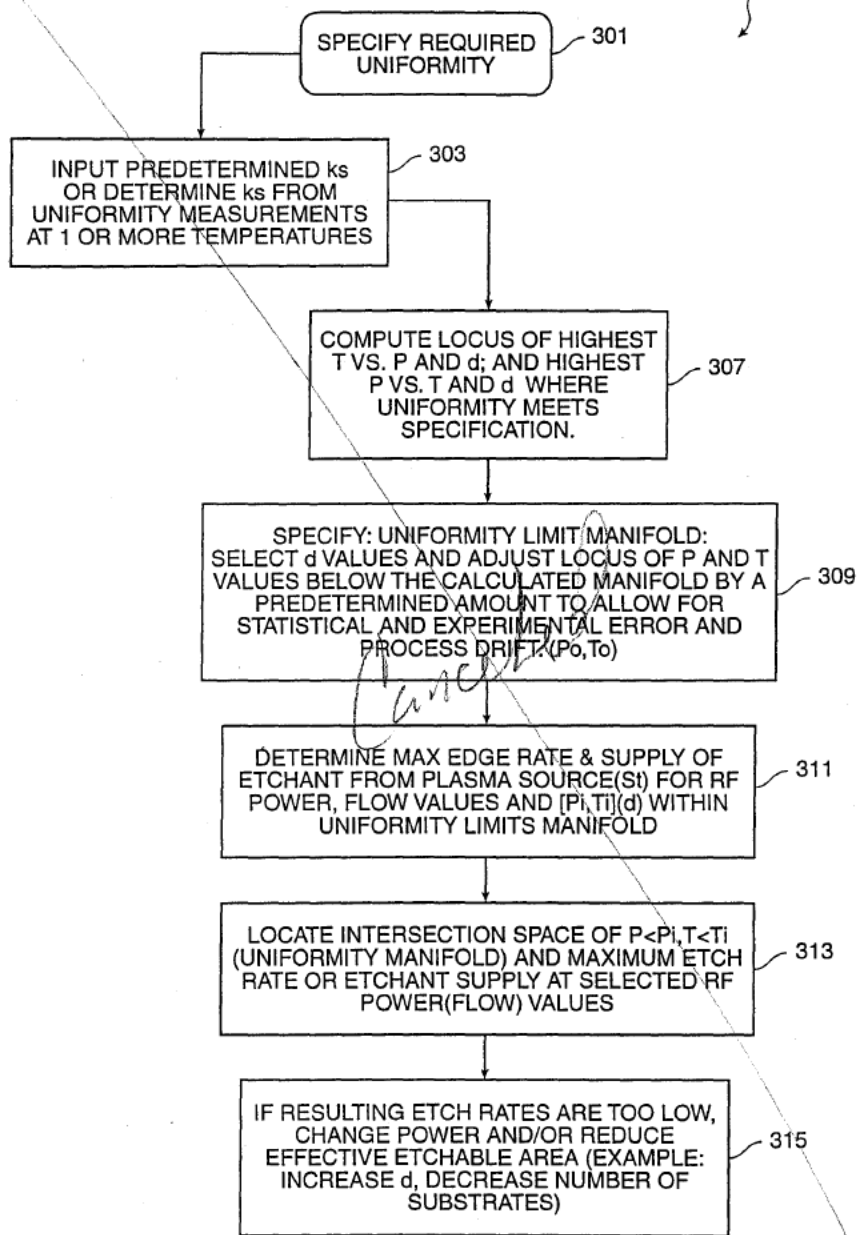


FIG. 5

LOADING EFFECT DATA

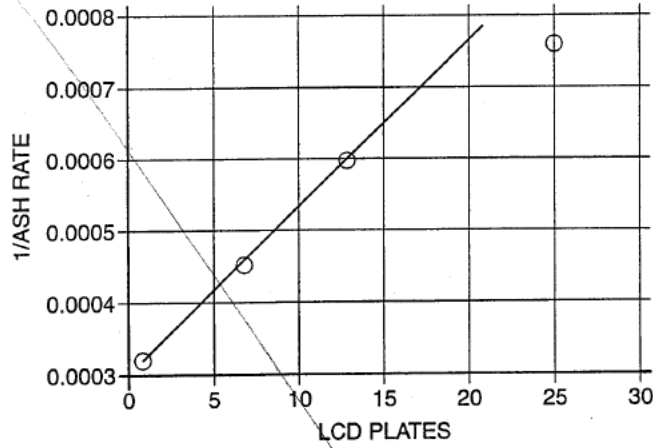


FIG. 6

APPROVED	O.G. FIG. 8
BY	CLASS / SUBCLASS
DRAFTSMAN	56 / 6431



FIG. 7

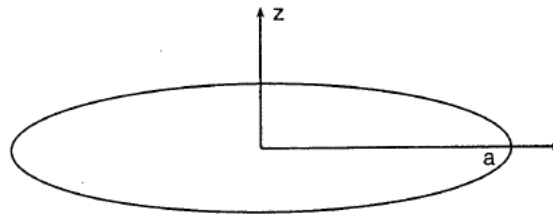


FIG. 8

7/8

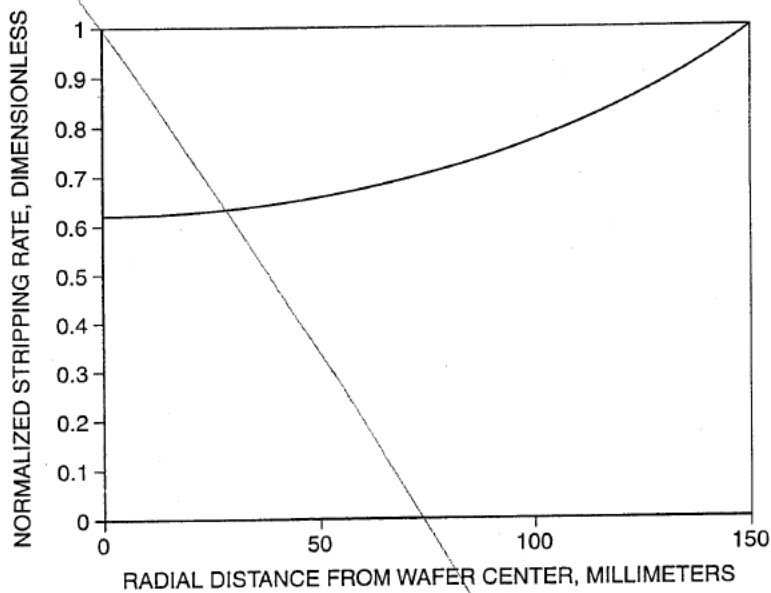


FIG. 9

APPROVED	O.G. FIG.
BY	CLASS
DRAFTSMAN	SUBCLASS

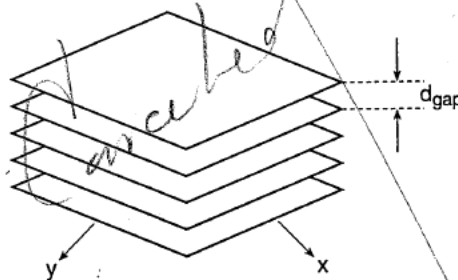


FIG. 10

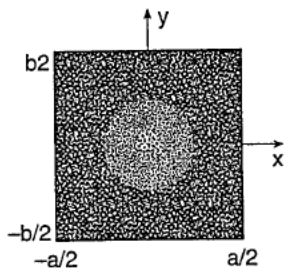


FIG. 11

APPROVED	O.G. FIG.
BY	CLASS / SUBCLASS
DRAFTSMAN	

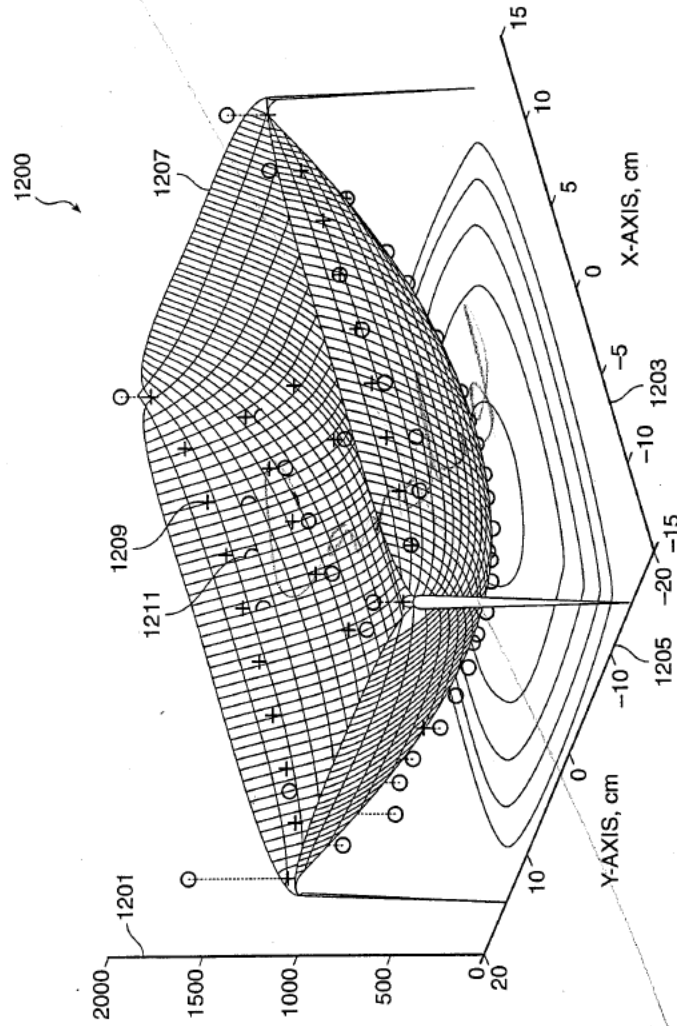


FIG. 12

**PART B—ISSUE FEE TRANSMITT/**

**MAILING INSTRUCTIONS:** This form should be used for transmitting the ISSUE FEE. Blocks 2 through 6 should be completed where appropriate. All further correspondence including the issue Fee Receipt, the Patent, advance orders and notification of maintenance fees will be mailed to addresses entered in Block 1 unless you direct otherwise, by: (a) specifying a new correspondence address in Block 3 below; or (b) providing the PTO with a separate "FEE ADDRESS" for maintenance fee notifications with the payment of issue Fee or thereafter. See reverse for Certificate of Mailing, below.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

**Burden Hour Statement:** This form is estimated to take 0.2 hours to complete. Time will vary depending on the needs of the individual case. Any comments on the amount of time required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, D.C. 20231.

DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Box Issue Fee, Assistant Commissioner for Patents, Washington D.C. 20231

1. CORRESPONDENCE ADDRESS	11M1/0610	2. INVENTOR(S) ADDRESS CHANGE (Complete only if there is a change)
RICHARD T OGAWA		INVENTOR'S NAME
TOWNSEND AND TOWNSEND KHOURIE AND CREW		Street Address
STEUART STREET TOWER		City, State and Zip Code
ONE MARKET PLAZA 20TH FLOOR		CO-INVENTOR'S NAME
SAN FRANCISCO CA 94105		Street Address
		City, State and Zip Code
		<input type="checkbox"/> Check if additional changes are enclosed

RECEIVED  
Publishing Division  
SEP 09 1997

APPLICATION NO.	FILING DATE	TOTAL CLAIMS	EXAMINER AND GROUP ART UNIT	DATE MAILED
08/433,623	05/03/95	029	ANGEBRANNDT, M 1113	06/10/97
First Named Applicant	FLAMM, DANIEL L.			

TITLE OF PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING INVENTION

ATTY'S DOCKET NO.	CLASS-SUBCLASS	BATCH NO.	APPLN. TYPE	SMALL ENTITY	FEE DUE	DATE DUE
1	16655-000100	156-643.100	N95 UTILITY	YES	\$645.00	09/10/97

3. Correspondence address change (Complete only if there is a change)	4. For printing on the patent front page, list the names of not more than 3 registered patent attorneys or agents OR, alternatively, the name of a firm having as a member a registered attorney or agent. If no name is listed, no name will be printed.
Townsend and Townsend and Crew LLP Two Embarcadero Center, 8th Floor San Francisco, CA 94111-3834	1 Townsend and Townsend and Crew LLP 2 _____ 3 _____

5. ASSIGNMENT DATA TO BE PRINTED ON THE PATENT (print or type)

(1) NAME OF ASSIGNEE: Daniel L. Flamm

(2) ADDRESS: (CITY & STATE OR COUNTRY) Walnut Creek, California

A.  This application is NOT assigned.  
 Assignment previously submitted to the Patent and Trademark Office.  
 Assignment is being submitted under separate cover. Assignment should be directed to Box ASSIGNMENTS.

PLEASE NOTE: Unless an assignee is identified in Block 5, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the PTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

6a. The following fees are enclosed:  
 Issue Fee  Advance Order - # of Copies \_\_\_\_\_

6b. The following fees should be charged to:  
 DEPOSIT ACCOUNT NUMBER 20-1430  
 (ENCLOSE A COPY OF THIS FORM)  
 Issue Fee  Advance Order - # of Copies 10  
 Any Deficiencies in Enclosed Fees

THE COMMISSIONER OF PATENTS AND TRADEMARKS is requested to apply the Issue Fee to the application identified above.  
 (For use by the Patent Office)  
 Richard T. Ogawa, Reg. No. 37,697

NOTE: The Issue Fee will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the Patent and Trademark Office.

**Certificate of Mailing**

Note: If this certificate of mailing is used, it can be used to transmit the Issue Fee. This certificate cannot be used for any other accompanying papers.

Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing.

I hereby certify that this correspondence is being deposited with the United States Postal Service with sufficient postage as first class mail in an envelope addressed to: **Box ISSUE FEE**

Assistant Commissioner for Patents  
Washington, D.C. 20231

on: September 9, 1997 (Date)  
 Diane Elzingre (Name of person making deposit)  
 Diane Elzingre (Signature)  
 September 9, 1997 (Date)

10/14/1997 LBERGER 00000177 DAH:203  
 01 FC:242 645.00 CH  
 02 FC:561 30.00 CH

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& CREW  
0843362

1. TRANSMIT THIS FORM WITH FEE



PTO UTILITY GRANT  
Paper Number 14

**The Commissioner of Patents  
and Trademarks**

*Has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.*

Therefore, this

**United States Patent**

*Grants to the person(s) having title to this patent the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States of America or importing the invention into the United States of America for the term set forth below, subject to the payment of maintenance fees as provided by law.*

*If this application was filed prior to June 8, 1995, the term of this patent is the longer of seventeen years from the date of grant of this patent or twenty years from the earliest effective U.S. filing date of the application, subject to any statutory extension.*

*If this application was filed on or after June 8, 1995, the term of this patent is twenty years from the U.S. filing date, subject to a statutory extension. If the application contains a specific reference to an earlier filed application or applications under 35 U.S.C. 120, 121 or 365(c), the term of the patent is twenty years from the date on which the earliest application was filed, subject to any statutory extension.*

*Bence Lehman*  
Commissioner of Patents and Trademarks

*Armita Marley*  
Attest.

The  
United  
States  
of  
America



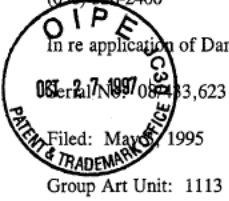
Form PTO-1584 (Rev. 2/97)

(RIGHT INSIDE)

TOWNSEND and TOWNSEND and CREW LLP  
 Two Embarcadero Center, 8th Floor  
 San Francisco, CA 94111-3834  
 (650) 326-2400

Amendment Transmittal

Atty. Docket No. 7560 GAU 1113  
 55-000100



In re application of Daniel L. Flamm, et al.

Serial No. 08/03,623

Filed: May 1995

Group Art Unit: 1113

For: PROCESS OPTIMIZATION IN GAS  
 PHASE DRY ETCHING

Express Mail Label No.: EM14058555US

I hereby certify that this is being deposited with the United States Postal Service "Express Mail Post Office to Addressee," service under 37 CFR 1.10 on the date indicated below and is addressed to: Group 1100 Director - Theodore Morris Assistant Commissioner for Patents Washington, D. C. 20231.

Date: 10/27/97  
J. Webeschütz

and I also hereby certify that this correspondence is being sent by facsimile transmission to:

Group Director - Theodore Morris  
 Fax No: 1-703-305-359  
 Assistant Commissioner for Patents, Washington, D.C. 20231, on 10/27/97

By Alison Elyse

ASSISTANT COMMISSIONER FOR PATENTS  
 Washington, D.C. 20231

Sir:

Transmitted herewith is an amendment in the above-identified application.

- Amendment After Payment of Issue Fee Under 37 CFR 1.312(b).
- Petition for Amendment After Payment of Issue Fee Under 37 CFR 1.312(b).
- Postcard (in Express Mail copy).

The filing fee has been calculated as shown below:

(Col. 1)		(Col. 2)		(Col. 3)		SMALL ENTITY		OTHER THAN A SMALL ENTITY		
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NO. PREVIOUSLY PAID FOR		PRESENT EXTRA	RATE	ADDIT. FEE	OR	RATE	ADDIT. FEE
TOTAL	*31	MINUS	**31		=0	6 x11=	\$0.00		x22=	\$
INDEP.	*6	MINUS	***6		=0	1 x41=	\$0.00		x78=	\$
[X] FIRST PRESENTATION OF MULTIPLE DEP. CLAIM: See claim 28, which is counted as three claims						+125=	\$0.00		+250=	\$
						TOTAL	\$0.00		TOTAL	\$
						ADDIT. FEE				

- \* If the entry in Col. 1 is less than the entry in Col. 2, write "0" in Col. 3.
- \*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, write "20" in this space.
- \*\*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, write "3" in this space. The "Highest Number Previously Paid For" (Total or Independent) is the highest number found from the equivalent box in Col. 1 of a prior amendment or the number of claims originally filed.

No fee is due.

Please charge Deposit Account No. 20-1430 as follows:

Claims fee \$0.00  
 Any additional fees associated with this paper or during the pendency of this application.

2 extra copies of this sheet are enclosed.

TOWNSEND and TOWNSEND and CREW LLP

Gary T. Alia  
 Gary T. Alia  
 Reg. No. 29,038  
 Attorneys for Applicant



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Assistant Commissioner for Patents,  
Washington, D.C. 20231,  
on

10/27/97  
Express Mail Label No. EM14058555US  
TOWNSEND and TOWNSEND and CREW LLP  
By J. H. ...

and I also hereby certify that this correspondence is being sent by facsimile transmission to:  
Group Director - Theodore Morris  
Fax No: 1-703-305-3599  
Assistant Commissioner for Patents, Washington,  
D.C. 20231, on 10/27/97  
By Alexandre Edgouze

PATENT

Attorney Docket No. 16655-000100

15/10/94

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: )  
)  
Daniel L. Flamm ) Examiner: M. Angebrannt  
)  
Application No.: 08/433,623 ) Art Unit: 1113  
)  
Filed: May 3, 1995 )  
)  
For: PROCESS OPTIMIZATION IN GAS ) PETITION FOR AMENDMENT AFTER  
PHASE DRY ETCHING ) PAYMENT OF ISSUE FEE UNDER 37  
) C.F.R. § 1.312(b)  
)

Assistant Commissioner for Patents  
Washington, D.C. 20231

Dear Sirs:

Pursuant to 37 C.F.R. § 1.312(b), Applicant petitions for entry of the changes in the accompanying amendment. As indicated in the amendment, Applicant believes the changes are necessary for the correction of various errors. In view of the many technical changes, the amendment was not earlier presented.

OK to  
Ewte  
WA  
12/4/97

12/04/1997 TSTOKES 00000120 DHH:201330 00433623  
01 FC:122 130.00 CH

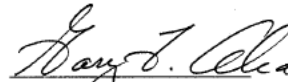
Daniel L. Flamm  
Application No.: 08/433,623  
Page 2

PATENT

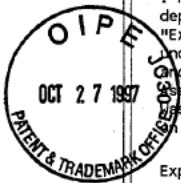
Please charge the petition fee of \$130.00 to Deposit Account 20-1430. This petition is submitted in triplicate. Please charge any other fees or credit any overpayment to Deposit Account 20-1430.

Respectfully submitted,

Date: 10/27/97

  
Gary T. Aka  
Reg. No. 29,038

TOWNSEND and TOWNSEND and CREW LLP  
Two Embarcadero Center, 8th Floor  
San Francisco, California 94111-3834  
(650) 326-2400  
Fax (650) 326-2422  
GTA:RTO:RA.de  
H:\WORK\16655\000100\312V1.PET



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Assistant Commissioner for Patents,  
Washington, D.C. 20231,

PATENT

Attorney Docket No. 16655-000100

10/27/97  
Express Mail Label No. EM14058555US  
TOWNSEND and TOWNSEND and CREW LLP

By J. Hieschke

and I also hereby certify that this correspondence is being sent by facsimile transmission to:  
Group Director - Theodore Morris  
Fax No: 1-703-305-3599  
Assistant Commissioner for Patents, Washington,  
D.C. 20231, on 10/27/97

By Alvin E. Brown

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:	)	
	)	
Daniel L. Flamm	)	Examiner: M. Angebrannt
	)	
Application No.: 08/433,623	)	Art Unit: 1113
	)	
Filed: May 3, 1995	)	
	)	
For: PROCESS OPTIMIZATION IN GAS	)	AMENDMENT AFTER PAYMENT OF
PHASE DRY ETCHING	)	ISSUE FEE UNDER 37 C.F.R. §1.312(b)
	)	
	)	

Assistant Commissioner for Patents  
Washington, D.C. 20231

Dear Sirs:

Pursuant to 37 C.F.R. §1.312(b), please amend the above-identified application as follows:

IN THE SPECIFICATION:

- At page 3, line 13, please delete "parameters" and insert --parameter--.
- At page 3, line 28, please delete "according of" and insert --according to--.
- At page 4, line 21, delete "flow source" and insert --controller--.
- At page 4, line 29, please delete "limiting" and insert --limited--.
- At page 7, line 25, please delete "such as" and insert --,--.

At page 8, line 5, please delete "way" and insert --way of--.

At page 8, line 9, please delete "applications to" and insert --applications of--.

At page 8, line 22, please delete "ω".

At page 9, lines 7-8, please delete "(u,x,y)" and insert --u(x,y)--.

At page 9, line 8, please delete "relative etch rate" and insert --relative etch rate is-

At page 9, line 34, please delete "is defined as follows" and insert --is often defined as follows--.

At page 10, in the first equation on the page, please insert --+-- after the term  $\cos \frac{m\pi y}{b}$ .

At page 10, line 5, after substrate, please delete "." and insert  $J_0$ ; and  $I_0$  is a modified Bessel function of the first kind--.

At page 10, line 16, please delete "collusion" and insert --collision--.

At page 11, line 15, please delete "follow equation." and insert --following equation:--.

At page 11, in the equation after line 23, please delete " $R_0$ " and insert -- $R_{os}$ --; please delete " $k_{vo}$ " and insert -- $k_s$ --.

At page 11, line 25, please delete " $R_0$ " and insert -- $R_{os}$ --.

At page 12, in the equation after line 18, please delete " $\frac{R_{MAX} - R_{MIN}}{2 \sum_{i=1}^m \frac{R_i}{m}}$ " and please

insert --  $[1 - \frac{R_{MAX} - R_{MIN}}{2 \sum_{i=1}^m \frac{R_i}{m}}]$  --.

At page 13, in the equation after line 10 and at line 11, please delete " $R_0$ " and insert -- $R_{os}$ --.

At page 13, line 11, please delete " $R_0$ " and insert -- $R_{os}$ --.

At page 14, " " line 30, please delete " $\frac{R_{MAX} - R_{MIN}}{2 \sum_{i=1}^m \frac{R_i}{m}}$ " and please insert --

$$\left[1 - \frac{R_{MAX} - R_{MIN}}{2 \sum_{i=1}^m \frac{R_i}{m}}\right] --.$$

At page 15, line 37, please insert --,-- after *T*.

At page 15, line 37, please delete "vs." and insert --versus--.

At page 15, line 38, please insert --,-- after *highest P*.

At page 15, line 38, please delete "vs." and insert --versus--.

At page 16, line 3, please insert --,-- after *highest T*.

At page 16, line 3, after *T*, please delete "vs." and insert --versus--.

At page 16, line 3, please insert --,-- after *highest P*.

At page 16, line 3, after *P*, please delete "vs." and insert --versus--.

At page 16, line 5, please insert --,-- after *highest T*.

At page 16, line 5, after *T*, please delete "vs." and insert --versus--.

At page 16, line 5, please insert --,-- after *highest P*.

At page 16, line 5, after *P*, please delete "vs." and insert --versus--.

At page 16, line 21, "*R<sub>o</sub>*" and insert --*R<sub>os</sub>*--.

At page 17, lines 22-23, please delete "surface recombination rate" and insert --  
effective surface recombination rate--.

At page 18, line 18, please delete "*A<sub>w</sub>*" and insert --*A<sub>eff</sub>*--.

At page 19, line 9, before etching rates, please insert --when etching uniformity is  
high the--.

At page 19, line 16, please delete "*k<sub>e</sub>*" and insert --*k<sub>s</sub>*--.

At page 19, in the equation after line 20, please delete "*k<sub>o</sub>*" and insert --*k<sub>s</sub>*--.

At page 19, in the equation after line 20, please delete "*A<sub>w</sub>*" and insert --*A<sub>eff</sub>*--.

At page 20, in the equation after line 5, please insert -- -- before *D*.

At page 20, in the equation after line 6, please delete "\*" and insert --(-- before  
*D∇n<sub>o</sub>* and insert --)-- after *D∇n<sub>o</sub>*.

At page 20, line 17, please delete " $n(x/L_x, y/L_y)$ " and insert  $--u(x/L_x, y/L_y)--$ .

At page 20, line 19, please delete " $n_0$ " and insert  $--n_0/n_0--$ .

At page 23, line 9, please delete "9" and insert  $--10--$ .

At page 23, line 26, please delete "where  $\lambda_x$  is given by".

At page 24, between the first and second equation on the page, please insert  $--$   
where  $\lambda_x$  is given by $--$ .

At page 24, line 1, please delete "the general" and insert  $--The\ general--$ .

At page 24, in the last equation on the page, please insert  $--+--$  after the term  
 $\cos \frac{m\pi y}{b}$ .

At page 25, line 1, please insert  $--two-dimensional--$  after *previous*.

At page 25, line 7, please delete "from" and insert  $--using\ relations\ in--$ .

At page 25, line 26, please delete "substitute" and insert  $--substituting--$ .

At page 25, line 31, please delete "11" and insert  $--12--$ .

At page 26, line 10, please delete "drove" and insert  $--sustained--$ .

At page 26, line 17, please delete "11" and insert  $--12--$ .

At page 26, line 18, please insert  $--to--$  after *fit*.

At page 26, line 35, please delete " $R$ " and insert  $--R_{os}--$ .

At page 27, line 10, please delete " $A_{w,eff}$ " and insert  $--A_{eff}--$ .

At page 27, in the equation after line 10, please replace all occurrences of " $A_{w,eff}$ "  
with  $--A_{eff}--$ .

At page 27, in the equation after line 10, please replace " $R_e$ " with  $--R_{os}--$ .

At page 27, line 11, please delete " $A_{w,eff}$ " and insert  $--A_{eff}--$ .

At page 27, line 19, please replace both occurrences of " $A_{w,eff}$ " with  $--A_{eff}--$ .

At page 28, line 6, please delete "describe" and insert  $--describes--$ .

IN THE DRAWINGS:

Applicant submits new figures 1-12, consisting of eight sheets of formal drawings. Newly submitted figures correct some inadvertent errors in the originally submitted formal drawings. Amendments to the originally submitted informal figures have been highlighted in red ink.



In Fig. 1, chemical flow source 14 was detached from the chemical feed  $F$ . In the new formal drawings chemical feed  $F$  is shown passing through the chemical flow source 14. Also, the ground connections have been amended to more clearly show the complete circuit for the rf discharge 8. Furthermore, the arrow indicating the exhaust  $E$  is moved to the chamber bottom.

In Fig. 1A, "Conc" on the y-axis is replaced by "Concentration" for clarity. Also  $n_{o0}$  has been aligned with the y-axis.

In Fig. 2, as discussed with respect to Fig. 1, the chemical flow source  $F$  is moved to pass through the flow controller 69.

In Fig. 3, as highlighted in red ink, some editorial changes are made in boxes 105, 106, 107, and 109. For example, in box 109  $k_i(T)$  has been replaced with  $k_s(T)$ . In box 106, "z" has been replaced with " $d_{gap}$ ". Similarly in box 107, "k" has been replaced with " $k_s$ ". In box 109,  $k_i$  has been replaced with  $k_s$  and "preexponential" has been added at the end.

In Fig. 4, some editorial changes are made in boxes 203 and 205. In box 203, " $S'$ " is replaced by " $S''$ ". In box 205, "of" is added after slope.

In Fig. 5, some editorial changes are made in boxes 301, 303, and 309. In box 301, "1" is replaced with "one". As discussed with respect to Fig. 4, in box 309, " $S'$ " is replaced by " $S''$ ". In box 309, ":" is replaced with a period.

In Fig. 5A, scaling numbers 0, 2, 4, 6, 8, and 10 on both axis are replaced with temperature and pressure values. Also, reference number 503 is deleted.

In Fig. 7, the two Cartesian axes at the bottom of the informal drawing are deleted.

In Fig. 8, the label " $S$ " has been added.

In Fig. 10, the x-y-z axes are added and new labels are added to show the relative gap between  $d=0$  and  $d=d_{gap}$ .

In Fig. 12, the units on the y-axis are changed. Also, the downward spikes at the four corners of the informal drawing are deleted.

#### REMARKS

This amendment does not affect the merits and no new matter is involved.

The Specification has been amended to make some editorial changes for consistency. For example, the amendment made at page 10, line 5, is editorial for consistency with  $I_0$ 's definition at page 22, line 5. Similarly, the amendments made to the equations at pages 12 and 14 are editorial to make the equations consistent with the text. See, e.g., the Specification, at page 12, lines 26-29. Those with ordinary skill in the art would understand that the confirmaty equation would include the term "[1- ...]". Accordingly, this error has been corrected in accordance with the text. Other amendments represent other minor typographical corrections to the text.

The newly submitted formal figures correct some inadvertent typographical errors in the originally submitted formal figures. Amendments to the originally filed informal figures have been highlighted in red ink.

With respect to Fig. 1, in the new formal drawings, chemical feed  $F$  is correctly shown passing through the chemical flow source 14. See, e.g., Specification, page 4, lines 15-22. Also, the ground connections now more clearly show the complete circuit for the rf discharge 8. Furthermore, the arrow indicating the exhaust  $E$  is moved to the chamber bottom for clarity because no opening is shown on the chamber side.

With respect to Fig. 2, as discussed with respect to Fig. 1, the chemical flow source  $F$  is moved to more properly pass through the flow controller 69. See, e.g., Specification, page 6, lines 35-37.

With respect to Fig. 3, some editorial changes are made in boxes 105, 106, 107, and 109 for consistency with the Specification or to correct some typographical errors. For example, in box 109  $k_f(T)$  is replaced with  $k_s(T)$  to maintain consistency with the text. See, e.g., Specification, page 11, the equation after line 15. In box 106, "z" is replaced with " $d_{gap}$ " for consistency with the Specification, for example, at page 11, the equation after line 5. Similarly in box 107, "k" is replaced with " $k_s$ " for consistency with the Specification.

With respect to Figs. 4 and 5, some editorial changes are made. For example, in box 203 of Fig. 4 and box 309 of Fig. 5, " $S'$ " is replaced by " $S''$ " for consistency with the Specification, for example, at page 13, line 7.

With respect to Fig. 5A, scaling numbers on both axis are replaced with temperature and pressure values. Also, reference number 503 is deleted because the text does not refer to it.

Daniel L. Flamm  
Application No.: 08/433,623  
Page 7

PATENT

With respect to Fig. 7, the two Cartesian axes at the bottom of the informal drawing are deleted because they are not referenced or used in the radial coordinate system of this figure.

With respect to Fig. 8, the label "S" is added to conform to the reference to a substrate as "S" in the Specification, at page 21, line 22.

In Fig. 10, all three x-y-z axes are shown to more clearly demonstrate the relative gap between  $d=0$  and  $d=d_{gap}$ .

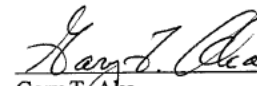
In Fig. 12, the units shown on the y-axis of the newly submitted formal drawing are twice as great as the units shown in the original informal drawing. This amendment corrects a typographical error made when making the original drawing. While Applicant believes that those skilled in the art would understand the invention and the error in Fig. 12, this correction is made to avoid any possible confusion on the part of the reader. Also, the downward spikes at the four corners of the informal drawing are absent in the formal drawing. These spikes were the result of utilizing a limited number of mathematical terms to generate the plotted surface. The gridded pattern shown in the formal drawing has no spikes, for example, in accordance with the complete equation in the Specification at page 24, after line 10, and the text at page 26, lines 1-4.

This amendment is submitted in triplicate. Please charge any other fees or credit any overpayment to Deposit Account 20-1430.

If the Examiner believes a telephone conference would expedite issuance of this application, please telephone the undersigned at (650) 326-2400.

Respectfully submitted,

Date: 10/27/97

  
Gary T. Aka  
Reg. No. 29,038

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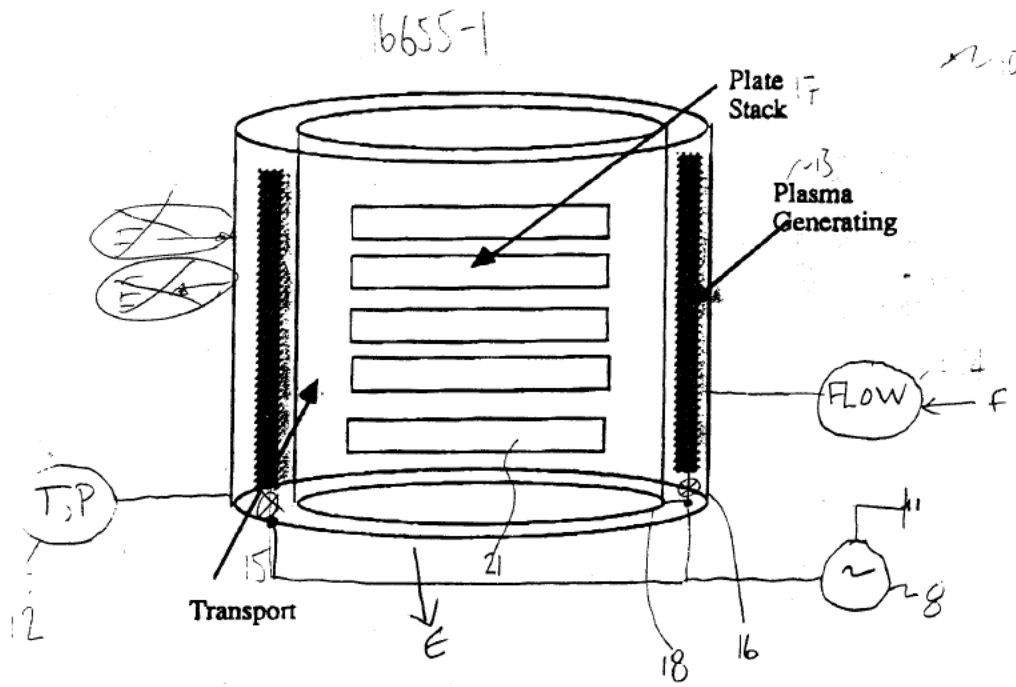


FIG. 1

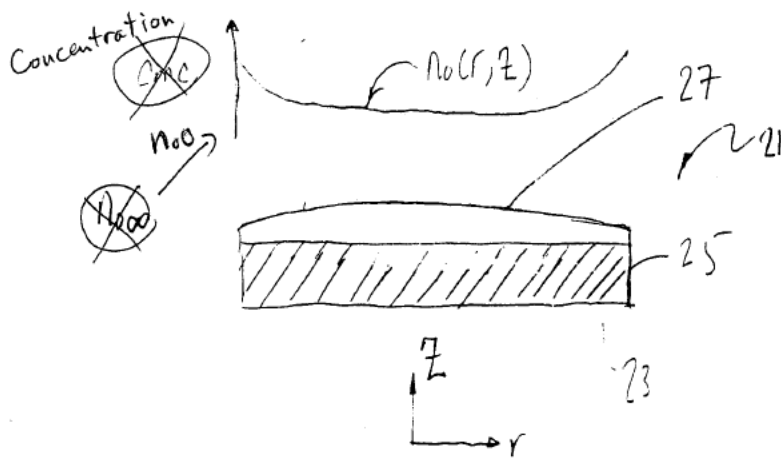


FIG. 1A

0055-1

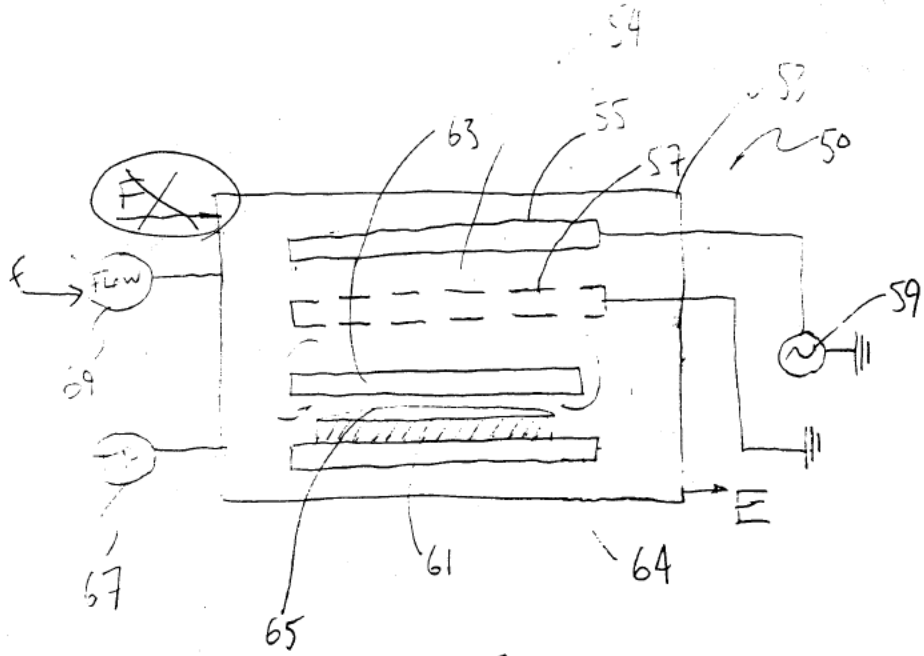


FIG. 2

16655-1

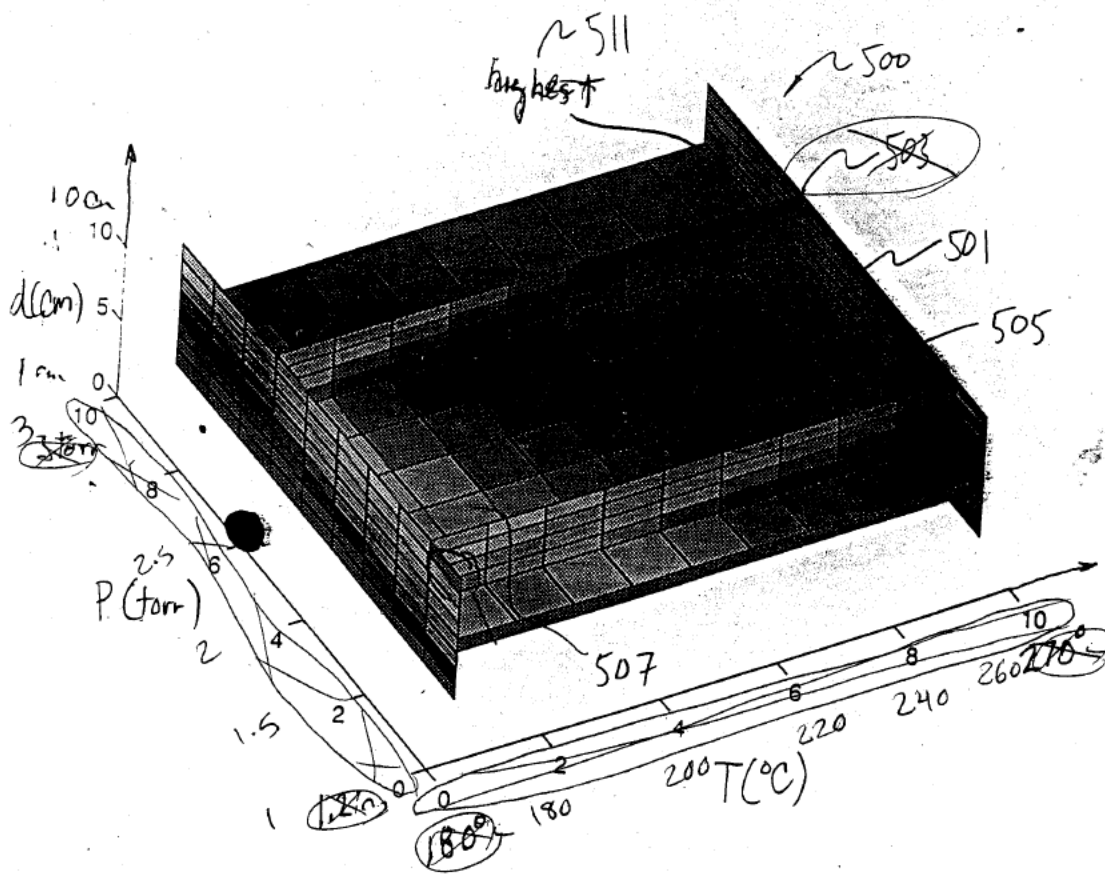


FIG. 5A

16655-1

### Extract Rate Constant & Etch Rate from the Etch Rate Profile Data

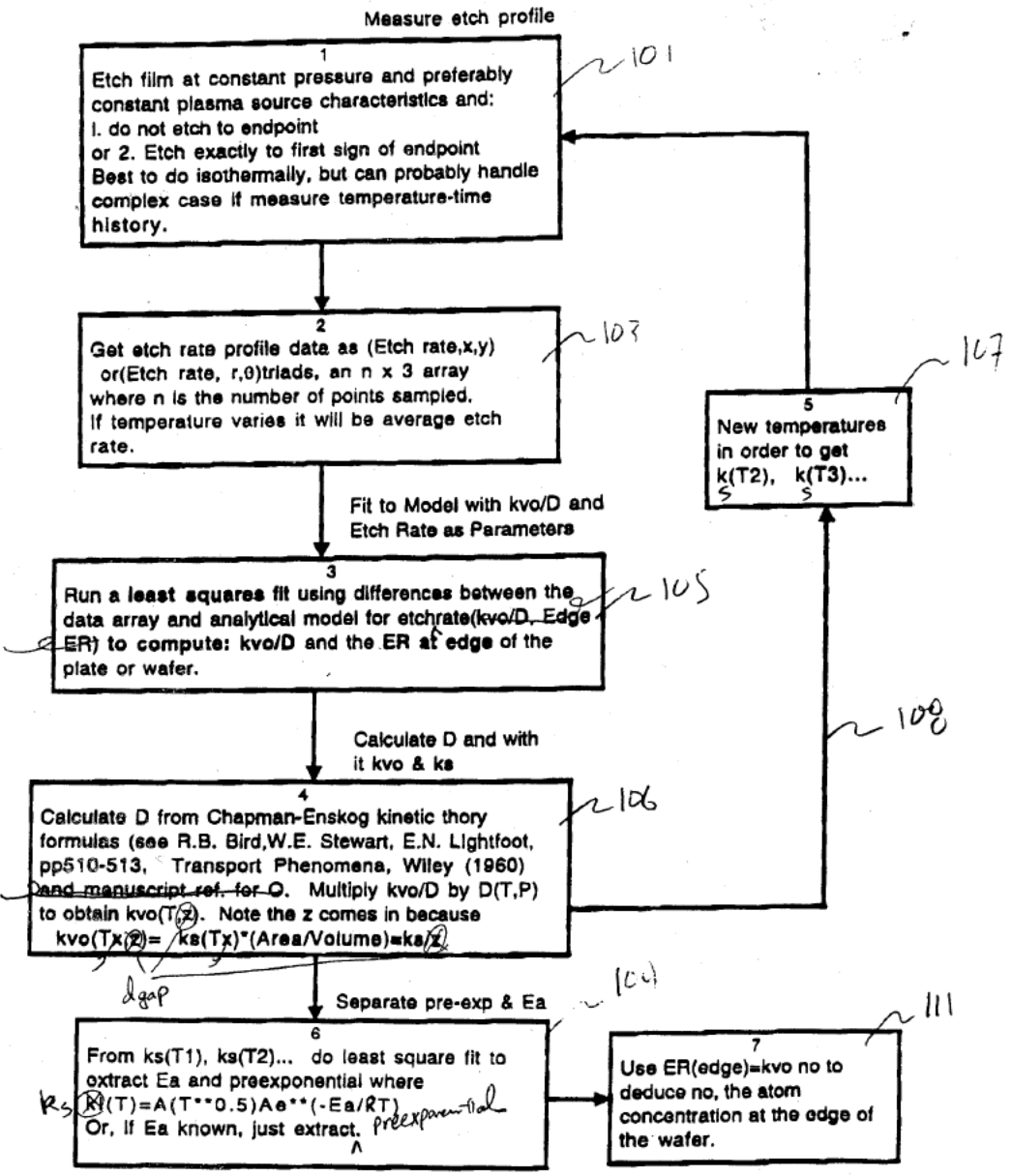
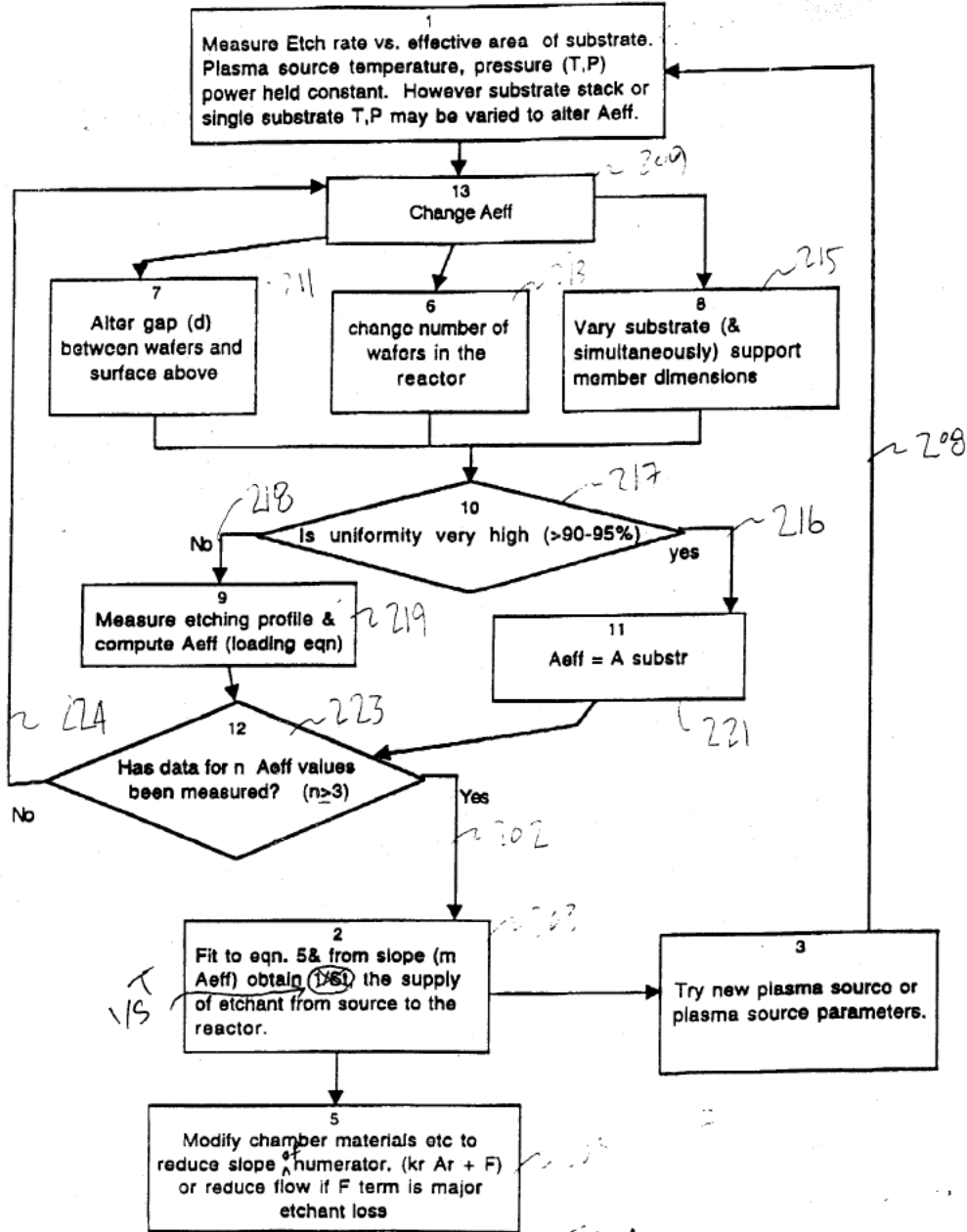


Fig. 3

16655-1

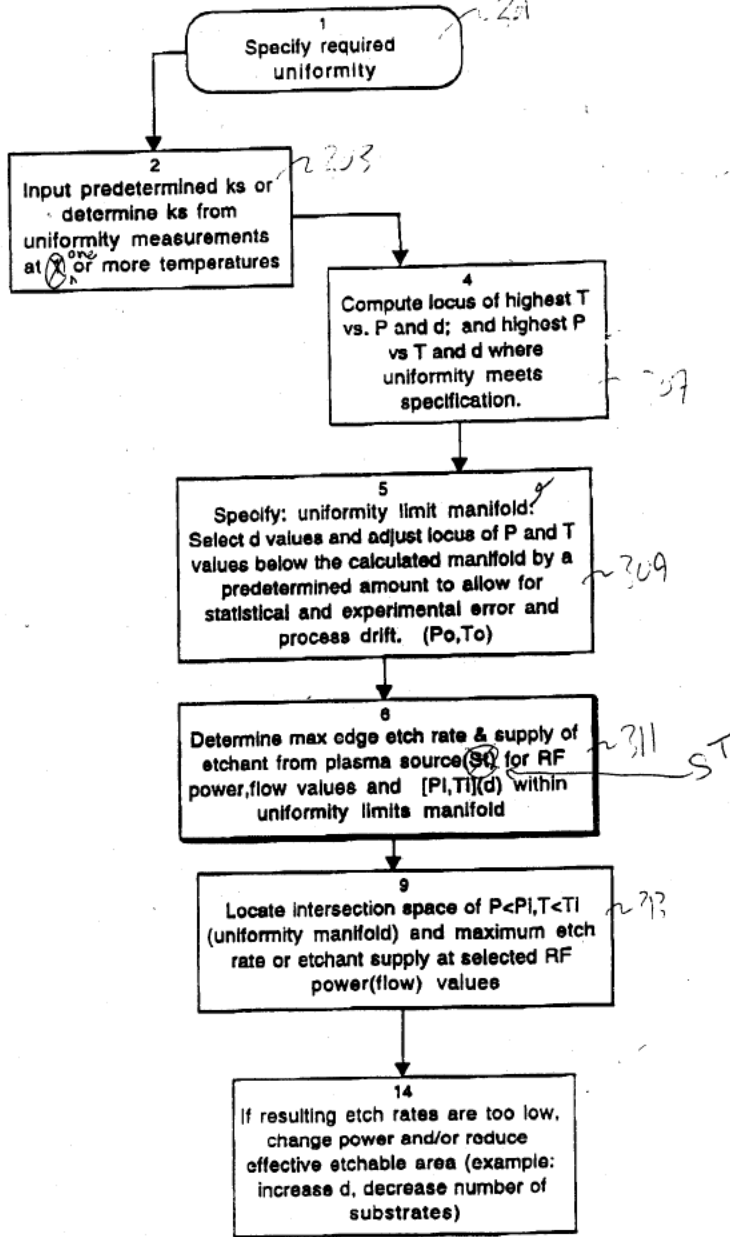
### Extract Plasma Source Intensity and "tune" the Plasma Source using Loading Effect Relationship





16655-1

### Optimize Etching Rate vs. P, T, rf Power with Uniformity Constraint



16655-1

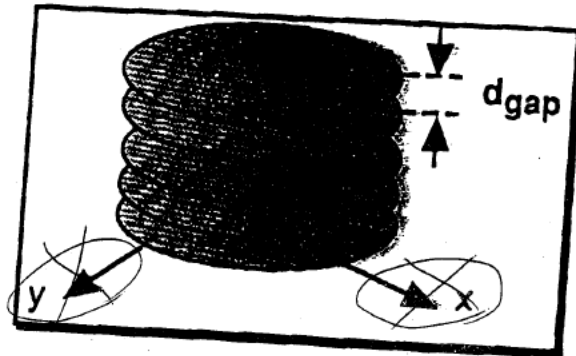


FIG. 7

433623

5711849<sup>9</sup>

1/8

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CLASSIFICATION: 643.1

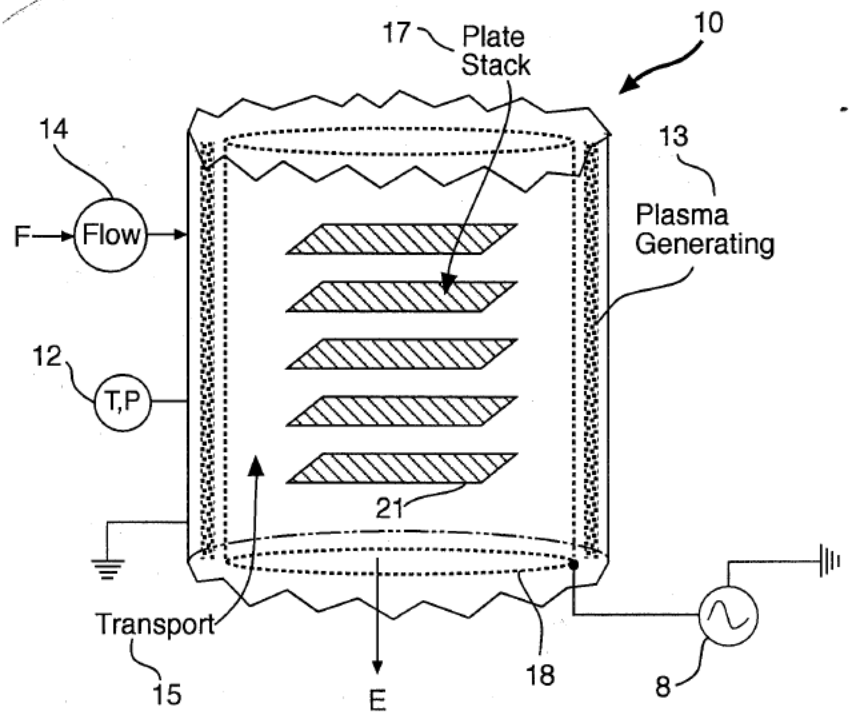


FIG. 1

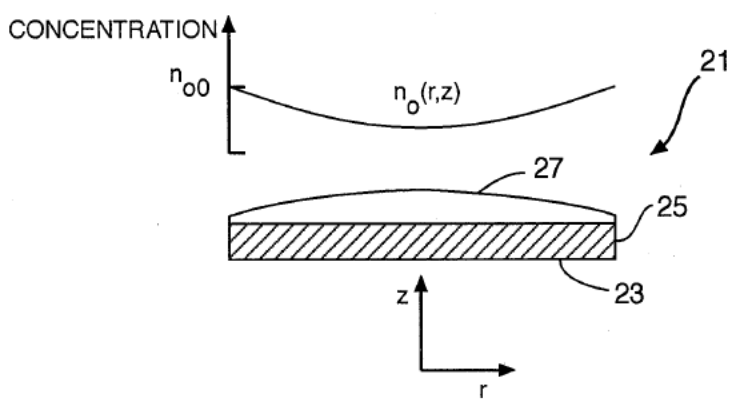


FIG. 1A

8  
648.1  
66

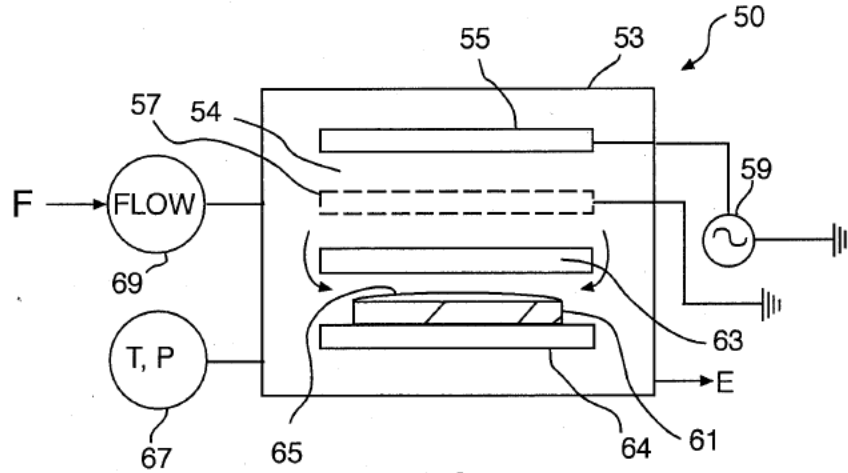


FIG. 2

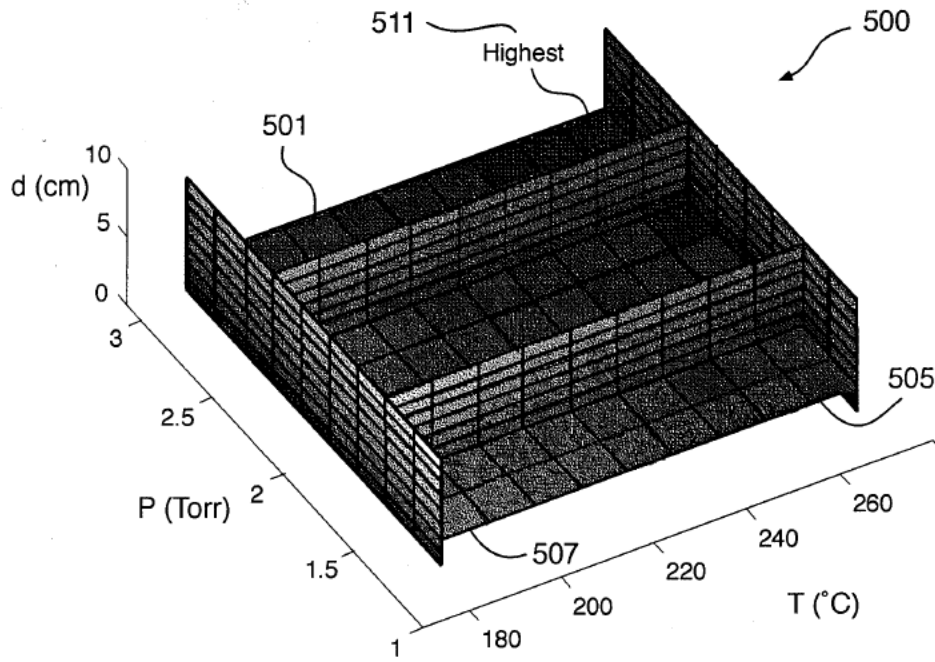


FIG. 5A

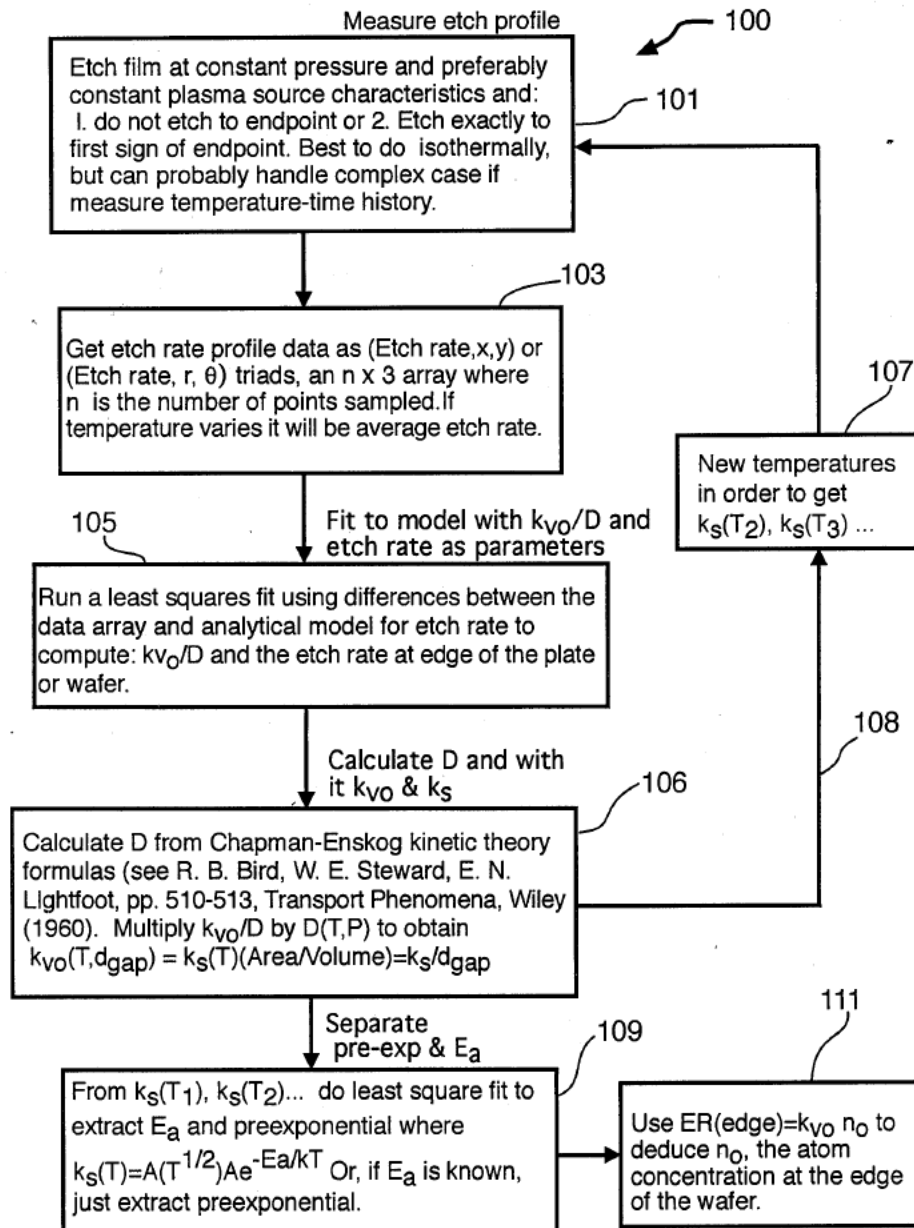
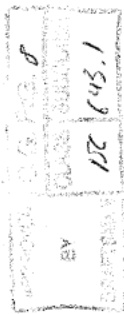


FIG. 3

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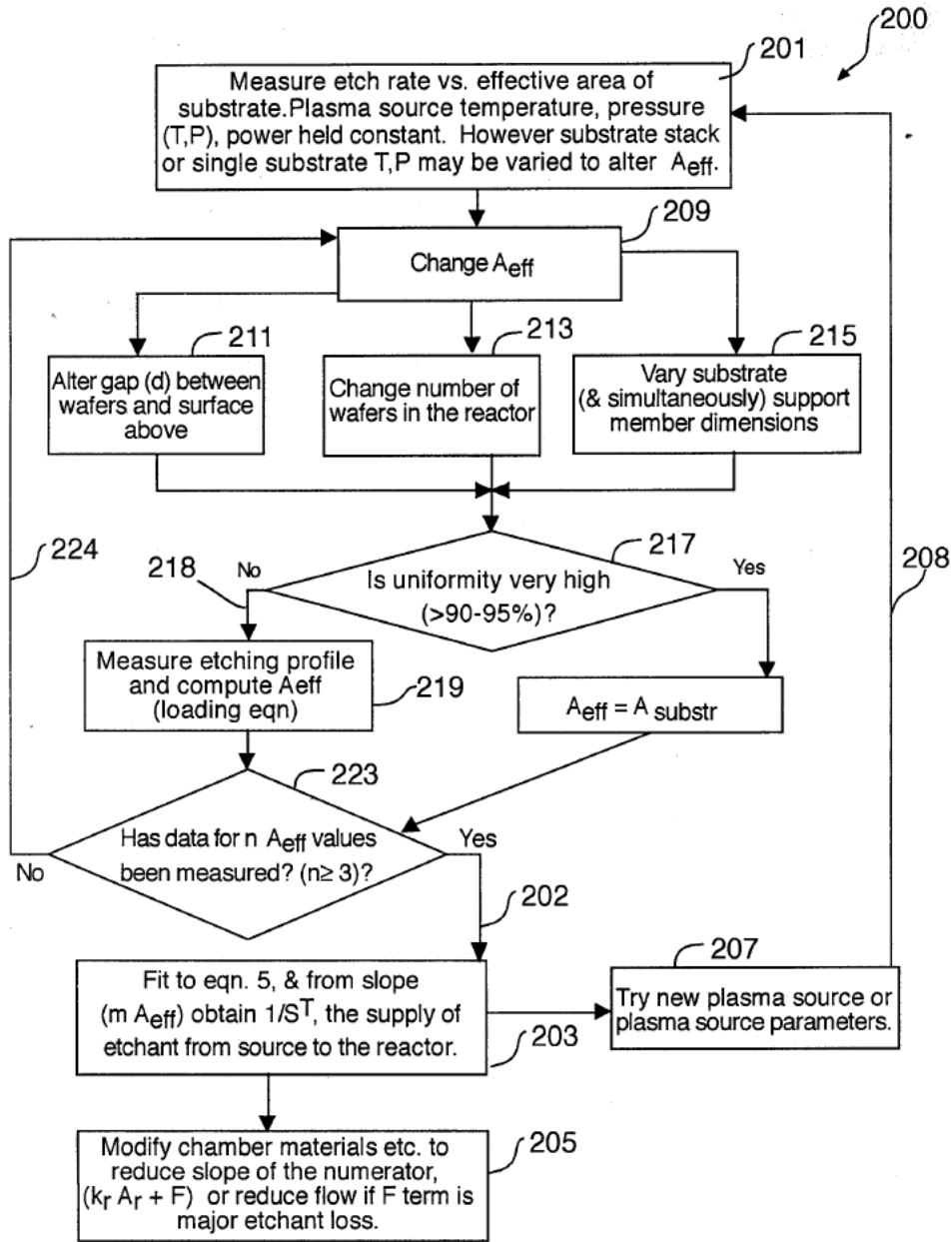


FIG. 4

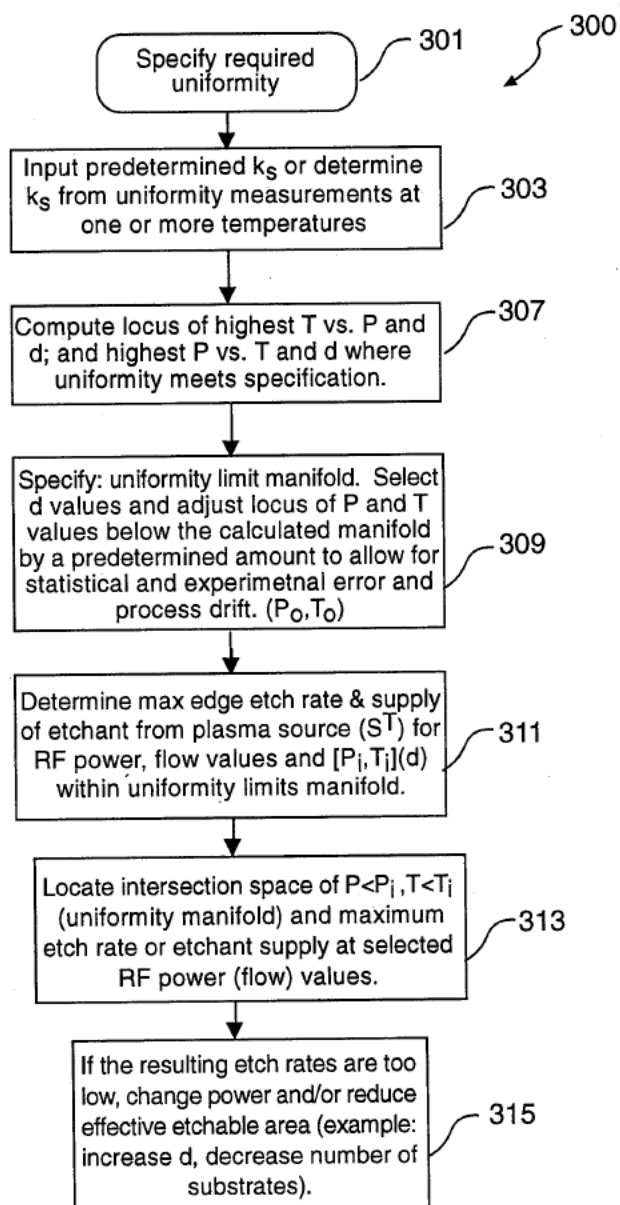
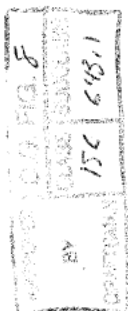


FIG. 5

158 643.1

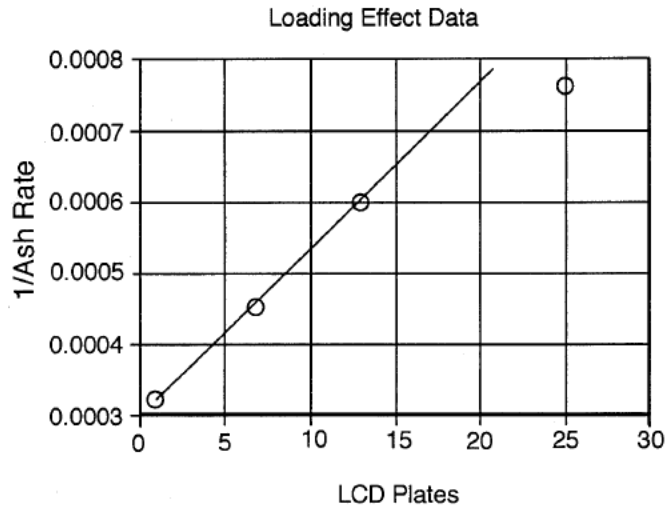


FIG. 6

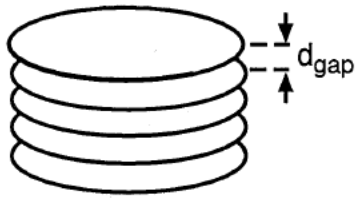


FIG. 7

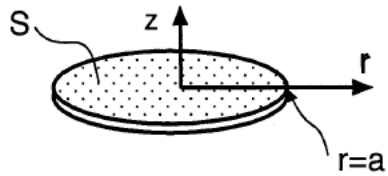


FIG. 8



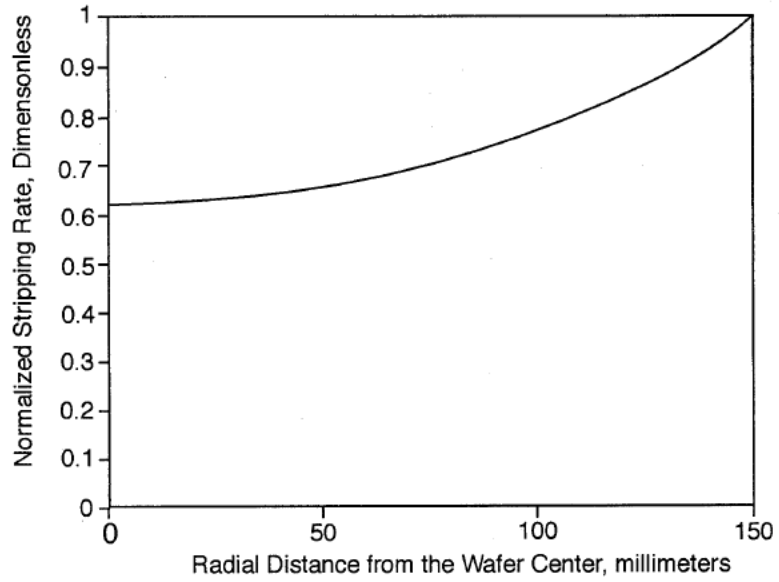


FIG. 9

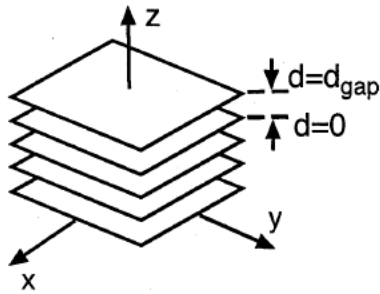


FIG. 10

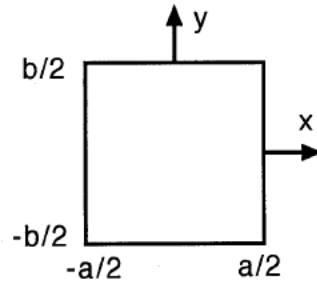


FIG. 11

158 6/3, 1

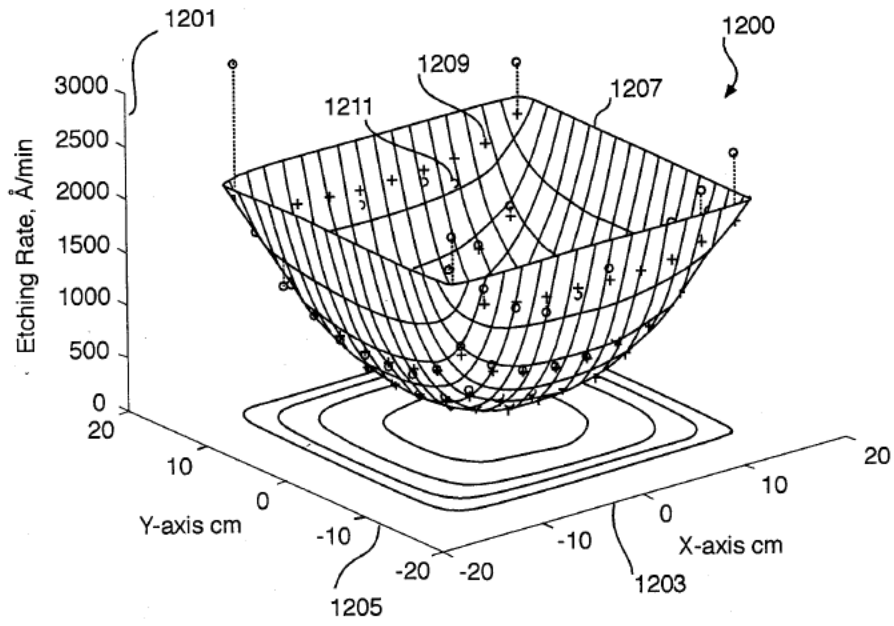


FIG. 12

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In re application of Daniel L. Flamm, et al.

Serial No: 08/433,623

Filed: May 3, 1995

Group Art Unit: 1113

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*J. Weberschuetz*

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By *Alison Edgerton*

ASSISTANT COMMISSIONER FOR PATENTS  
 Washington, D.C. 20231

Sir:  
 Transmitted herewith is an amendment in the above-identified application.  
 Amendment After Payment of Issue Fee Under 37 CFR 1.312(b).  
 Petition for Amendment After Payment of Issue Fee Under 37 CFR 1.312(b).  
 Postcard (in Express Mail copy).  
 The filing fee has been calculated as shown below:

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TOTAL	*31	MINUS	**31	=	0	6 x11=	\$0.00		22=	\$
INDEP.	*6	MINUS	***6	=	0	1 x41=	\$0.00		78=	\$
[X] FIRST PRESENTATION OF MULTIPLE DEP. CLAIM: See claim 28, which is counted as three claims						+125=	\$0.00		250=	\$
						TOTAL	\$0.00		TOTAL	\$
						ADDIT. FEE				

- \* If the entry in Col. 1 is less than the entry in Col. 2, write "0" in Col. 3.
- \*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, write "20" in this space.
- \*\*\* If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, write "3" in this space.  
 The "Highest Number Previously Paid For" (Total or Independent) is the highest number found from the equivalent box in Col. 1 of a prior amendment or the number of claims originally filed.

[X] No fee is due.

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TOWNSEND and TOWNSEND and CREW LLP

*Gary T. Allen*  
 Gary T. Allen  
 Reg. No. 29,038  
 Attorneys for Applicant

166551-312.m

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Daniel L. Flamm ) Examiner: M. Angebrannt
Application No.: 08/433,623 ) Art Unit: 1113
Filed: May 3, 1995 )
For: PROCESS OPTIMIZATION IN GAS ) PETITION FOR AMENDMENT AFTER
PHASE DRY ETCHING ) PAYMENT OF ISSUE FEE UNDER 37
C.F.R. § 1.312(b)

Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sirs:

Pursuant to 37 C.F.R. § 1.312(b), Applicant petitions for entry of the changes in the accompanying amendment. As indicated in the amendment, Applicant believes the changes are necessary for the correction of various errors. In view of the many technical changes, the amendment was not earlier presented.

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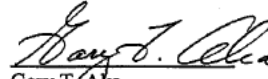
Daniel L. Flamm  
Application No.: 08/433,623  
Page 2

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Respectfully submitted,

Date: 10/27/97



Gary T. Aka  
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H:\WORK\16655\000100\312V1.PET

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By: J. Lindeschmidt

and I also hereby certify that this correspondence is being sent by facsimile transmission to: Group Director - Theodore Morris Fax No: 1-703-305-3599 Assistant Commissioner for Patents, Washington, D.C. 20231, on 10/27/97

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By: Robert E. Gagnier

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:
Daniel L. Flamm
Application No.: 08/433,623
Filed: May 3, 1995
For: PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING
Examiner: M. Angebrannt
Art Unit: 1113
AMENDMENT AFTER PAYMENT OF ISSUE FEE UNDER 37 C.F.R. §1.312(b)

Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sirs:

Pursuant to 37 C.F.R. §1.312(b), please amend the above-identified application as follows:

IN THE SPECIFICATION:

- At page 3, line 13, please delete "parameters" and insert --parameter--
At page 3, line 28, please delete "according of" and insert --according to--
At page 4, line 21, delete "flow source" and insert --controller--
At page 4, line 29, please delete "limiting" and insert --limited--
At page 7, line 25, please delete "such as" and insert --,--

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At page 8, line 5, please delete "way" and insert --way of--.

At page 8, line 9, please delete "applications to" and insert --applications of--.

At page 8, line 22, please delete "z".

At page 9, lines 7-8, please delete "(u,x,y)" and insert --u(x,y)--.

At page 9, line 8, please delete "relative etch rate" and insert --relative etch rate is-

At page 9, line 34, please delete "is defined as follows" and insert --is often defined as follows--.

At page 10, in the first equation on the page, please insert --+-- after the term  
 $\cos \frac{mY}{b}$ .

At page 10, line 5, after substrate, please delete "." and insert --; and  $I_0$  is a modified Bessel function of the first kind--.

At page 10, line 16, please delete "collusion" and insert --collision--.

At page 11, line 15, please delete "follow equation." and insert --following equation:--.

At page 11, in the equation after line 23, please delete " $R_0$ " and insert -- $R_{0s}$ --; please delete " $k_0$ " and insert -- $k_s$ --.

At page 11, line 25, please delete " $R_0$ " and insert -- $R_{0s}$ --.

At page 12, in the equation after line 18, please delete " $\frac{R_{MAX} - R_{MIN}}{2 \sum_{i=1}^m \frac{R_i}{m}}$ " and please

insert --  $[1 - \frac{R_{MAX} - R_{MIN}}{2 \sum_{i=1}^m \frac{R_i}{m}}]$  --.

At page 13, in the equation after line 10 and at line 11, please delete " $R_0$ " and insert -- $R_{0s}$ --.

At page 13, line 11, please delete " $R_0$ " and insert -- $R_{0s}$ --.



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At page 14, " " line 30, please delete " $\frac{R_{MAX}-R_{MIN}}{2 \sum_{i=1}^n \frac{R_i}{m}}$ " and please insert --

$$\left[1 - \frac{R_{MAX}-R_{MIN}}{2 \sum_{i=1}^n \frac{R_i}{m}}\right] --.$$

At page 15, line 37, please insert --,-- after *T*.

At page 15, line 37, please delete "vs." and insert --versus--.

At page 15, line 38, please insert --,-- after *highest P*.

At page 15, line 38, please delete "vs." and insert --versus--.

At page 16, line 3, please insert --,-- after *highest T*.

At page 16, line 3, after *T*, please delete "vs." and insert --versus--.

At page 16, line 3, please insert --,-- after *highest P*.

At page 16, line 3, after *P*, please delete "vs." and insert --versus--.

At page 16, line 5, please insert --,-- after *highest T*.

At page 16, line 5, after *T*, please delete "vs." and insert --versus--.

At page 16, line 5, please insert --,-- after *highest P*.

At page 16, line 5, after *P*, please delete "vs." and insert --versus--.

At page 16, line 21, "*R<sub>o</sub>*" and insert --*R<sub>o</sub>*--.

At page 17, lines 22-23, please delete "surface recombination rate" and insert --  
 effective surface recombination rate--.

At page 18, line 18, please delete "*A<sub>w</sub>*" and insert --*A<sub>eff</sub>*--.

At page 19, line 9, before etching rates, please insert --when etching uniformity is  
 high the--.

At page 19, line 16, please delete "*k<sub>c</sub>*" and insert --*k<sub>c</sub>*--.

At page 19, in the equation after line 20, please delete "*k<sub>c</sub>*" and insert --*k<sub>c</sub>*--.

At page 19, in the equation after line 20, please delete "*A<sub>w</sub>*" and insert --*A<sub>eff</sub>*--.

At page 20, in the equation after line 5, please insert -- -- before *D*.

At page 20, in the equation after line 6, please delete "\*" and insert --(-- before  
*D∇n<sub>o</sub>* and insert --)-- after *D∇n<sub>o</sub>*.

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At page 20, line 17, please delete " $n(x/L_x, y/L_y)$ " and insert  $--u(x/L_x, y/L_y)--$ .

At page 20, line 19, please delete " $n_0$ " and insert  $--n/n_0--$ .

At page 23, line 9, please delete "9" and insert  $--10--$ .

At page 23, line 26, please delete "where  $\lambda_x$  is given by".

At page 24, between the first and second equation on the page, please insert --  
where  $\lambda_x$  is given by--.

At page 24, line 1, please delete "the general" and insert  $--The\ general--$ .

At page 24, in the last equation on the page, please insert  $--+--$  after the term  
 $\cos \frac{m\pi y}{b}$ .

At page 25, line 1, please insert  $--two-dimensional--$  after *previous*.

At page 25, line 7, please delete "from" and insert  $--using\ relations\ in--$ .

At page 25, line 26, please delete "substitute" and insert  $--substituting--$ .

At page 25, line 31, please delete "11" and insert  $--12--$ .

At page 26, line 10, please delete "drove" and insert  $--sustained--$ .

At page 26, line 17, please delete "11" and insert  $--12--$ .

At page 26, line 18, please insert  $--to--$  after *fit*.

At page 26, line 35, please delete "R" and insert  $--R_{ox}--$ .

At page 27, line 10, please delete " $A_{w,eff}$ " and insert  $--A_{eff}--$ .

At page 27, in the equation after line 10, please replace all occurrences of " $A_{w,eff}$ "  
with  $--A_{eff}--$ .

At page 27, in the equation after line 10, please replace " $R_e$ " with  $--R_{ox}--$ .

At page 27, line 11, please delete " $A_{w,eff}$ " and insert  $--A_{eff}--$ .

At page 27, line 19, please replace both occurrences of " $A_{w,eff}$ " with  $--A_{eff}--$ .

At page 28, line 6, please delete "describe" and insert  $--describes--$ .

IN THE DRAWINGS:

Applicant submits new figures 1-12, consisting of eight sheets of formal drawings. Newly submitted figures correct some inadvertent errors in the originally submitted formal drawings. Amendments to the originally submitted informal figures have been highlighted in red ink.

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In Fig. 1, chemical flow source 14 was detached from the chemical feed  $F$ . In the new formal drawings chemical feed  $F$  is shown passing through the chemical flow source 14. Also, the ground connections have been amended to more clearly show the complete circuit for the rf discharge 8. Furthermore, the arrow indicating the exhaust  $E$  is moved to the chamber bottom.

In Fig. 1A, "Conc" on the y-axis is replaced by "Concentration" for clarity. Also  $n_{e0}$  has been aligned with the y-axis.

In Fig. 2, as discussed with respect to Fig. 1, the chemical flow source  $F$  is moved to pass through the flow controller 69.

In Fig. 3, as highlighted in red ink, some editorial changes are made in boxes 105, 106, 107, and 109. For example, in box 109  $k_i(T)$  has been replaced with  $k_e(T)$ . In box 106, "z" has been replaced with " $d_{gap}$ ". Similarly in box 107, "k" has been replaced with " $k_e$ ". In box 109,  $k_i$  has been replaced with  $k_e$  and "preexponential" has been added at the end.

In Fig. 4, some editorial changes are made in boxes 203 and 205. In box 203, " $S'$ " is replaced by " $S''$ ". In box 205, "of" is added after slope.

In Fig. 5, some editorial changes are made in boxes 301, 303, and 309. In box 301, "1" is replaced with "one". As discussed with respect to Fig. 4, in box 309, " $S'$ " is replaced by " $S''$ ". In box 309, "." is replaced with a period.

In Fig. 5A, scaling numbers 0, 2, 4, 6, 8, and 10 on both axis are replaced with temperature and pressure values. Also, reference number 503 is deleted.

In Fig. 7, the two Cartesian axes at the bottom of the informal drawing are deleted.

In Fig. 8, the label " $S$ " has been added.

In Fig. 10, the x-y-z axes are added and new labels are added to show the relative gap between  $d=0$  and  $d=d_{gap}$ .

In Fig. 12, the units on the y-axis are changed. Also, the downward spikes at the four corners of the informal drawing are deleted.

**REMARKS**

This amendment does not affect the merits and no new matter is involved.

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Daniel L. Flamm  
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The Specification has been amended to make some editorial changes for consistency. For example, the amendment made at page 10, line 5, is editorial for consistency with  $I_0$ 's definition at page 22, line 5. Similarly, the amendments made to the equations at pages 12 and 14 are editorial to make the equations consistent with the text. See, e.g., the Specification, at page 12, lines 26-29. Those with ordinary skill in the art would understand that the confirmaty equation would include the term "[1- ...]". Accordingly, this error has been corrected in accordance with the text. Other amendments represent other minor typographical corrections to the text.

The newly submitted formal figures correct some inadvertent typographical errors in the originally submitted formal figures. Amendments to the originally filed informal figures have been highlighted in red ink.

With respect to Fig. 1, in the new formal drawings, chemical feed  $F$  is correctly shown passing through the chemical flow source 14. See, e.g., Specification, page 4, lines 15-22. Also, the ground connections now more clearly show the complete circuit for the rf discharge 8. Furthermore, the arrow indicating the exhaust  $E$  is moved to the chamber bottom for clarity because no opening is shown on the chamber side.

With respect to Fig. 2, as discussed with respect to Fig. 1, the chemical flow source  $F$  is moved to more properly pass through the flow controller 69. See, e.g., Specification, page 6, lines 35-37.

With respect to Fig. 3, some editorial changes are made in boxes 105, 106, 107, and 109 for consistency with the Specification or to correct some typographical errors. For example, in box 109  $k(T)$  is replaced with  $k_c(T)$  to maintain consistency with the text. See, e.g., Specification, page 11, the equation after line 15. In box 106, " $z$ " is replaced with " $d_{gap}$ " for consistency with the Specification, for example, at page 11, the equation after line 5. Similarly in box 107, " $k$ " is replaced with " $k_c$ " for consistency with the Specification.

With respect to Figs. 4 and 5, some editorial changes are made. For example, in box 203 of Fig. 4 and box 309 of Fig. 5, " $S$ " is replaced by " $S^m$ " for consistency with the Specification, for example, at page 13, line 7.

With respect to Fig. 5A, scaling numbers on both axis are replaced with temperature and pressure values. Also, reference number 503 is deleted because the text does not refer to it.

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With respect to Fig. 7, the two Cartesian axes at the bottom of the informal drawing are deleted because they are not referenced or used in the radial coordinate system of this figure.

With respect to Fig. 8, the label "S" is added to conform to the reference to a substrate as "S" in the Specification, at page 21, line 22.

In Fig. 10, all three x-y-z axes are shown to more clearly demonstrate the relative gap between  $d=0$  and  $d=d_{gap}$ .

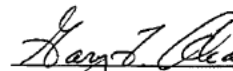
In Fig. 12, the units shown on the y-axis of the newly submitted formal drawing are twice as great as the units shown in the original informal drawing. This amendment corrects a typographical error made when making the original drawing. While Applicant believes that those skilled in the art would understand the invention and the error in Fig. 12, this correction is made to avoid any possible confusion on the part of the reader. Also, the downward spikes at the four corners of the informal drawing are absent in the formal drawing. These spikes were the result of utilizing a limited number of mathematical terms to generate the plotted surface. The gridded pattern shown in the formal drawing has no spikes, for example, in accordance with the complete equation in the Specification at page 24, after line 10, and the text at page 26, lines 1-4.

This amendment is submitted in triplicate. Please charge any other fees or credit any overpayment to Deposit Account 20-1430.

If the Examiner believes a telephone conference would expedite issuance of this application, please telephone the undersigned at (650) 326-2400.

Respectfully submitted,

Date: 10/27/97

  
Gary T. Aka  
Reg. No. 29,038

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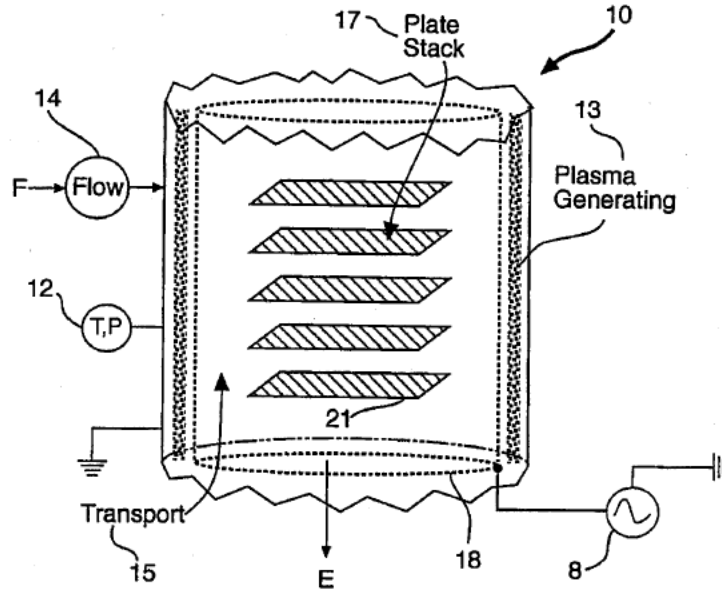


FIG. 1

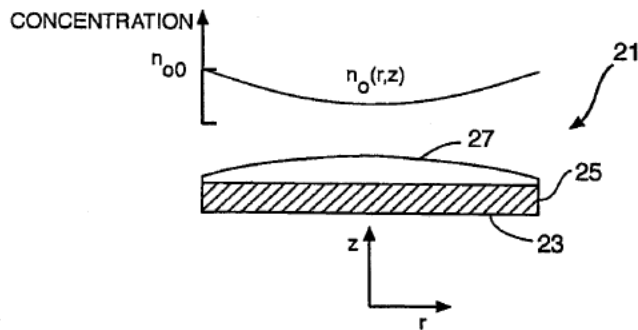


FIG. 1A

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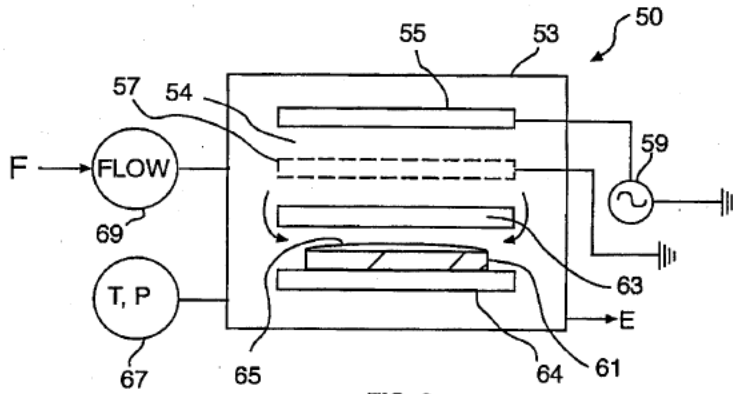


FIG. 2

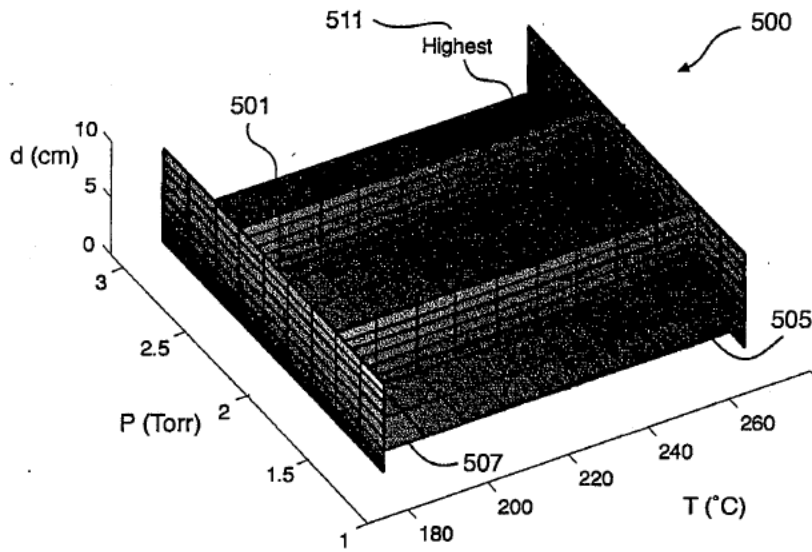


FIG. 5A

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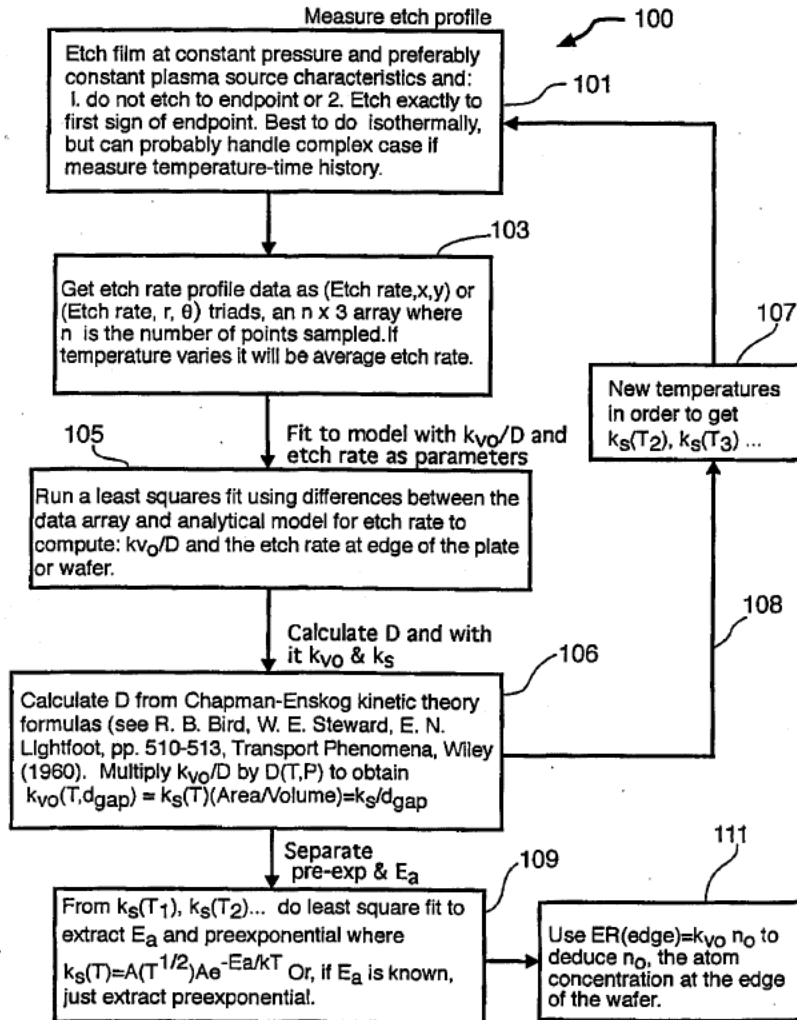


FIG. 3



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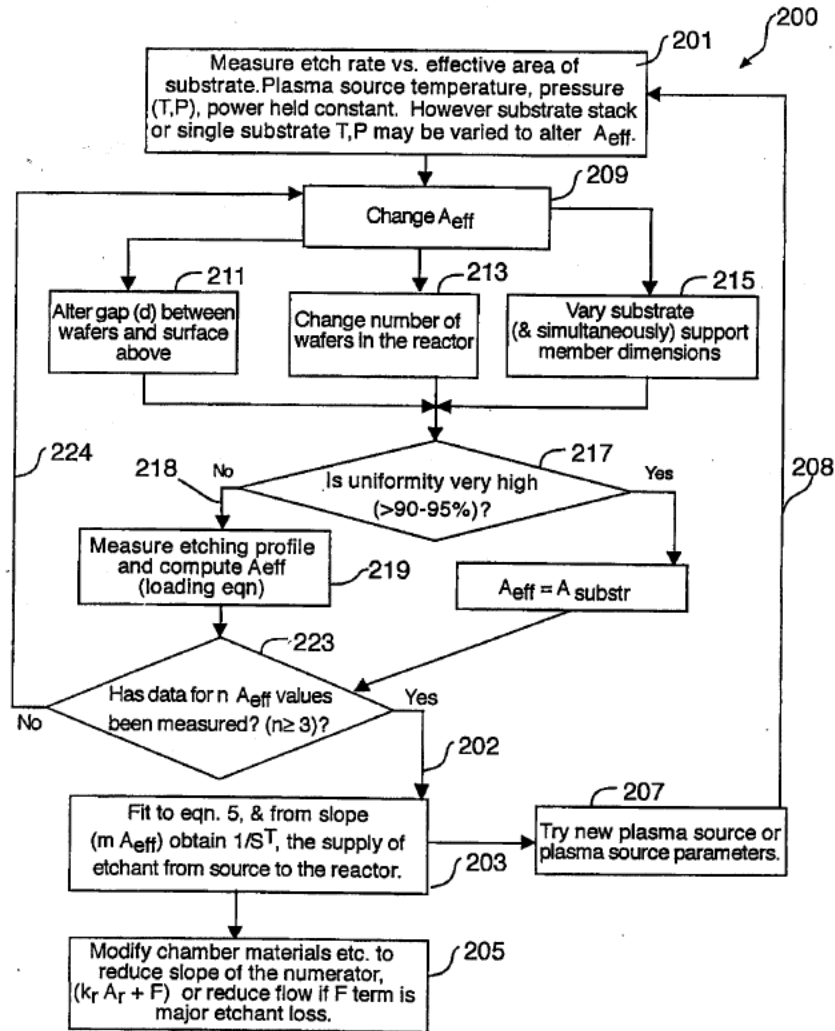


FIG. 4

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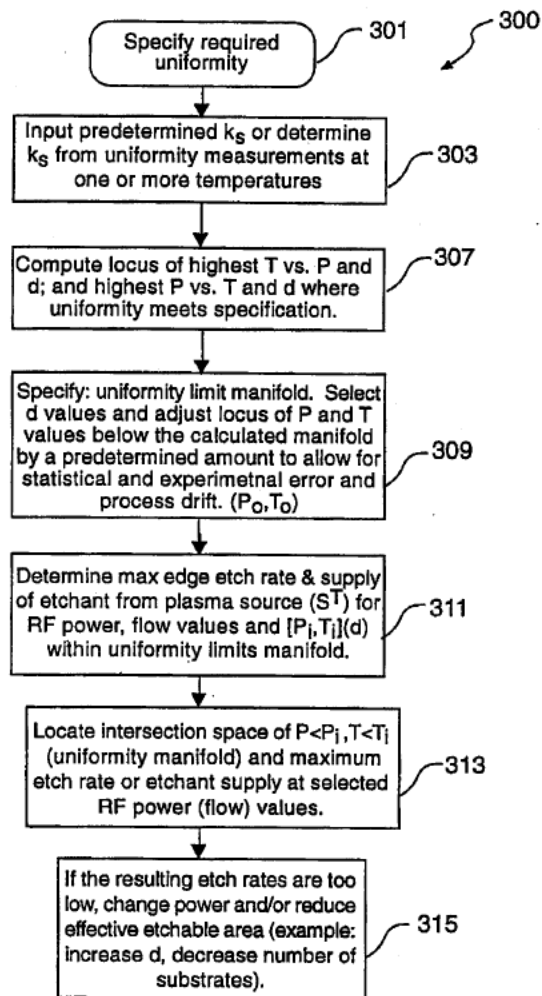


FIG. 5

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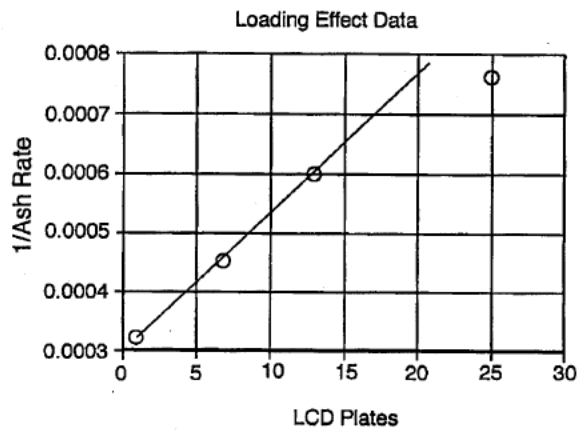


FIG. 6

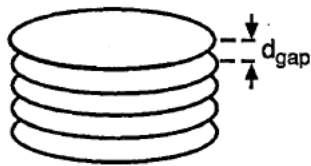


FIG. 7

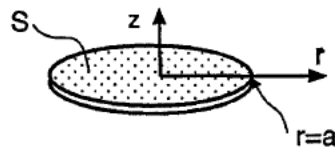


FIG. 8

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P.18

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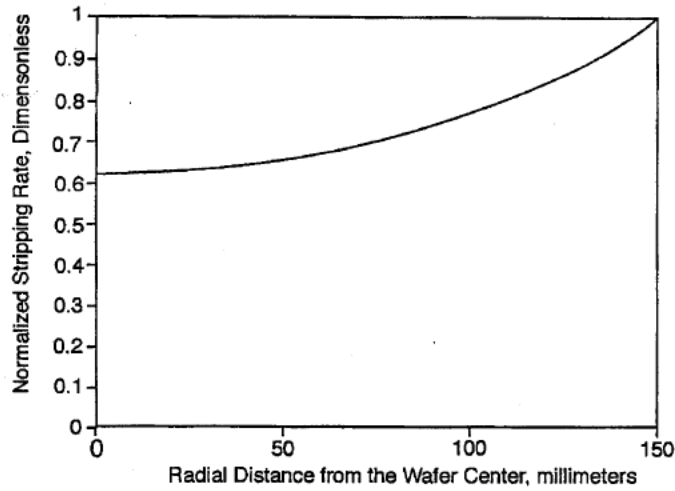


FIG. 9

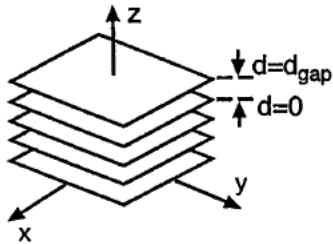


FIG. 10

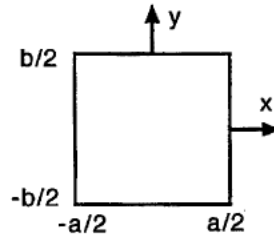


FIG. 11

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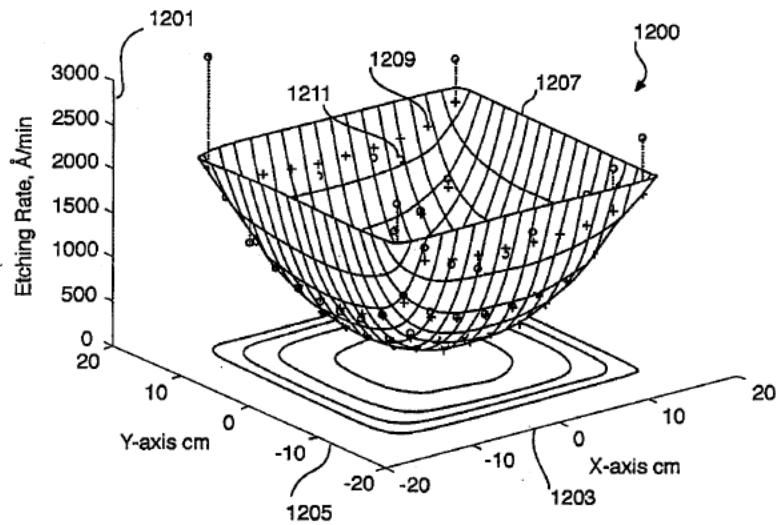


FIG. 12

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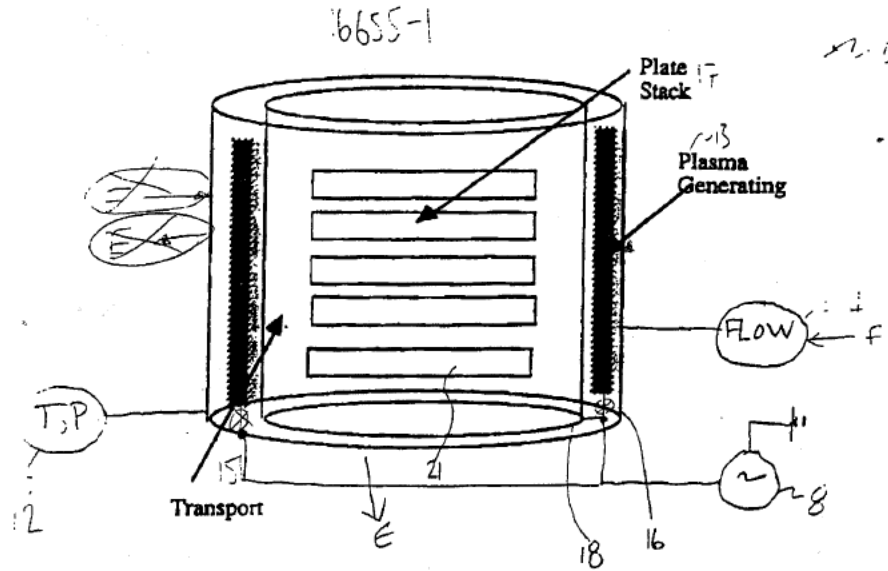


FIG. 1

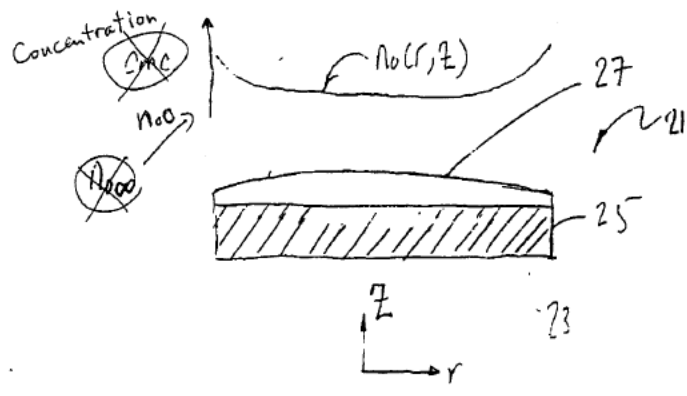


FIG. 1A

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P.21

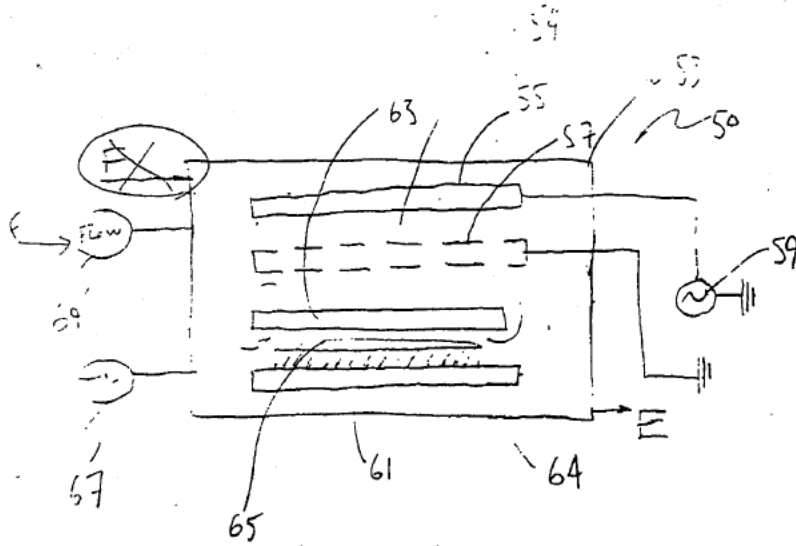


FIG. 2

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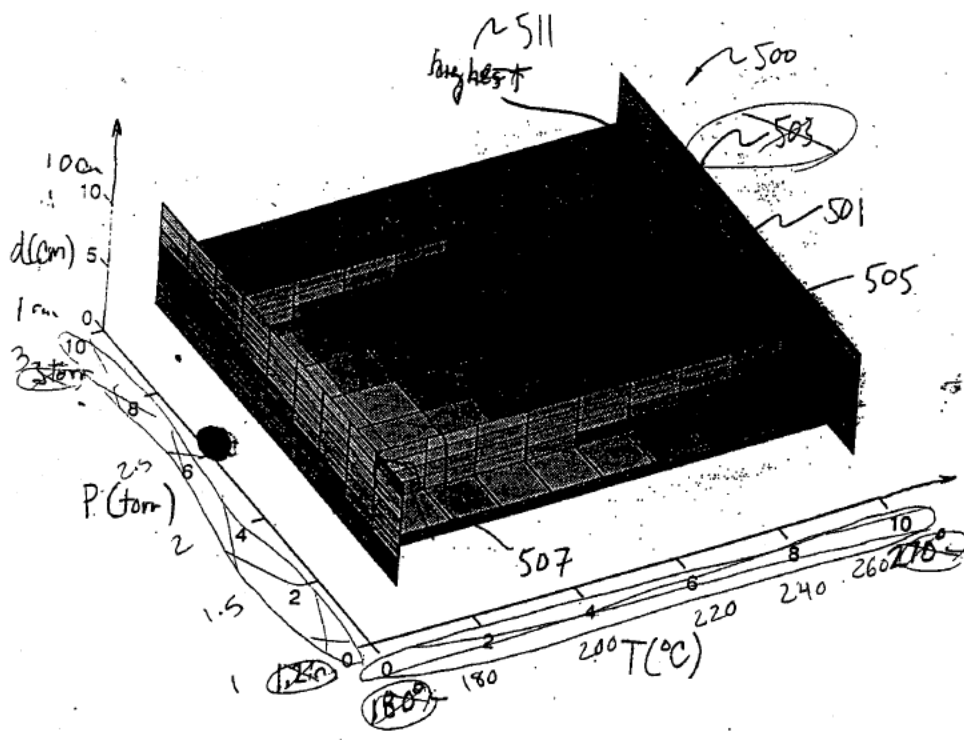


FIG. 5A





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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.
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08/433,623 05/03/95 FLAMM D 16655-000100

EXAMINER

11M1/1298

RICHARD T OGAWA  
TOWNSEND AND TOWNSEND AND CREW LLP  
TWO EMBARCADERO CENTER, 8TH FLOOR  
SAN FRANCISCO CA 94111-3834


ANGEBRANDT, M  
ART UNIT PAPER NUMBER

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17  
12/08/97

**Please find below and/or attached an Office communication concerning this application or proceeding.**

**Commissioner of Patents and Trademarks**

<b>Response to Rule 312 Communication</b>	Application No. <b>08/433,623</b>	Applicant(s) <b>Flamm</b>	
	Examiner <b>Martin J. Angebrannt</b>	Group Art Unit <b>1113</b>	


The petition filed on Oct 27, 1997 under 37 CFR 1.312(b) is granted. The paper has been forwarded to the examiner for consideration on the merits.

  
 Theodore Morris  
 Director,  
 Patent Examining Group 1100

The amendment filed on Oct 27, 1997 under 37 CFR 1.312 has been considered, and has been:

- entered.
- entered as directed to matters of form not affecting the scope of the invention (Order 3311).
- disapproved. See explanation below.
- entered in part. See explanation below.

*The changes to the specification are minor and the drawing changes have been approved by both the examiner and the Draftsman.*

  
**MARTIN J. ANGEBRANDT**  
**PRIMARY EXAMINER**  
**ART UNIT 1113**



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LOCATION 7560 SERIAL NUMBER 08433623 PATENT NUMBER

THE CORRESPONDENCE ADDRESS HAS BEEN CHANGED TO CUSTOMER # 20350

ON 07/07/97 THE ADDRESS OF RECORD FOR CUSTOMER NUMBER 20350 IS:

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TWO EMBARCADERO CENTER EIGHTH FLOOR  
SAN FRANCISCO CA 94111

PTO-FMD  
TALBOT-1/97

The file was thoroughly reviewed by our staff. Correspondence Address Change/Power of Attorney dated 04/18/2001 is missing in this file.

This has been brought to your attention so that you will know it has not been overlooked.

AO 120 (Rev. 2/99)

<b>TO: Mail Stop 8</b> <b>Director of the U.S. Patent &amp; Trademark Office</b> <b>P.O. Box 1450</b> <b>Alexandria, VA 22313-1450</b>	<b>REPORT ON THE</b> <b>FILING OR DETERMINATION OF AN</b> <b>ACTION REGARDING A PATENT OR</b> <b>TRADEMARK</b>
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In Compliance with 35 § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Northern District of California on the following  Patents or  Trademarks:

DOCKET NO. CV 15-01277 JSC	DATE FILED 3/18/15	U.S. DISTRICT COURT 450 Golden Gate Avenue, Box 36060, San Francisco, CA 94102
PLAINTIFF LAM RESEARCH CORP		DEFENDANT DANIEL L FLAMM
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1 see Complaint		
2 5,711,849		
3 6,017,221		
4 RE40,264		
5		

In the above—entitled case, the following patent(s) have been included:

DATE INCLUDED	INCLUDED BY <input type="checkbox"/> Amendment <input type="checkbox"/> Answer <input type="checkbox"/> Cross Bill <input type="checkbox"/> Other Pleading		
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK	
1			
2			
3			
4			
5			

In the above—entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT
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CLERK Richard W. Wicking	(BY) DEPUTY CLERK Sheila Rash	DATE March 19, 2015
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Copy 1—Upon initiation of action, mail this copy to Commissioner Copy 3—Upon termination of action, mail this copy to Commissioner  
 Copy 2—Upon filing document adding patent(s), mail this copy to Commissioner Copy 4—Case file copy

1111

<b>PATENT APPLICATION FEE DETERMINATION RECORD</b> Effective October 1, 1994					Application or Docket Number <b>433623</b>						
<b>CLAIMS AS FILED - PART I</b>											
(Column 1)			(Column 2)			SMALL ENTITY		OR		OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED		NUMBER EXTRA		RATE	FEE	RATE	FEE			
BASIC FEE						365.00		30.00			
TOTAL CLAIMS	23 minus 20 =		* 3		x\$11=	33	x\$22=	66			
INDEPENDENT CLAIMS	4 minus 3 =		* 1		x38=	38	x76=	76			
MULTIPLE DEPENDENT CLAIM PRESENT											
* If the difference in column 1 is less than zero, enter "0" in column 2											
<b>CLAIMS AS AMENDED - PART II</b>											
(Column 1)			(Column 2)			SMALL ENTITY		OR		OTHER THAN SMALL ENTITY	
AMENDMENT A	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE	ADDITIONAL FEE	RATE	ADDITIONAL FEE			
	Total	* 25	Minus ** 23	= 2	x\$11=	27.50	x\$22=				
	Independent	* 5	Minus ** 4	= 1	x38=	39.00	x76=				
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM										
(Column 1) (Column 2) (Column 3)											
AMENDMENT B	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE	ADDITIONAL FEE	RATE	ADDITIONAL FEE			
	Total	* 31	Minus ** 25	= 6	x\$11=	66.00	x\$22=				
	Independent	* 6	Minus *** 5	= 1	x38=	39.00	x76=				
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM										
(Column 1) (Column 2) (Column 3)											
AMENDMENT C	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE	ADDITIONAL FEE	RATE	ADDITIONAL FEE			
	Total	*	Minus **	=	x\$11=		x\$22=				
	Independent	*	Minus ***	=	x38=		x76=				
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM										
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3. ** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20." *** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3." The Highest Number Previously Paid For (Total or Independent) is the highest number found in the appropriate box in column 1.											
TOTAL ADDIT. FEE					64.00 PAID		TOTAL ADDIT. FEE				

PACE DATA ENTRY CODING SHEET

U.S. DEPARTMENT OF COMMERCE  
Patent and Trademark Office

1ST EXAMINER *DSS/COY*  
2ND EXAMINER *Dill*

DATE *5-19-95*  
DATE *8-4-95*



APPLICATION NUMBER  
**08433623**

TYPE APPL  
 P  C

FILING DATE  
MONTH DAY YEAR  
*05 03 95*

SPECIAL HANDLING  
 0

GROUP ART UNIT  
*11109*

SHEETS OF DRAWING  
*113*

TOTAL CLAIMS  
*23*

INDEPENDENT CLAIMS  
*4*

SMALL ENTITY?  
 1

FOREIGN LICENSE  
*7*

ATTORNEY DOCKET NUMBER  
*116655-000100*

CONTINUITY DATA

CONT STATUS CODE


PCT APPLICATION SERIAL NUMBER


PARENT PATENT NUMBER


PARENT FILING DATE


PCT/FOREIGN APPLICATION DATA

FOREIGN PRIORITY CLAIMED


COUNTRY CODE


PCT/FOREIGN APPLICATION SERIAL NUMBER


FOREIGN FILING DATE


**MULTIPLE DEPENDENT CLAIM  
FEE CALCULATION SHEET  
(FOR USE WITH FORM PTO-875)**

SERIAL NO.  
*08/433,623*  
APPLICANT(S)  
*FIA MM*

FILING DATE  
*5/3/95*

**CLAIMS**

	AS FILED		AFTER 1st AMENDMENT		AFTER 2nd AMENDMENT			*		*		*	
	IND.	DEP.	IND.	DEP.	IND.	DEP.		IND.	DEP.	IND.	DEP.	IND.	DEP.
1	/		/		/		51						
2		/		/		/	52						
3		/		/		/	53						
4		/		/		/	54						
5		/		/		/	55						
6		/		/		/	56						
7		/		/		/	57						
8		/		/		/	58						
9	/		/		/		59						
10		/		/		/	60						
11		/		/		/	61						
12		/		/		/	62						
13		/		/		/	63						
14		/		/		/	64						
15		/		/		/	65						
16		/		/		/	66						
17		/		/		/	67						
18		/		/		/	68						
19	/		/		/		69						
20	/		/		/		70						
21		/		/		/	71						
22		/		/		/	72						
23		/		/		/	73						
24		/		/		/	74						
25			/		/		75						
26						/	76						
27						/	77						
28						3	78						
29						/	79						
30							80						
31							81						
32							82						
33							83						
34							84						
35							85						
36							86						
37							87						
38							88						
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40							90						
41							91						
42							92						
43							93						
44							94						
45							95						
46							96						
47							97						
48							98						
49							99						
50							100						
TOTAL IND.	4		5		6		TOTAL IND.						
TOTAL DEP.	19		20		25		TOTAL DEP.						
TOTAL CLAIMS	23		25		31		TOTAL CLAIMS						



=> d his

(FILE 'USPAT' ENTERED AT 11:11:39 ON 01 MAR 96)

L1 963 S ((NONUNIFORM? OR UNIFORM?) (8A) (WAFER OR CHAMBER OR SUBST  
RAT

L2 12841 S (DRY OR PLASMA OR GAS?) (3A) (ETCH?)

L3 242 S L1(P)L2

L4 7 S ((NONUNIFORM? OR UNIFORM?) (8A) ((POSITION OR LOCATION OR  
SPA

L5 25 S ((NONUNIFORM? OR UNIFORM?) (8A) (ETCH?)) (15A) ((POSITION OR  
LO

L6 2 S (L FLAMM) (5A) (ED#)

L7 9 S (RATE CONSTANT) (5A) (ETCH?)

FILE 'JPOABS' ENTERED AT 12:05:55 ON 01 MAR 96

L8 4 S (RATE CONSTANT) (5A) (ETCH?)

L9 6 S L5

=> d his  
      (FILE 'USPAT' ENTERED AT 15:57:26 ON 17 JAN 97)  
L1      18 S (ETCH?) (P) (RATE CONSTANT#)  
      (FILE 'JPOABS' ENTERED AT 16:01:24 ON 17 JAN 97)  
L2      8 S L1