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ISSUE CLASSIFICATION	
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UTILITY SERIAL NUMBER	PATENT DATE	PATENT NUMBER
	JAN 27 1998	

SERIAL NUMBER	FILING DATE	CLASS	SUBCLASS	GROUP ART UNIT	EXAMINER
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SAN FRANCISCO CA ~~94105~~ 94111-3834

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

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		Total Claims	Print Claim
6/10/97	Assistant Examiner	29	20

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MARTIN ANGEBRANNDT
PRIMARY EXAMINER
GROUP 1100
Primary Examiner

DRAWING		
Sheets Drwg.	Figs. Drwg.	Print Fig.
~~4~~ 13	14	8

ISSUE BATCH NUMBER N95

PREPARED FOR ISSUE

Label Area

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Form PTO-436A
(Rev. 8/92)

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ISSUE FEE IN FILE

67479 U.S. PTO
08433623
06/03/95

PATENT APPLICATION

08433623

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CONTENTS

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	3. Dec + Fee	6/27/95
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CLASSIFIER		8	5-16-95
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Final	Original	3/11/96	1/3/97	6/9/97					
1	1	✓	✓	=					
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SYMBOLS

✓ .... Rejected
= .... Allowed
- (Through numberal) Canceled
\+ .... Restricted
N .... Non-elected
I .... Interference
A .... Appeal
O .... Objected

Claim		Date							
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APPLICANT'S NAME (PLEASE PRINT)
Flamm et al.

IF REISSUE, ORIGINAL PATENT NUMBER

CROSS REFERENCE(S)

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1113

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MARTIN J. ANGEBRANNDT

PTO 270
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U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

[redacted]

SEARCHED

Class	Sub.	Date	Exmr.
~~204~~ 216 156	258,31 258,32 58, 58,74,79 246 P 625.1, 643.1 626.1 646.1 658.1, 662.1	3/1/96	
updated Search 156	658.11	1/24/97	
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APS enclosed	1/24/97	
None	6/9/97	

INTERFERENCE SEARCHED

Class	Sub.	Date	Exmr.
204 216 156	258.31 258.32 58, 57, 74 79, ~~[illegible]~~ 246 P 625.1, 643.1 626.1 646.1 658.1, 662.1	6/9/97	

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APPLICANT

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CONTINUING DATA*******************
VERIFIED

FOREIGN/PCT APPLICATIONS**********
VERIFIED

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ADDRESS

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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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08433623
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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

By Richard T. Ogawa

Sir:

Transmitted herewith for filing is the
   [x] patent application of
   [ ] design patent application of
   [ ] continuation-in-part patent application of

Inventor: DANIEL L. FLAMM ~~and JOHN VERBONCOEUR~~ et al

For: PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

Enclosed are:

- [x] 13 sheet(s) of [ ] formal [x] informal drawing(s).
- [ ] An assignment of the invention to ______ .
- [x] A [ ] signed [x] 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.
- [ ]

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.

DO NOT CHARGE THE FILING FEE AT THIS TIME.

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APPNOFEE.TRN 12/92

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Attorney Docket No. 016655-0001

PATENT APPLICATION

U.S. PTO
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05/03/95

PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

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PATENT
Attorney Docket No. 016655-0001

PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

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.

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.

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

2

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 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, reliable, faster, predictable, and cost effective is often desired.

SUMMARY OF THE INVENTION

According to the present invention, a plasma etching 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, 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 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 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 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 parameter~~s~~ 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 ~~of~~ 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;

4

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 controller ~~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 limited ~~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,

5

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 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 $n_O(r,z)$, where r is the distance from the center of the substrate and z is the distance above the substrate. A diffusive velocity v_O of etchant species in the plate stack zone is characterized by Fick's law.

T60X

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

In a specific embodiment, a gap d_{gap} above the substrate is much less than the lateral extent $d_{gap}<<r$ and gas phase mass transfer resistance across the small axial distance 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 etching reaction bears a first order form:

$$O+S \rightarrow SO$$

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 reaction can be defined as follows:

T61X

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

where

R_{OS} defines a reaction rate;
n_O defines a concentration;
A defines a reaction rate constant;
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 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 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 corresponding to different etchant species concentrations. A concentration profile $n_o(r,z)$ 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 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 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 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 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,

7

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 a 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 of 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 ~~to~~ of 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.

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 (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 θ coordinates. The etching profile is characterized as a relative etch rate *u*, a *r-location*, and a θ-*location (u, r, θ)*. An array of data points in either the *x-y* coordinates or *r*-θ coordinates define the etching profile. The array of data points can be defined as an n x 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.

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.

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 often defined as follows:

where

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

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T110X

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

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

Ins D1

a is an outer radius (or edge) of the substrate. D1

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

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

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;
σ_{AB} is a collision diameter; and
$\Omega_{D,AB}$ is a ~~collusion~~ collision integral.

D

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.

||

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

T120X

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

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, $T_3 \ldots T_n$ to calculate additional reaction rate constants $k(T_2)$, $k(T_3) \ldots k(T_n)$. 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 $k(T_2)$, $k(T_3) \ldots k(T_n)$ at T_2, $T_3 \ldots T_n$ collected via step 109 by way of the ~~follow~~ following equation:

T121X

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

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:

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

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.

12

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:

7/30X

$$uniformity=100*\left[1-\frac{R_{MAX}-R_{MIN}}{2\sum_{i=1}^{m}\frac{R_i}{m}}\right.$$

where

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 *ith* sample;
uniformity is a planarity measurement in 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, 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.

13

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.

T140X

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

where ~~R_o~~ 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

14

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 this method. Uniformity can be defined by, for example:

T150X

$$uniformity=100 * \left[1-\frac{R_{MAX}-R_{MIN}}{2\sum_{i=1}^{m}\frac{R_i}{m}}\right] \wedge$$

where

R_{MAX} is a maximum etch rate;
R_{MIN} is a minimum etch rate;
m is a sample number;

15

R_i is a general etch rate for an *ith* sample;
uniformity is a planarity measurement in percentage.

In certain embodiments, the selected uniformity ranges from 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 stating point to extract a plurality of reaction rate constants k_s. 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_s at one or more temperatures, and preferably two or more temperatures (step 303) from a 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 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 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 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, 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, ~~vs.~~ versus P and d_{gap}, and of highest P, ~~vs.~~ versus T and d_{gap} 511 where

16

uniformity meets the specification, e.g., the selected uniformity from step 301. All points bounded within the highest T, ~~vs.~~ versus P and d_{gap}, and the highest P, ~~vs.~~ versus T and d_{gap} fall within the uniformity specification. Points outside the highest T, ~~vs.~~ versus P and d_{gap} and the highest P, ~~vs.~~ versus 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 effective 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:

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

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 relationship:

T190X

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

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 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 $A_{\cancel{w}}^{eff}$ 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. Accordingly, A_{eff} becomes a function of parameters such as temperature, pressure, reactor configuration, and the like.

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

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

where

C_o = 0.00030171936426 min/Å;

19

and $C_1A_w = 2.3003912550 \times 10^{-5}$ 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, when etching uniformity is high the 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_{s} 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

T200X

$$\frac{\partial\left[\frac{1}{k_{so}n_o}\right]}{\partial m}=\frac{A_{eff}}{S^T}$$

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.

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,

20

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

T210X

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

where k_{vo} is the volume equivalent surface reaction rate constant, and v is the diffusive velocity of oxygen atoms. Inserting Fick's law

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

the diffusion equation is obtained

T211X

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

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 $u(x/L_x,\ y/L_y)$ is a function solely of k_{vo}/D and the boundary conditions. Consequently, if experimental values of ~~n~~ $u(x/L_x,\ y/L_y)$ 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_o~~ n_o/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.

For circular substrates, there is only one independent dimension (*e.g.*, where $r=a$ is the substrate radius). At steady state in one dimensional cylindrical coordinates the equation can be written:

T22BX

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

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

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 uniformity relationships for flat panel resist stripping equipment.

Examples

1. Circular Substrate (Wafer) Stacked Etcher

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 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.

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 substantially uniform in the axial direction z. Accordingly, only radial diffusion in the *r-direction* needs consideration. Assuming an equi-molal counterdiffusion

22

T230X

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

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

T231X

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

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

T232X

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

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:

T233X

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

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 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 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.

23

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~~ 10. 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

T240X

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

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.

T241X

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

The sign of the sum decomposing λ^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 $m = 1,3,5,\ldots$ Similarly, the solution for X is ~~where λ_x is given by~~:

24

$$X = c_x \cosh \lambda_x x,$$

where λ_x is given by

T250X

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

The ~~the~~ general solution is the sum:

T251X

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

where $c_m = 0$ for $m = 0,2,4,\ldots$ 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,

T252X

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

and after the integration

T253X

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

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

T254X

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

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

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

T255X

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

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

5

T260X

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

The previous two-dimensional 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 $D(cm^2/s)=0.044T^{3/2}$ (T is in K) using relations in ~~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 substituting ~~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. ~~11~~ 12 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

26

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 sustained ~~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. ~~11~~ 12 represents a least squares fit to 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 $D(cm^2/s)=0.044T^{3/2}$ yields $D=400\ cm^2/s$. By way of the relationship $k_{vo}/D=0.047$, the etch rate constant is now $k_{vo}=19.5\ sec.^{-1}$. 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_{os} ~~R~~$=k_s n_{o0}$. 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 $A_{\cancel{w}\,eff}$

T22X0Y

$$R_{\underset{os}{\cancel{w}}}\cdot A_{\cancel{w}\,eff}=\iint A_{substr}k_{vo}n_o(x,y)\,dxdy=n_{o0}k_{vo}\iint_{substr}u(x,y)\,dxdy=n_{o0}k_{vo}A_{\cancel{w}\,eff}$$

so that $n_{O0}k_{vo}A_{\cancel{w}\,eff}$ 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:

T22X1Y

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

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 $k_{vo}A_{\cancel{w}\,eff}$. $A_{\cancel{w}\,eff}$ 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

8

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.

29

WHAT IS CLAIMED IS:

Sub B1

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 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.~~

~~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:

B4 Concl'd

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.~~

Sub C5

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.

Sub B5

~~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.~~

B5 Cancel

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

18 ~~17~~. The method of claim 10 ~~9~~ wherein said second plasma etching apparatus is a co-axial reactor.

19 ~~18~~. The method of claim 10 ~~9~~ 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.~~

~~21~~ 23. The method of claim ~~20~~ 22 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

433623

PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

ABSTRACT OF THE DISCLOSURE

A method of designing a reactor 10. The present 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 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.

N:\WP\WP51\PAT\16655-1.RTO

1

Attorney Docket No. 16655-000100

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05/03/95

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 applications(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 ____ 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
N/A		___ 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.

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

Send Correspondence to: **WILLIAM J. BOHLER** **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: WILLIAM J. BOHLER** **Reg. No. 31,487** **Telephone: 27,301**

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

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 **DANIEL L. FLAMM**	Signature of Inventor 2 **JOHN VERBONCOEUR**
Date	Date

16655-1

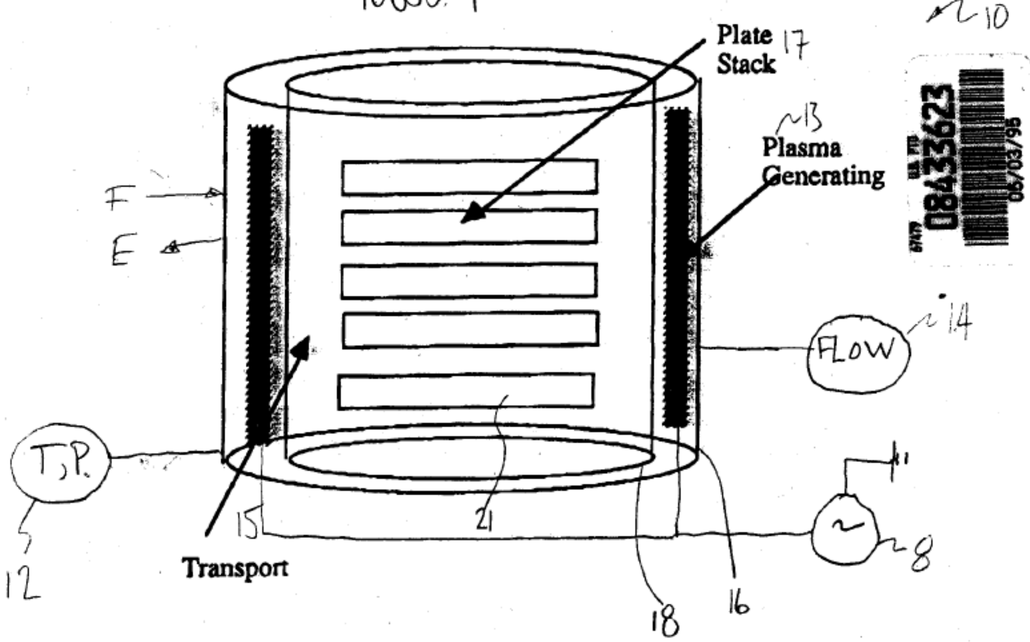

FIG. 1

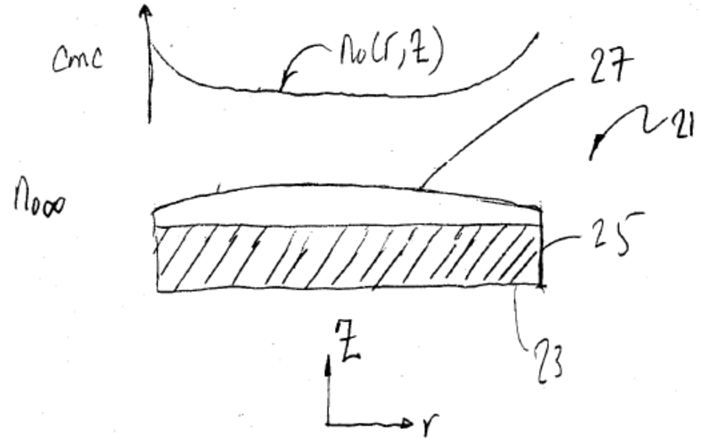

FIG. 1A

16655-1

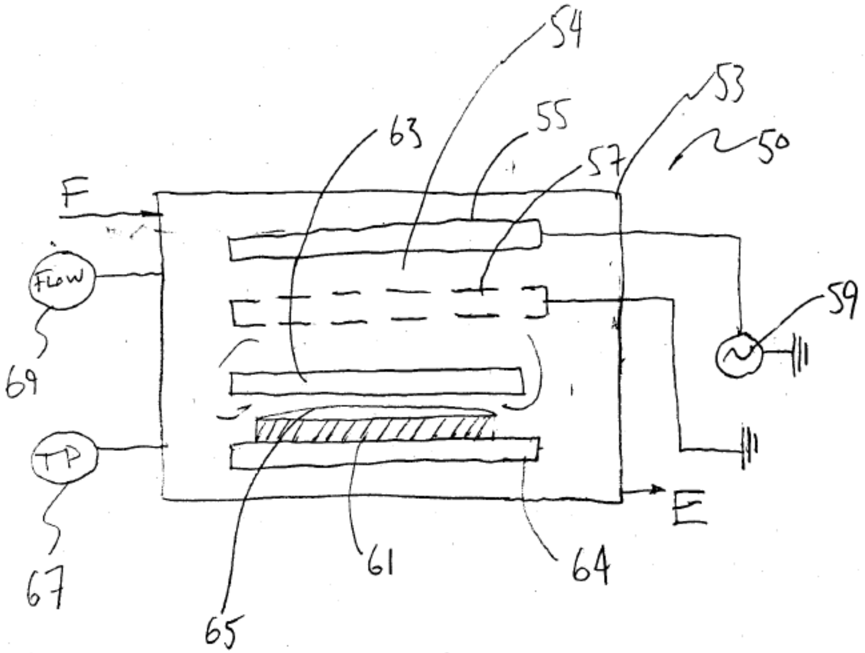

FIG. 2

16655-1

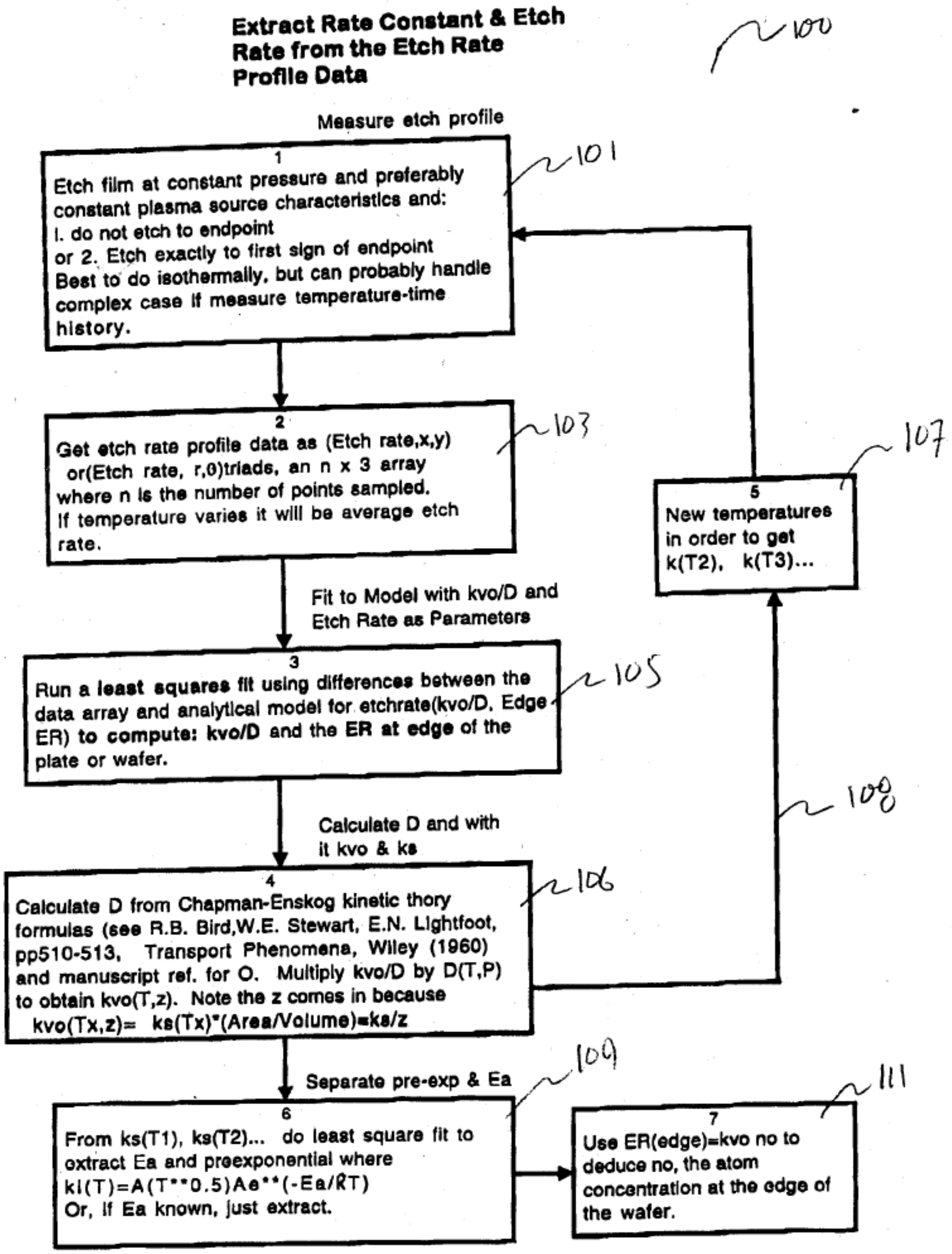
Extract Rate Constant & Etch Rate from the Etch Rate Profile Data
100
Measure etch profile
1
Etch film at constant pressure and preferably constant plasma source characteristics and:
I. do not etch to endpoint
or 2. Etch exactly to first sign of endpoint
Best to do isothermally, but can probably handle complex case if measure temperature-time history.
101
2
Get etch rate profile data as (Etch rate,x,y) or(Etch rate, r,θ)triads, an n x 3 array where n is the number of points sampled.
If temperature varies it will be average etch rate.
103
Fit to Model with kvo/D and Etch Rate as Parameters
3
Run a least squares fit using differences between the data array and analytical model for etchrate(kvo/D, Edge ER) to compute: kvo/D and the ER at edge of the plate or wafer.
105
Calculate D and with it kvo & ks
4
Calculate D from Chapman-Enskog kinetic thory formulas (see R.B. Bird,W.E. Stewart, E.N. Lightfoot, pp510-513, Transport Phenomena, Wiley (1960) and manuscript ref. for O. Multiply kvo/D by D(T,P) to obtain kvo(T,z). Note the z comes in because kvo(Tx,z)= ks(Tx)*(Area/Volume)=ks/z
106
5
New temperatures in order to get k(T2), k(T3)...
107
108
Separate pre-exp & Ea
109
6
From ks(T1), ks(T2)... do least square fit to extract Ea and preexponential where kI(T)=A(T**0.5)Ae**(-Ea/RT)
Or, if Ea known, just extract.
7
Use ER(edge)=kvo no to deduce no, the atom concentration at the edge of the wafer.
111

FIG. 3

16655-1

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

200

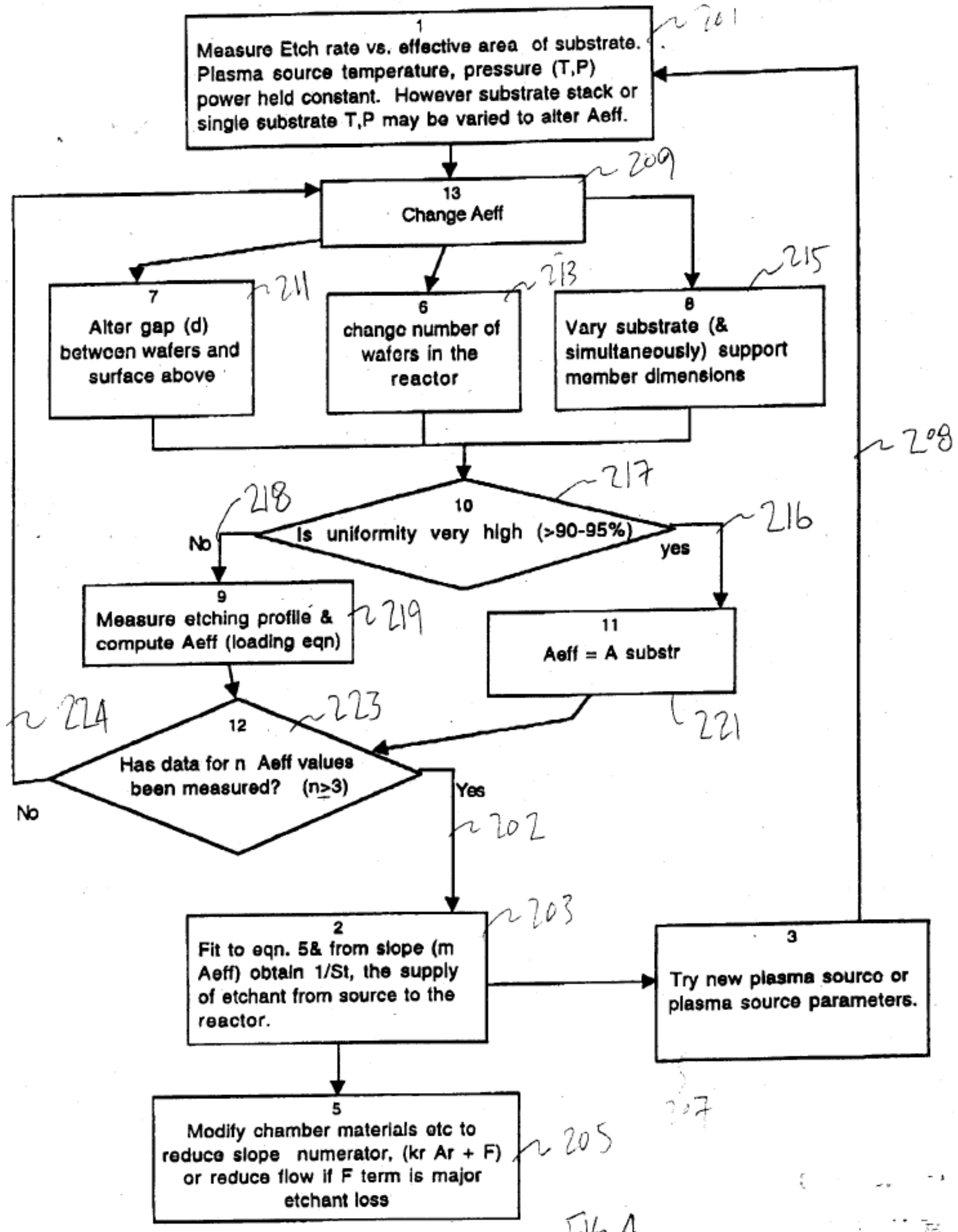

FIG 4

16655-1

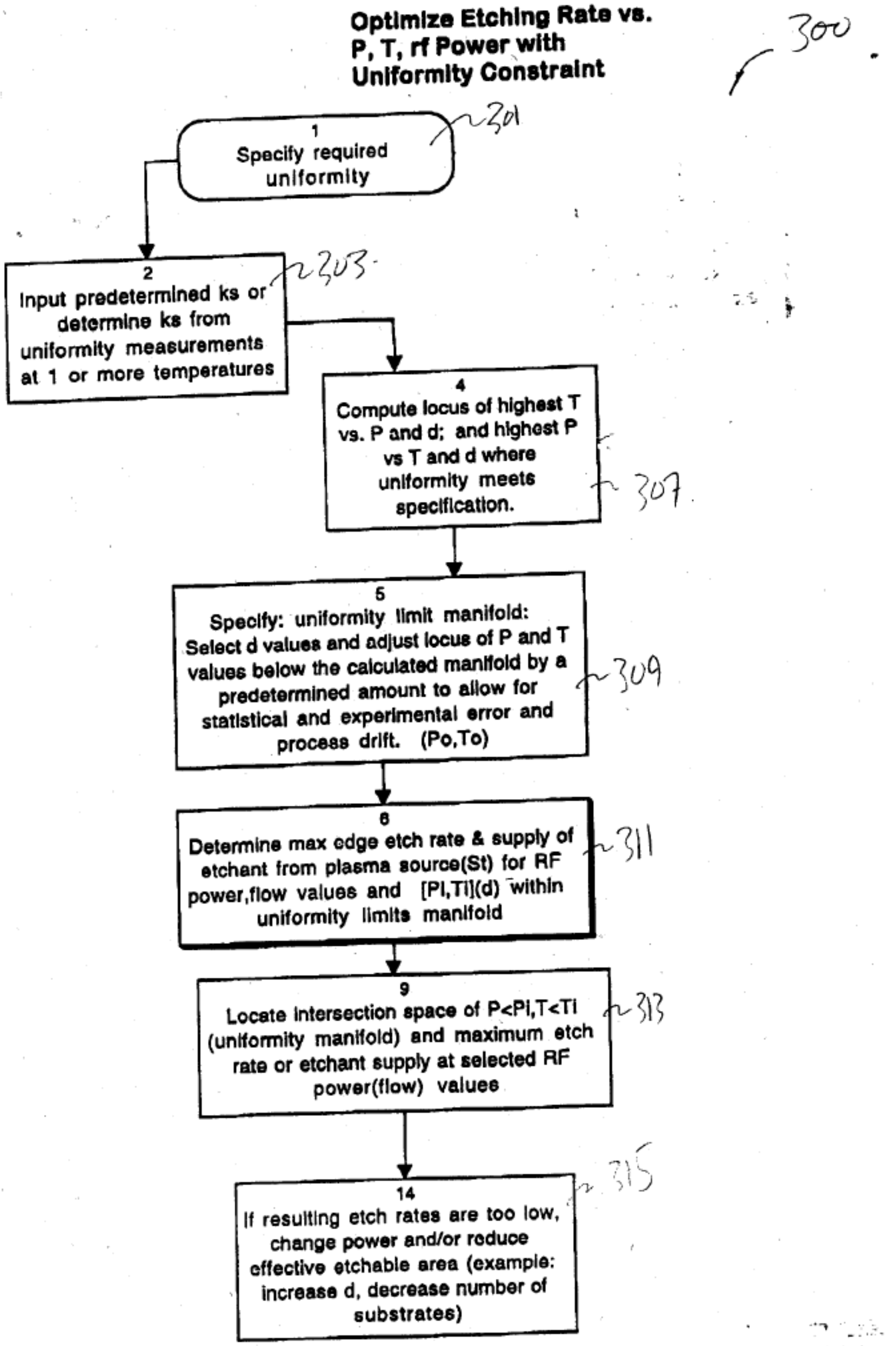
Optimize Etching Rate vs. P, T, rf Power with Uniformity Constraint
300
1
Specify required uniformity
301
2
Input predetermined ks or determine ks from uniformity measurements at 1 or more temperatures
303
4
Compute locus of highest T vs. P and d; and highest P vs T and d where uniformity meets specification.
307
5
Specify: uniformity limit manifold: Select d values and adjust locus of P and T values below the calculated manifold by a predetermined amount to allow for statistical and experimental error and process drift. (Po,To)
309
6
Determine max edge etch rate & supply of etchant from plasma source(St) for RF power,flow values and [Pl,Tl](d) within uniformity limits manifold
311
9
Locate intersection space of P<Pl,T<Tl (uniformity manifold) and maximum etch rate or etchant supply at selected RF power(flow) values
313
14
If resulting etch rates are too low, change power and/or reduce effective etchable area (example: increase d, decrease number of substrates)
315

FIG. 5

16655-1

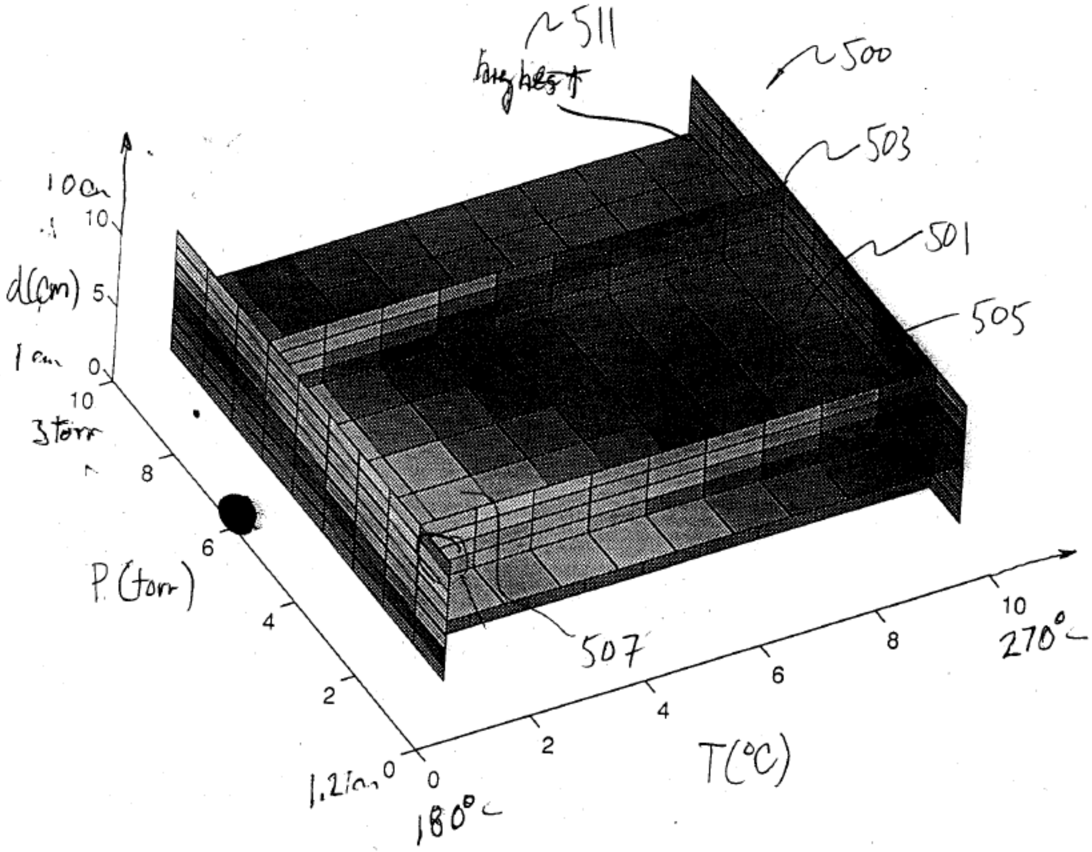

FIG. 5A

166551-1

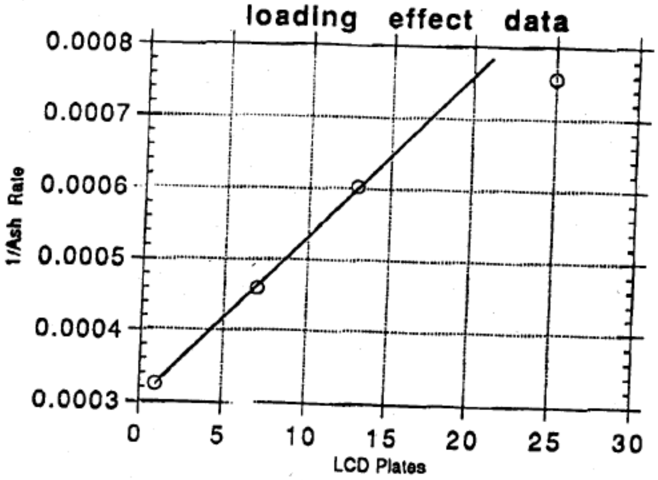

FIG. 0

16655-1

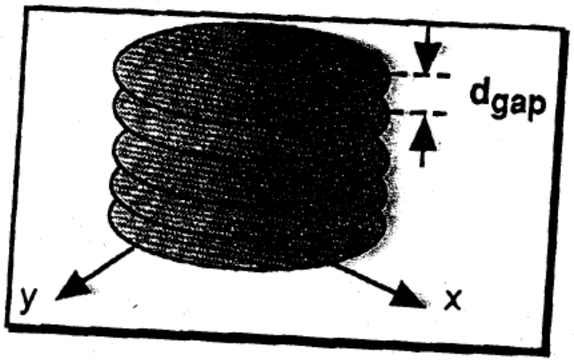

FIG. 7

16655-1

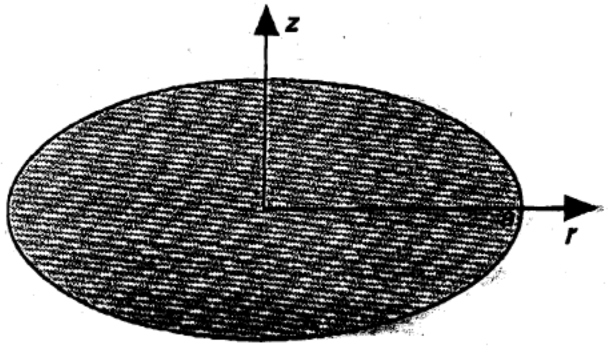

FIG. 9

16655-1

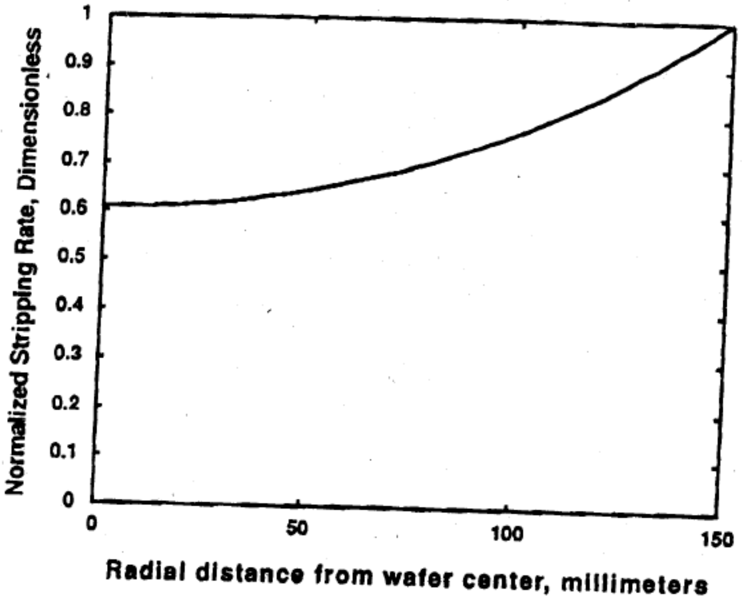
Normalized Stripping Rate, Dimensionless
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
50
100
150
Radial distance from wafer center, millimeters

FIG. 9

166551

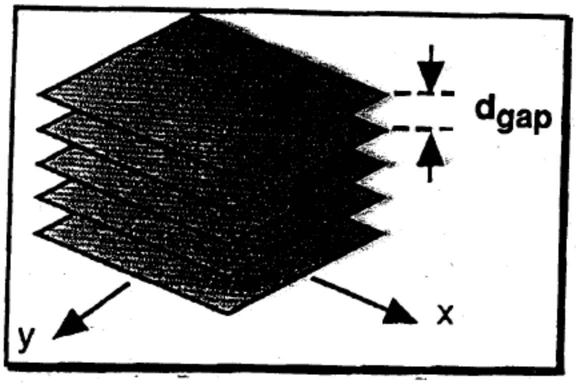

FIG. 10

166551

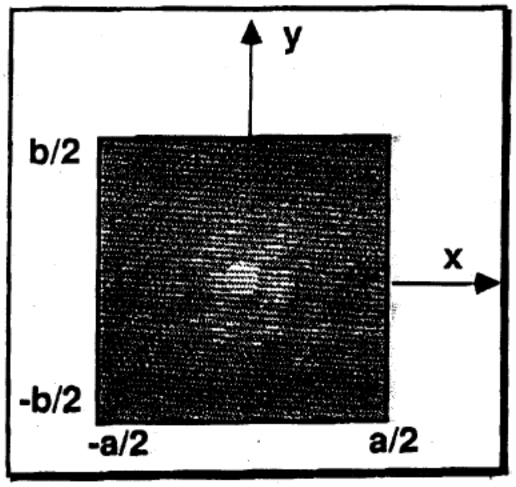

FIG. 11

16655-1

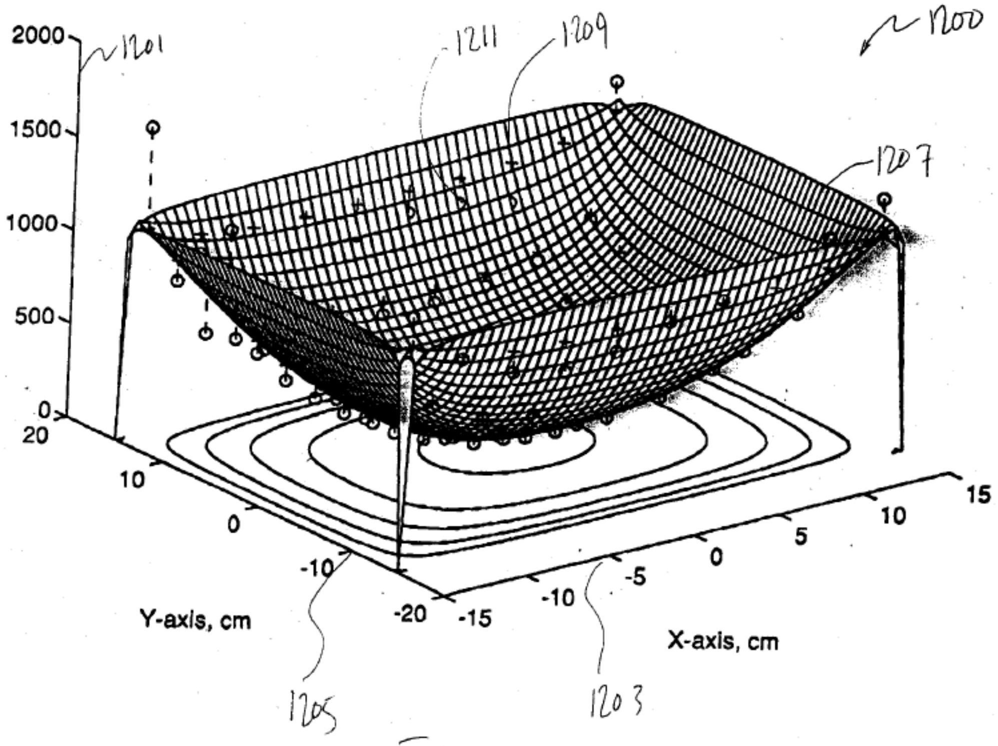

FIG. 12

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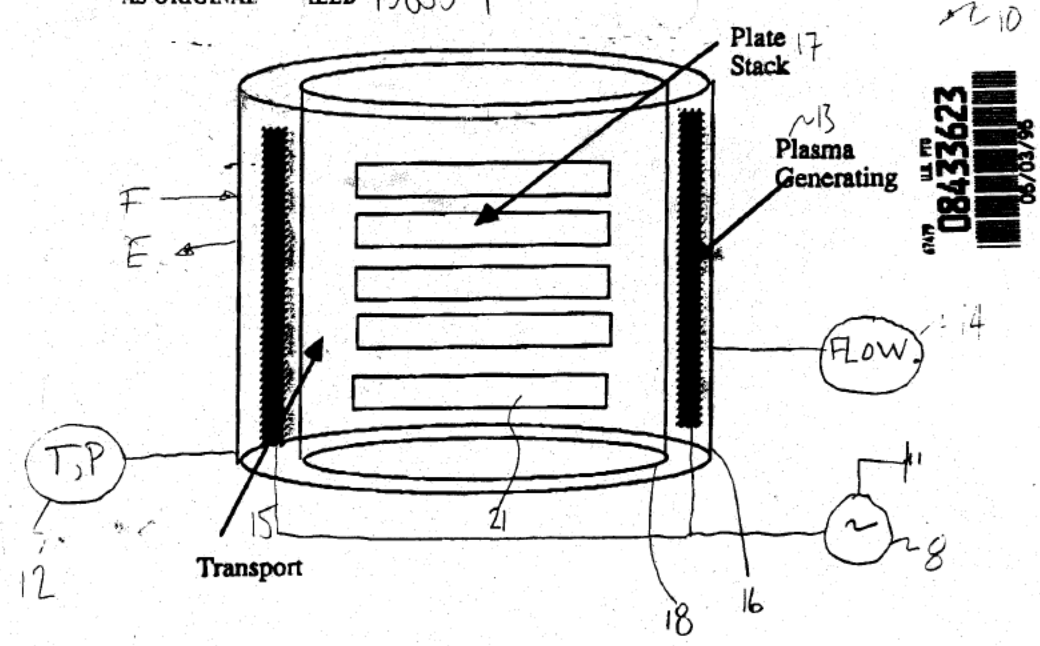

FIG. 1

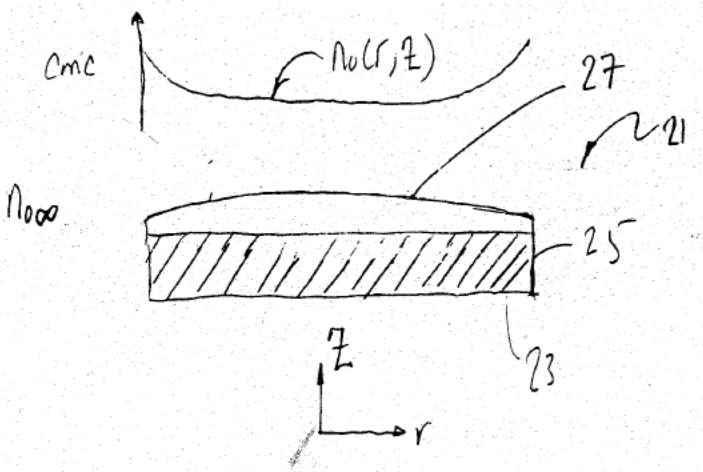

FIG. 1A

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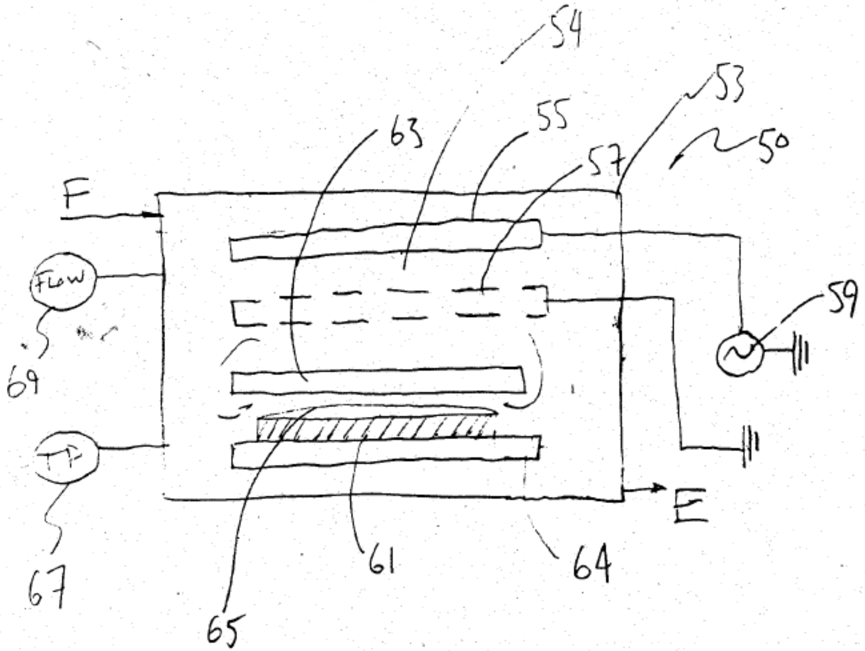

FIG. 2

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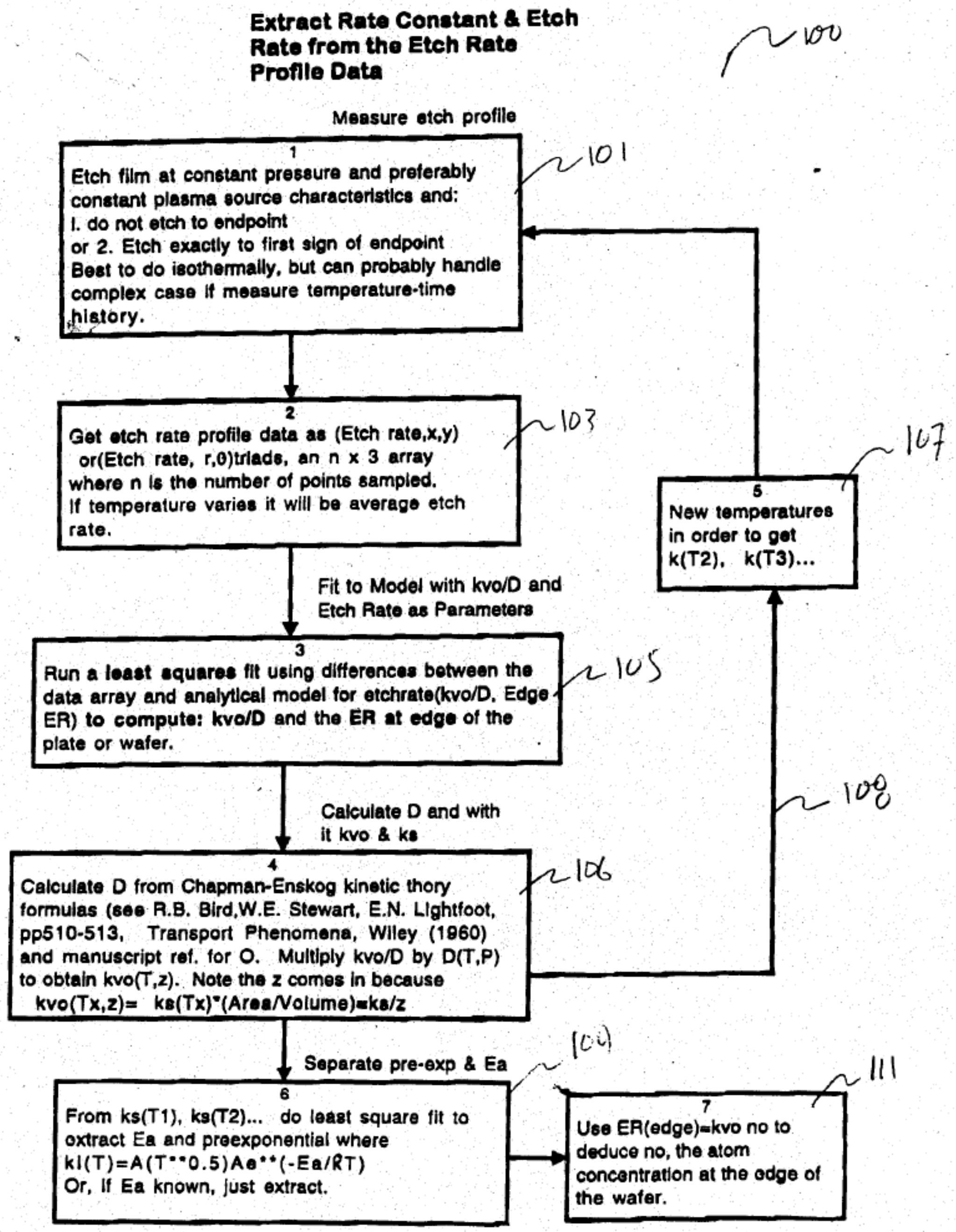

FIG. 3

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05/03/95

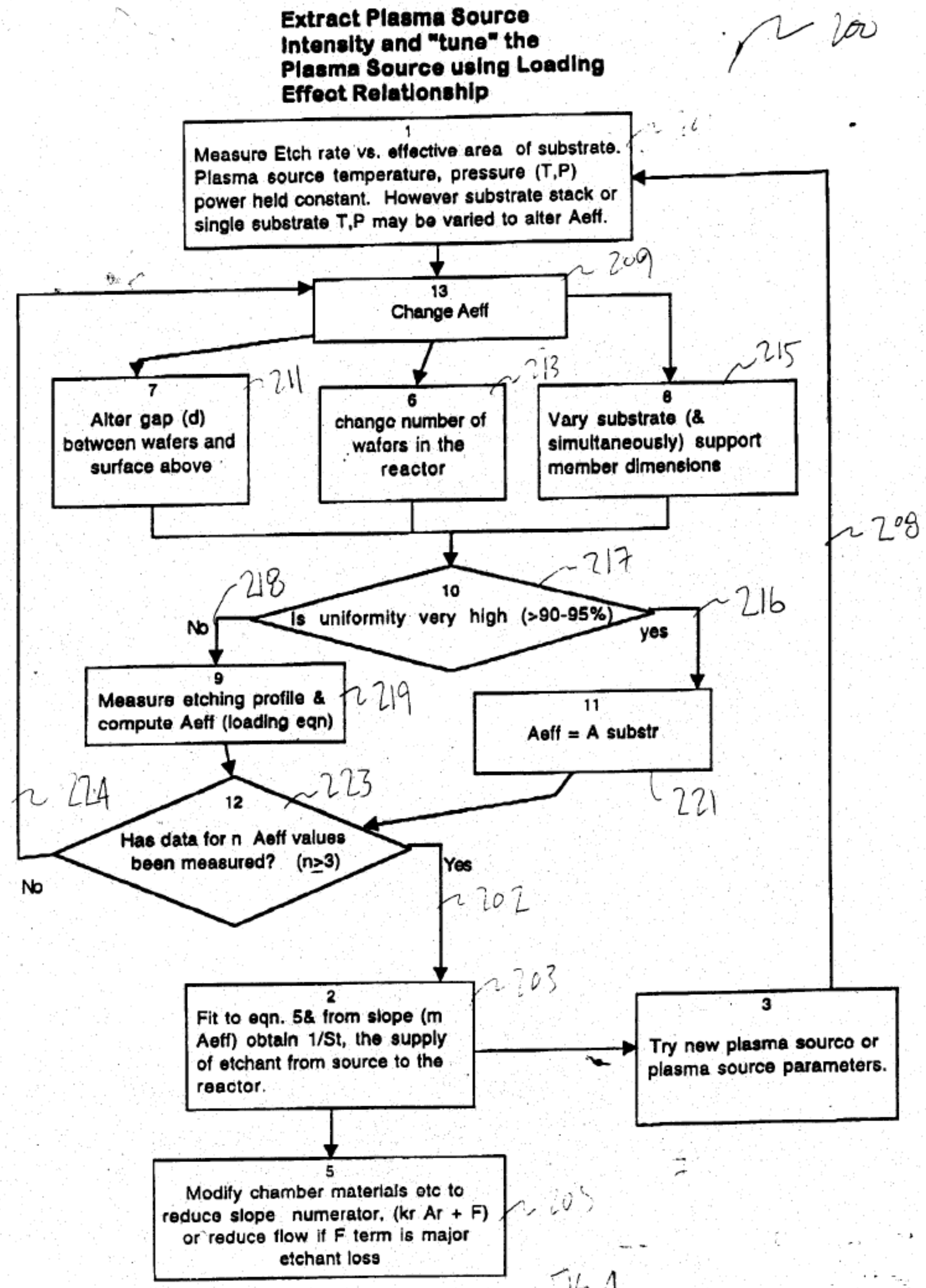

FIG 4

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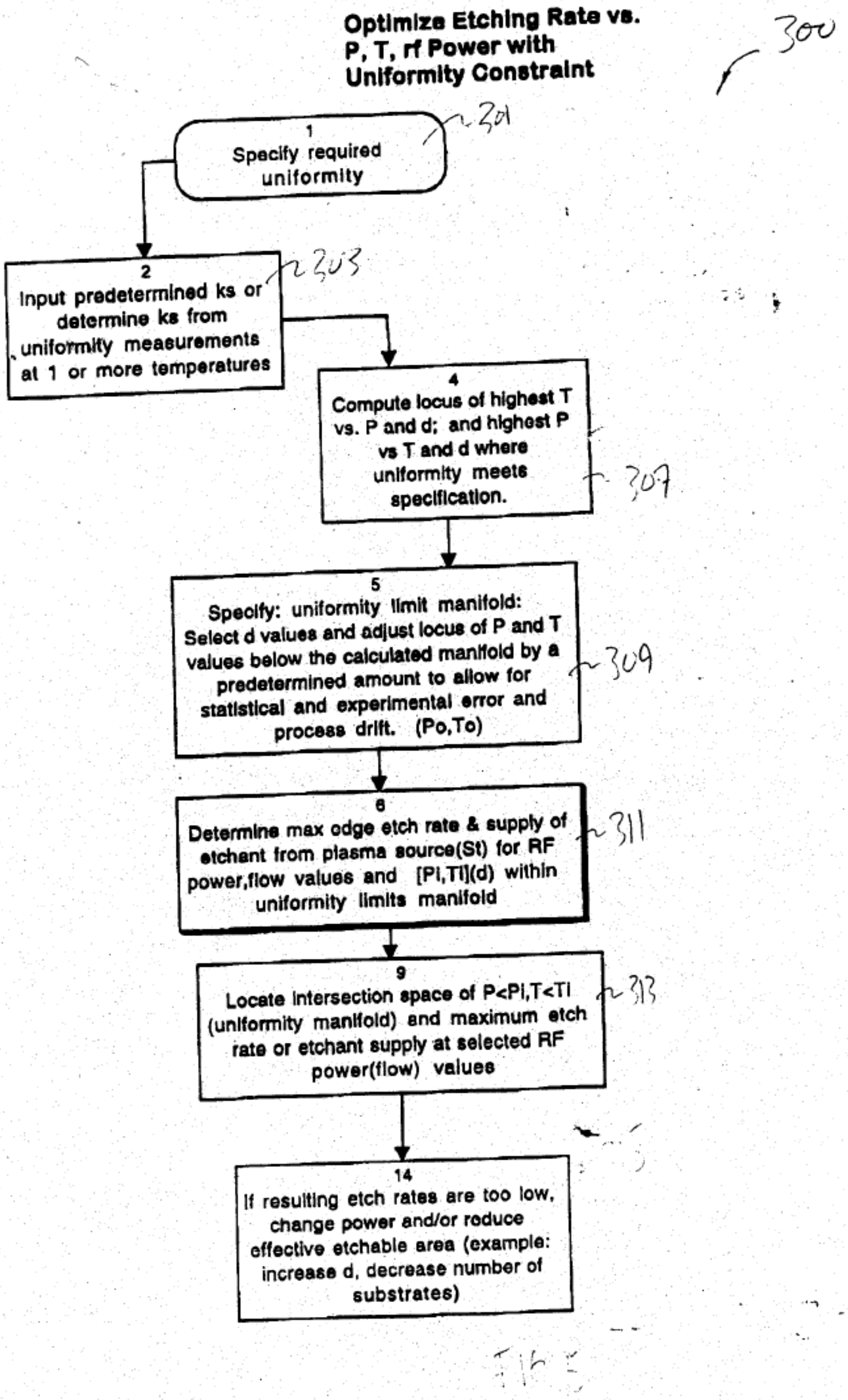

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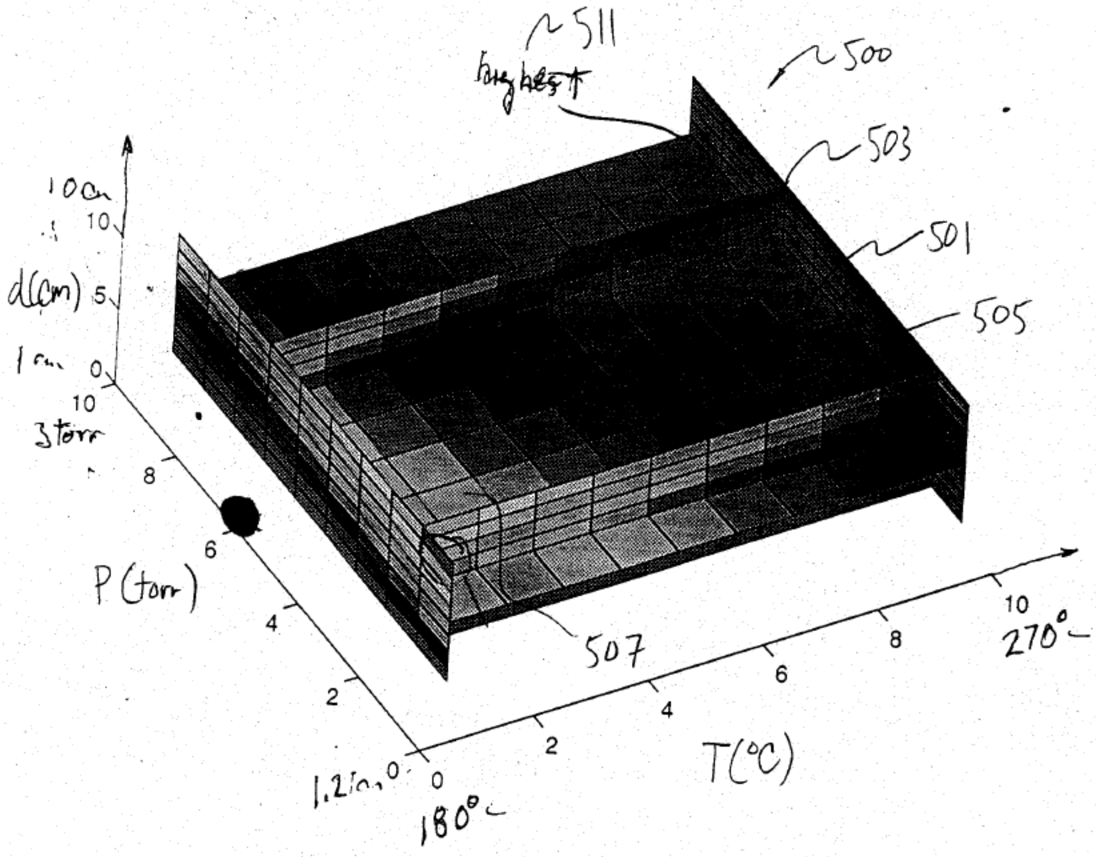

FIG. 5A

16655-1

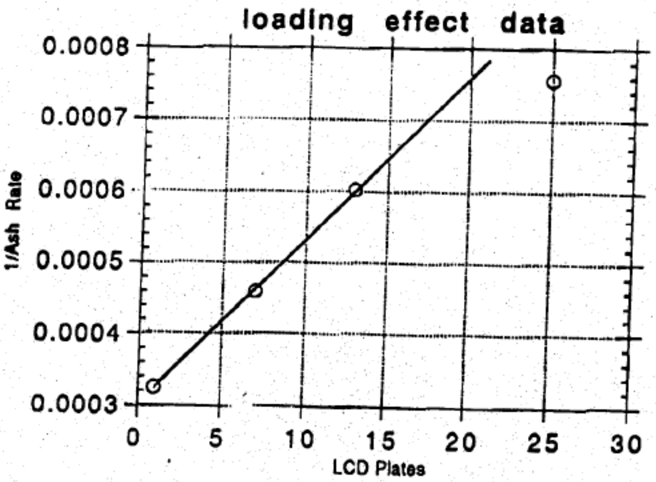
loading effect data
1/Ash Rate
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0
5
10
15
20
25
30
LCD Plates

Fig. 5

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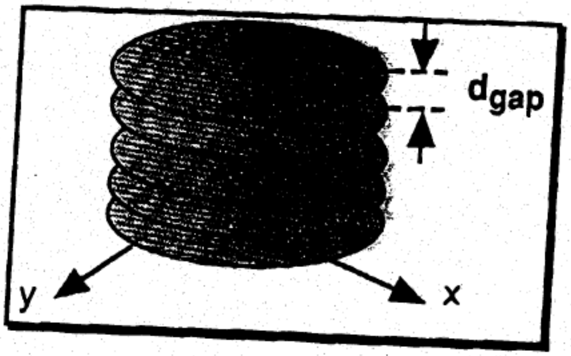

FIG. 7

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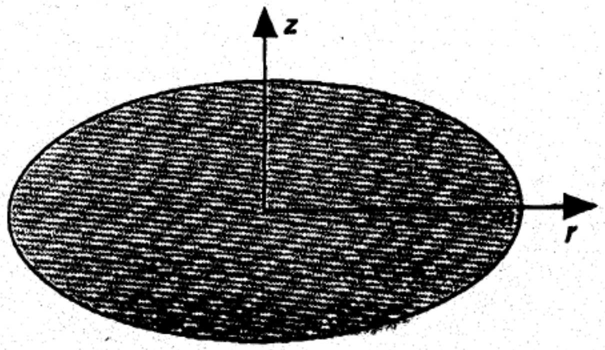

FIG 9

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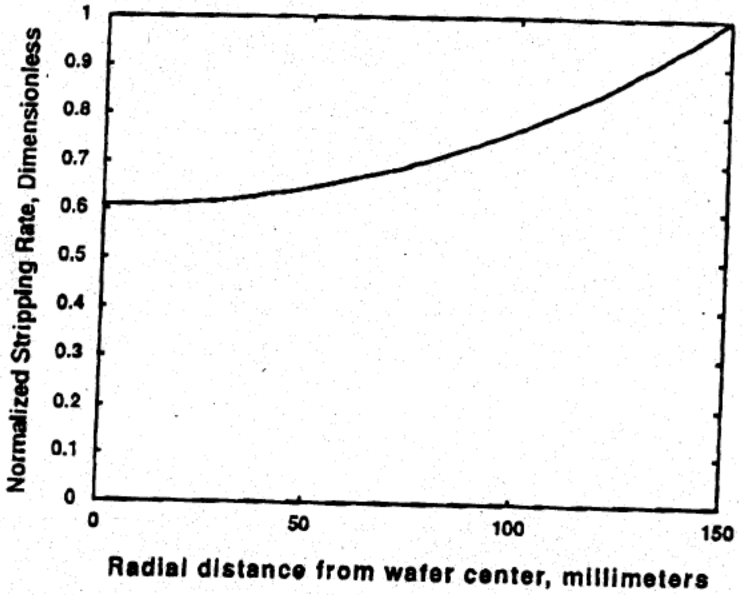

FIG. 9

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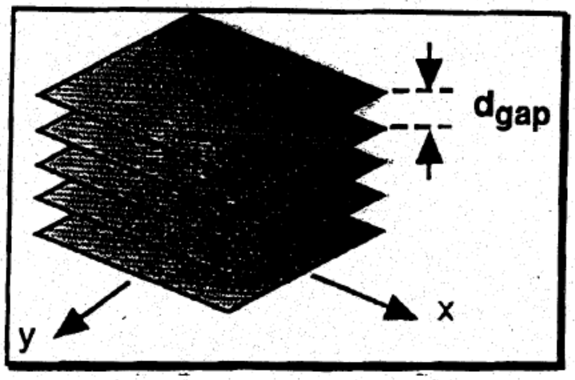

FIG. 10

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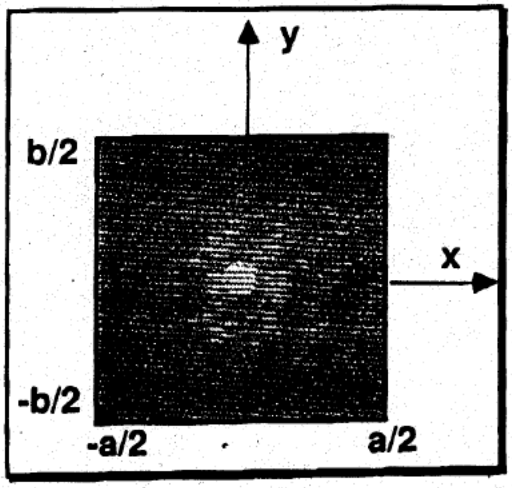

FIG. 11

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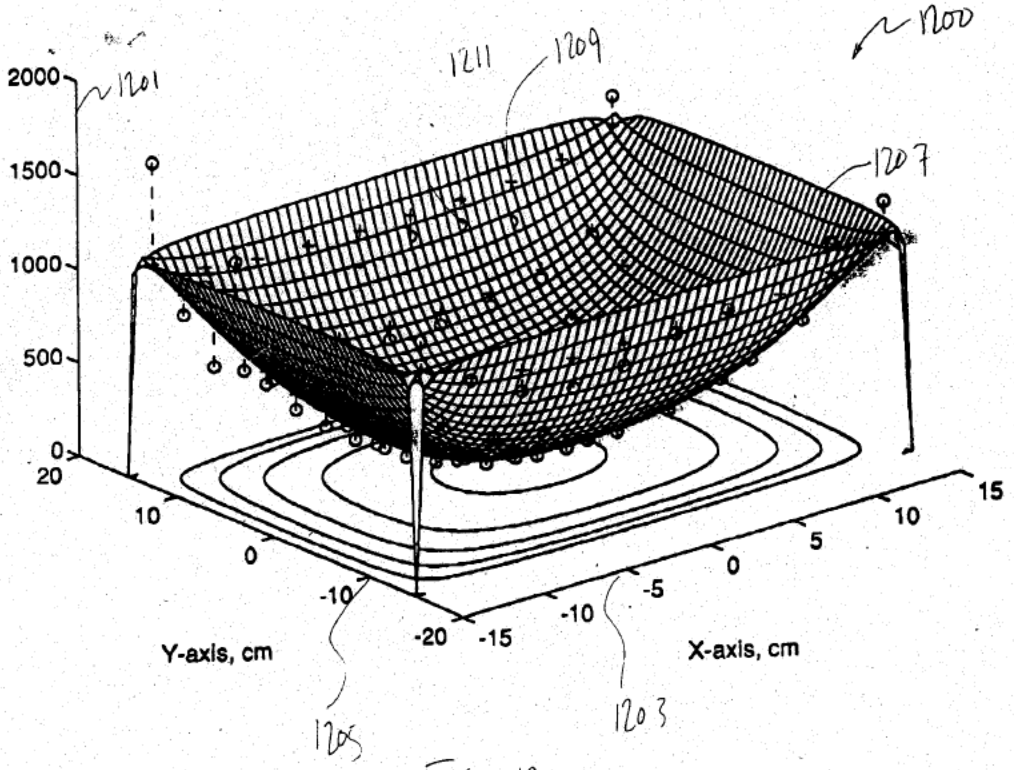

FIG. 12

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

#2

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

0000

DATE MAILED: 05/22/95

NOTICE TO FILE MISSING PARTS OF APPLICATION
FILING DATE GRANTED

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).

1. ☑ The statutory basic filing fee is: ☑ missing ☐ insufficient. Applicant as a ☑ large entity ☐ small entity, must submit $ 730 to complete the basic filing fee.
2. ☑ 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.
3. ☐ 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.
4. ☐ 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.
5. ☑ 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.
6. ☐ 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.
7. ☐ 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.
8. ☐ A $______________ processing fee is required since your check was returned without payment. (37 CFR 1.21(m)).
9. ☐ Your filing receipt was mailed in error because your check was returned without payment.
10. ☐ The application does not comply with the Sequence Rules. See attached Notice to Comply with Sequence Rules 37 CFR 1.821-1.825.
11. ☐ 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 <u>MUST</u> be returned with the response.

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JUN 27 1995
PAT. & TRADEMARK

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,
Attn: Application Processing Division
Special Processing and Correspondence Branch
Washington, D.C. 20231, on 6/20/95

By

PATENT

Attorney Docket No. 16655-1

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Daniel L. Flamm et al.

Serial No.: 08/433,623

Filed: May 3, 1995

For: PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

Examiner: Unassigned

Art Unit: Unassigned

TRANSMITTAL LETTER

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

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

MAIL ROOM
EXP
JUN 27 1995
PAT. & TRADEMARK OFF.

Attorney Docket No. 16655-1

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 applications(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.

3

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 1-00 **Flamm**	First Name **Daniel**	Middle Name or Initial **L.**	
Residence & Citizenship	City **Walnut Creek** CA	State/Foreign Country **California**	Country of Citizenship **U.S.A.**	
Post Office Address	Post Office Address **476 Green View Drive**	City **Walnut Creek**	State/Country **California**	Zip Code **94596**
Full Name of Inventor 2	Last Name 2-00 **Verboncoeur**	First Name **John**	Middle Name or Initial **P.**	
Residence & Citizenship	City **Hayward** CA	State/Foreign Country **California**	Country of Citizenship **U.S.A.**	
Post Office Address	Post Office Address **3350 Oakes Drive**	City **Hayward**	State/Country **California**	Zip Code **94542**
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 Daniel L. Flamm **Daniel L. Flamm**	Signature of Inventor 2 John P. Verboncoeur **John P. Verboncoeur**	Signature of Inventor 3
Date June 9, 1995	**Date** 06-12-95	**Date**

Attorney Docket No. 16655-1

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 applications(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: **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 **Flamm**	First Name **Daniel**	Middle Name or Initial **L.**	
Residence & Citizenship	City **Walnut Creek**	State/Foreign Country **California**	Country of Citizenship **U.S.A.**	
Post Office Address	Post Office Address **476 Green View Drive**	City **Walnut Creek**	State/Country **California**	Zip Code **94596**
Full Name of Inventor 2	Last Name **Verboncoeur**	First Name **John**	Middle Name or Initial **P.**	
Residence & Citizenship	City **Hayward**	State/Foreign Country **California**	Country of Citizenship **U.S.A.**	
Post Office Address	Post Office Address **3350 Oakes Drive**	City **Hayward**	State/Country **California**	Zip Code **94542**
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 Daniel L. Flamm **Daniel L. Flamm**	Signature of Inventor 2 **John P. Verboncoeur**	Signature of Inventor 3
Date June 9, 1995	**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

Appl[illegible]: 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.

NAME OF INVENTOR: DANIEL L. FLAMM	NAME OF INVENTOR:	NAME OF INVENTOR:
Daniel L. Flamm Signature of Inventor	Signature of Inventor	Signature of Inventor
Date June 9, 1995	Date:	Date:

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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.
☒ 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
☒ 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

☒ 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.

NAME OF INVENTOR: JOHN P. VERBONCOEUR	NAME OF INVENTOR:	NAME OF INVENTOR:
John P. Verboncoeur Signature of Inventor	Signature of Inventor	Signature of Inventor
Date 06-12-95	Date:	Date:

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JUN 27 1995
EXP 15
PAT. & TRADEMARK

H/M

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

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

#3

DATE MAILED: 0000
05/22/95

NOTICE TO FILE MISSING PARTS OF APPLICATION
FILING DATE GRANTED

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).

1. ☑ The statutory basic filing fee is: ☑ missing ☐ insufficient. Applicant as a ☑ large entity ☐ small entity, must submit $ 730 to complete the basic filing fee.

2. ☑ 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.

3. ☐ 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.

4. ☐ 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.

5. ☑ 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.

6. ☐ 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.

P 30125 07/24/95 08433623 20-1430 030 201 365.00CH
P 30126 07/24/95 08433623 20-1430 030 203 65.00CH
P 30127 07/24/95 08433623 20-1430 030 203 56.00CH

7. ☐ 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.

8. ☐ A $______ processing fee is required since your check was returned without payment. (37 CFR 1.21(m)).

9. ☐ Your filing receipt was mailed in error because your check was returned without payment.

10. ☐ The application does not comply with the Sequence Rules. See attached Notice to Comply with Sequence Rules 37 CFR 1.821-1.825.

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

11. ☐ 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.

FORM PTO-1533 (REV. 11-94)

COPY TO BE RETURNED WITH RESPONSE

Preliminary Amendment Ange! mdt 11X 10-20
An 1113

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

Atty. Docket No. 16655-000100

Date November 9, 1995

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

Serial No: 08/433,623

Filed: May 3, 1995

Group Art Unit:

For: PROCESS OPTIMIZATION IN 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: November 9, 1995

Aline Elzingre

ASSISTANT COMMISSIONER FOR PATENTS
Washington, D.C. 20231

Sir:

Transmitted herewith is a preliminary amendment in the above-identified application.
[X]Amendment.
[X]Small entity status of this application under 37 CFR 1.9 and 1.27 has been established by a verified statement previously submitted.
[X]Postcard.
The filing fee has been calculated as shown below:

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

[X] Claims fee $61.00
[X] 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
Reg. No.: 37,692
Attorneys for Applicant

rto\work\16655\1-pam.trn

Gp 110

8/13

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: Diane Elzinga

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 GAS PHASE DRY ETCHING	<u>PRELIMINARY AMENDMENT</u>

4/a

ASSISTANT COMMISSIONER FOR PATENTS
Washington, D.C. 20231

Sir:

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

<u>IN THE CLAIMS</u>:

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:

Sub B1

~~1. (Amended)~~ [An integrated circuit] <u>A</u> ~~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;~~

A

~~chemical etching said top film surface to de~~fine 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 B3

~~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.

13

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\16655\1-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
ANGEBRANDT, M

11M1/0306

RICHARD T OGAWA
TOWNSEND AND TOWNSEND KHOURIE AND CREW
STEUART 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 apppears 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

PTOL-326 (Rev. 2/93)

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.

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 negatived 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 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 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 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) 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)

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.

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

'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.

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 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) 308-2417.

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
Patent Examiner, Group 1100
March 4, 1996

SUBSTITUTE PTO-892 U. S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **NOTICE OF REFERENCES CITED**	SERIAL NO. 08/433623	GROUP ART UNIT 1113	ATTACHMENT TO PAPER NUMBER	5
	APPLICANT(S) Flamm et al.			

U.S. PATENT DOCUMENTS

*		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						

FOREIGN PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. DWG	PERTINENT PP. SPEC.
	L								
	M								
	N								
	O								
	P								
	Q								

OTHER REFERENCES (Including Author, Title, Date, Pertinent Pages, Etc.)

*		
	R	Thompson et al. "Introduction to Microlithography" © 1983 ACS pp 228-235.
		Giapis et al. Appl. Phys Lett 57(10) 983-985 (9/1990)
	S	Gregus et al. Plasma Chem. Plasma Process. 13(3) 521-537 (1993)
		Babanov et al. Plasma Chem. Plasma Process. 13(1) 37-59 (1993)
	T	Ha et al. Plasma Chem. Plasma Process. 11(2) 311-321 (1991)
		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	DATE 3/4/96	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

MAIL ROOM
FEB 22 1996
PAT. & TRADEMARK OFFICE

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
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:

[X] 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. Og

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,
on February 16, '96

TOWNSEND and TOWNSEND and CREW

By Michael A. Miranda

1113 C 3-7-96

#6/B6 3/21/96

~~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 A GAS PHASE DRY ETCHING

Examiner: T. Lee

Art Unit: ~~1100~~

INFORMATION DISCLOSURE STATEMENT UNDER 37 CFR §1.97 and §1.98

Assistant Commissioner for Patents
Washington, D.C. 20231

Sir:

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

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

H:\HOME\MAM\16655\1.IDS

FORM PTO-1449 (Modified) LIST OF PATENTS AND PUBLICATIONS FOR APPLICANT'S INFORMATION DISCLOSURE STATEMENT (Use several sheets if necessary)	Attorney Docket No. 16655-000100	Serial No.: 08/433,623
	Applicant: DANIEL L. FLAMM et al.	
	Filing Date: 05/03/95	Group: ~~1109~~ 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.)

AR	Bird et al., Transport Phenomena, 1960, John Wiley & Sons, pg. 510.
AS	Manos, D. M. and Flamm, D. L., Plasma Etchings, An In~~d~~troduction, 1989, Academic Press, (title page and table of contents. only)
___ AT	

EXAMINER DATE CONSIDERED 1/4/97

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.

1449.WP 4/95

Amendment Transmittal

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

Atty. Docket No. [illegible]55-000100

Date 9/6/96

MAIL ROOM
SEP 10 1996
38
PAT. & TRADEMARK OFF.

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

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

ASSISTANT COMMISSIONER FOR PATENTS
Washington, D.C. 20231

Sir:

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

[X] Amendment.
[X] Petition to Extend Time.
[X] Small entity status of this application under 37 CFR 1.9 and 1.27 has been established by a verified statement previously submitted.
[X] 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	*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	OR	+250=	$
					TOTAL ADDIT. FEE	$230.00		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:

[X] Claims fee $230.00
[X] Any additional fees associated with this paper or during the pendency of this application.

360 IL 20-1430 10/03/96 08433623
36199 203
36200 202 39.00CH
36201 204 125.00CH

2 extra copies of this sheet are enclosed.

TOWNSEND and TOWNSEND and CREW LLP

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

16655\1-oa1.trn

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 9/6/96

TOWNSEND and TOWNSEND and CREW LLP

By Richard T. Ogawa

MAIL ROOM
SEP 10 1996
PAT. & TRADEMARK OFF.

1113
#7/Ext. of time
3 mos. PATENT

Attorney Docket No. 16655-000100

M. Watts
10/9/96

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

Examiner: M. Angebrandt

Art Unit: 1113

RECEIVED
OCT 8 1996
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
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
RTO:de
rto\work\16655\1-ext.tme

360 TL 20-1430 10/03/96 08433623
36198 217 450.00CH 16655-000100

1113

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 9/6/96

TOWNSEND and TOWNSEND and CREW LLP

By

MAIL ROOM
SEP 10 1996
38
PAT. & TRADEMARK OFF.

PATENT

Attorney Docket No. 16655-000100

#8/Amdt B
M. Watts
11/9/96

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

<u>AMENDMENT UNDER 37 CFR §1.115</u>

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.

B1
Sub C1

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;

B

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.

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

34

Sub C4

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

14 ~~13~~. (Amended) The method of claim 10 ~~9~~ 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.

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

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

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B5

~~16~~ 17. (Amended) The method of claim **[9]** ~~15~~ 16 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

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

25 ~~23~~. (Amended) The method of claim 22 ~~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~~

Sub 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

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

37

21 ~~28~~. (New) The method of claims 1, 10 ~~9~~, or 20 ~~19~~ wherein said etching is provided whereupon chemical effects are enhanced over ion bombardment effects.

B9
Sub C9

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 <u>not</u> 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

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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 <u>surface reaction rate constant</u> 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 <u>required</u> 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 fabriating 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.

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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APPLICATION NUMBER	FILING DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET NO.
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EXAMINER
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11M1/0124

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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 2/22/96 & 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 --

PTOL-326 (Rev. 10/95)

★ U.S. GPO: 1996-410-238/40050

15 The reponses 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 availible 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

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 disimilar processes renderig 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

> 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 negatived 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.

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 proecess 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 preform the calculations disclosed by Thompson "Introduction to Microlithography" in the process disclosed by Mogab '665 for the different etching apparatus/conditions to preform diagnistics which describe the physical processes occuring within the plasma etching apparatus thereby allowing for optimization of the parameters for a particular etch process with a reasonable expectation of success.

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).

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 unifomity 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 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 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
January 21, 1997

SUBSTITUTE PTO-892 U. S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE **NOTICE OF REFERENCES CITED**	SERIAL NO. **08/433623**	GROUP ART UNIT **1113**	ATTACHMENT TO PAPER NUMBER	**9**
	APPLICANT(S) **Flamm et al.**			

U.S. PATENT DOCUMENTS

*		DOCUMENT NO.	DATE	NAME	CLASS	SUB-CLASS	FILING DATE IF APPROPRIATE
	A						
	B						
	C						
	D						
	E						
	F						
	G						
	H						
	I						
	J						
	K						

FOREIGN PATENT DOCUMENTS

		DOCUMENT NO.	DATE	COUNTRY	NAME	CLASS	SUB-CLASS	PERTINENT SHTS. DWG	PERTINENT PP. SPEC.
	L								
	M								
	N								
	O								
	P								
	Q								

OTHER REFERENCES (Including Author, Title, Date, Pertinent Pages, Etc.)

	R	**Manos et al. "Plasma Etching, An Introduction", © 1989, Academic Press, pp 91-183.**
	S	
	T	
	U	

EXAMINER	DATE	
	1/19/97	**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).)

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.

Serial No: 08/433,623

Filed: May 3, 1995

Group Art Unit: 1113

For: PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

MAIL ROOM
MAY 19 1997
PAT. & TRADEMARK OFF.

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: 5/13/97

Kristina Alvarez

Kristina Alvarez

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

RECEIVED
JUN 4 1997
GROUP 1100

Sir:

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

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=	$	OR	+250=	$
					TOTAL ADDIT. FEE	$		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.

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

[X]	Petition to Extend Time (1-mo)	$55.00
[X]	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
Reg. No.: 37,692
Attorneys for Applicant

16655\1-.TR2

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 Kristina Chao

MAIL R
MAY 19 1997
PAT. & TRADEMARK OFF.

10/ 6/4

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)

RECEIVED
JUN 4 1997
GROUP 1100

BOX FEE AMENDMENT
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 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,

Richard T. Ogawa
Reg. No. 37,692

Dated: 5/13/97

TOWNSEND and TOWNSEND and CREW LLP
Two Embarcadero Center, 8th Floor
San Francisco, California 94111-3834
(415) 326-2400
RTO:ka
rto\work\16655\1-ext.tm2

06/03/1997 LCHALMER 00000023 DA#:201430 08433623
Sale Ref: 00000023 DA#: 201430 08433623
01 FC: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

MAIL ROOM
MAY 19 1997
PAT. & TRADEMARK OFF.

PATENT

Attorney Docket No. 16655-000100

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

RECEIVED
JUN 4 1997
GROUP 1100

Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Sirs:

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

OK to Enter
MA
6/6/97

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.

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

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.

40

34

10 ~~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.

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

35

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

13 ~~12~~. (Amended) The method of claim 10 ~~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]**.

22 ~~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.

C7

26 ~~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.

C8

27 ~~26~~. (Amended) The process of claim 26 ~~25~~ wherein said surface reaction rate constant is derived **[from]** using at least a diffusivity value that is determined by an equation.

13

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 ~~25~~ 26 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 Angebranndt 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

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

414

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_{loss} is generally not know, and is likely to be difficult to obtain. Moreover, the etching rate constant K_{etch} is also not know. Accordingly, the loading effect equation has at least three variables including k_{etch}, k_{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 procesing 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 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
Fax (415) 326-2422

RTO:de

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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

DATE MAILED: 06/10/97

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

PTOL-37 (REV. 4-89) ★

USCOMM-DC 89-3789

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 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

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 INVENTION: PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

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:

I. Review the SMALL ENTITY status shown above.
If the SMALL ENTITY is shown as yes, verify your current SMALL ENTITY status:

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

B. If the status is the same, pay the FEE DUE shown above.

If the SMALL ENTITY is shown as NO:

A. Pay FEE DUE shown above, or

B. File verified statementof Small Entity Status before, or with, payment of 1/2 the FEE DUE shown above.

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.

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.

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

PTOL-85 (REV. 05-96)(0651-0033)

*U.S. GPO: 1996-404-496/40511

TRANSMITTAL LETTER

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

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

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
Diane Elzinga

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.

[X] A fee in the amount of $645.00 is due.

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TOWNSEND and TOWNSEND and CREW LLP

Richard T. Og

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

16655\1-issfee.trn

#13
Bny

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Assistant Commissioner of Patents and Trademarks,
Washington, D.C. 20231, on September 9, 1997

By Diane Elzinga

PATENT

Attorney Docket No. 16655-000100

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Daniel L. Flamm, et al.

Serial No.: 08/433,623

Filed: May 3, 1995

For: PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

Examiner: M. Angebranndt

Art Unit: 1113

Batch No.: N95

LETTER TO OFFICIAL DRAFTSPERSON

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
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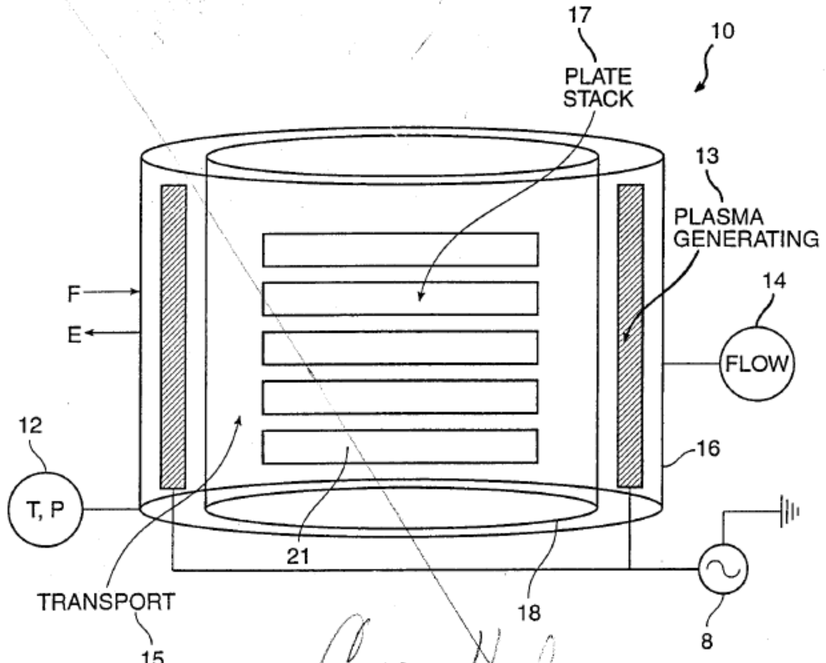

FIG. 1

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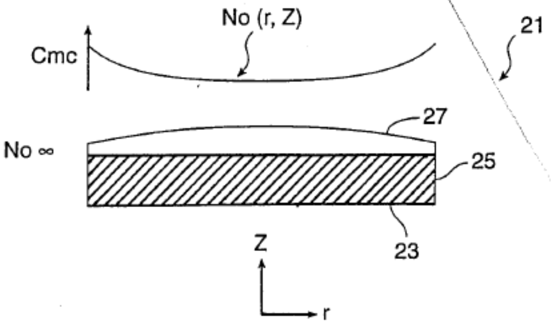


FIG. 1A

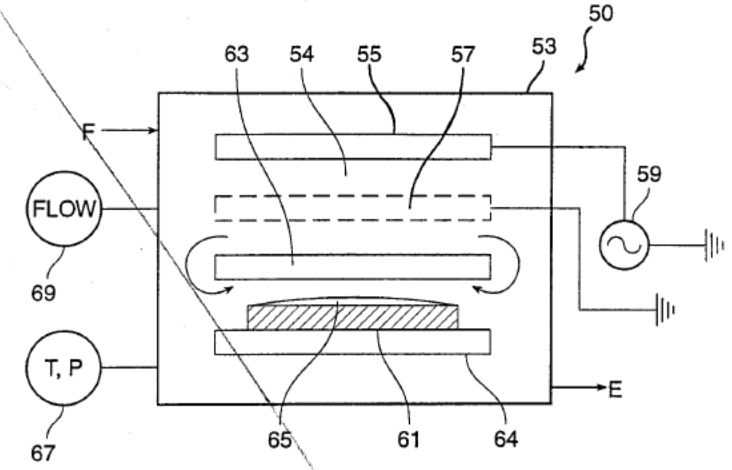


FIG. 2

Canceled

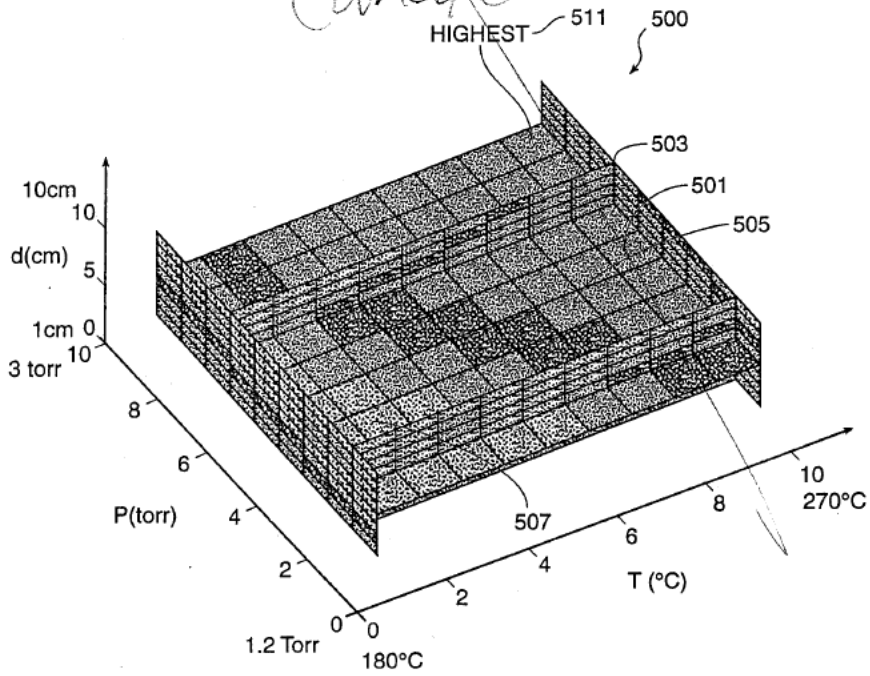
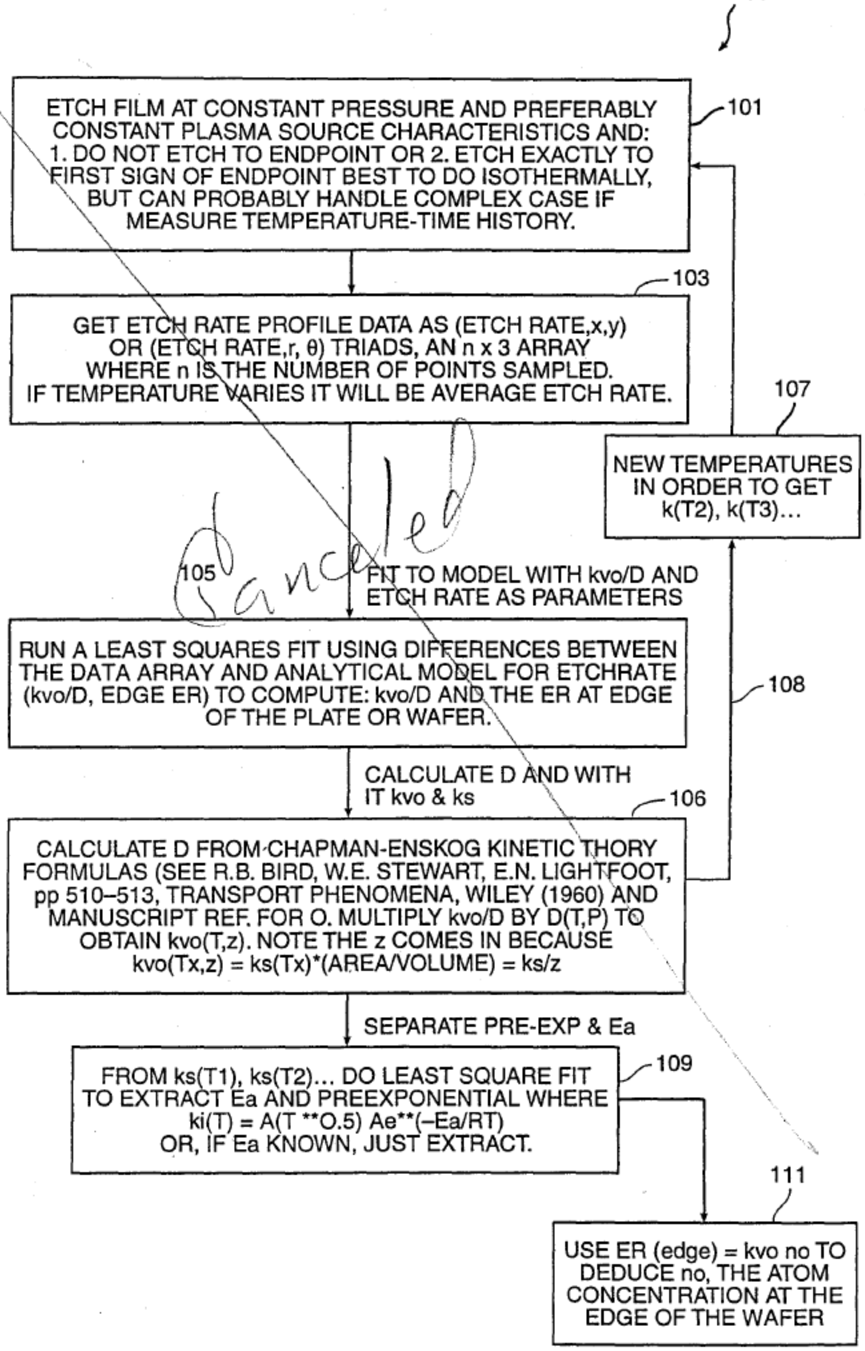


FIG. 5A



Cancelled

FIG. 3

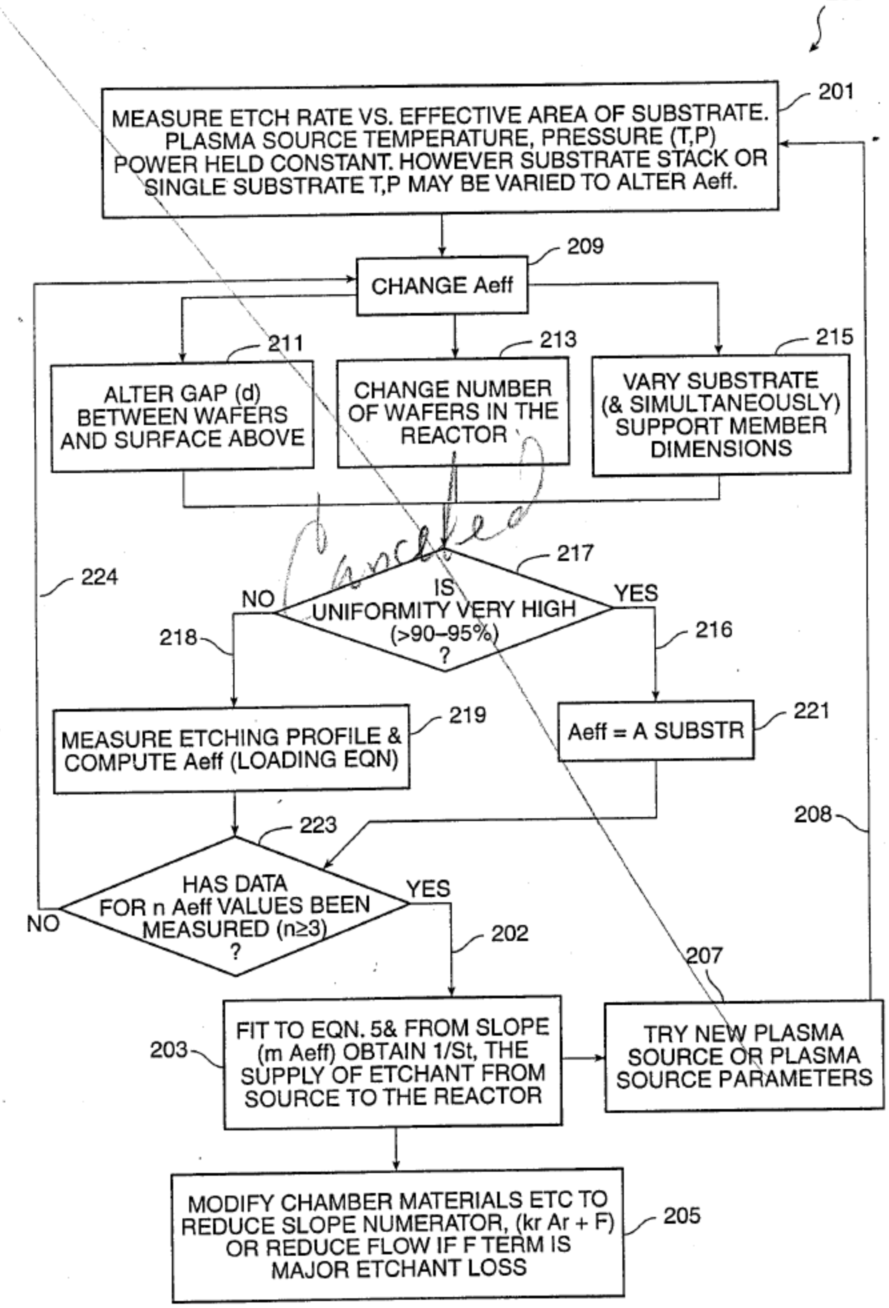


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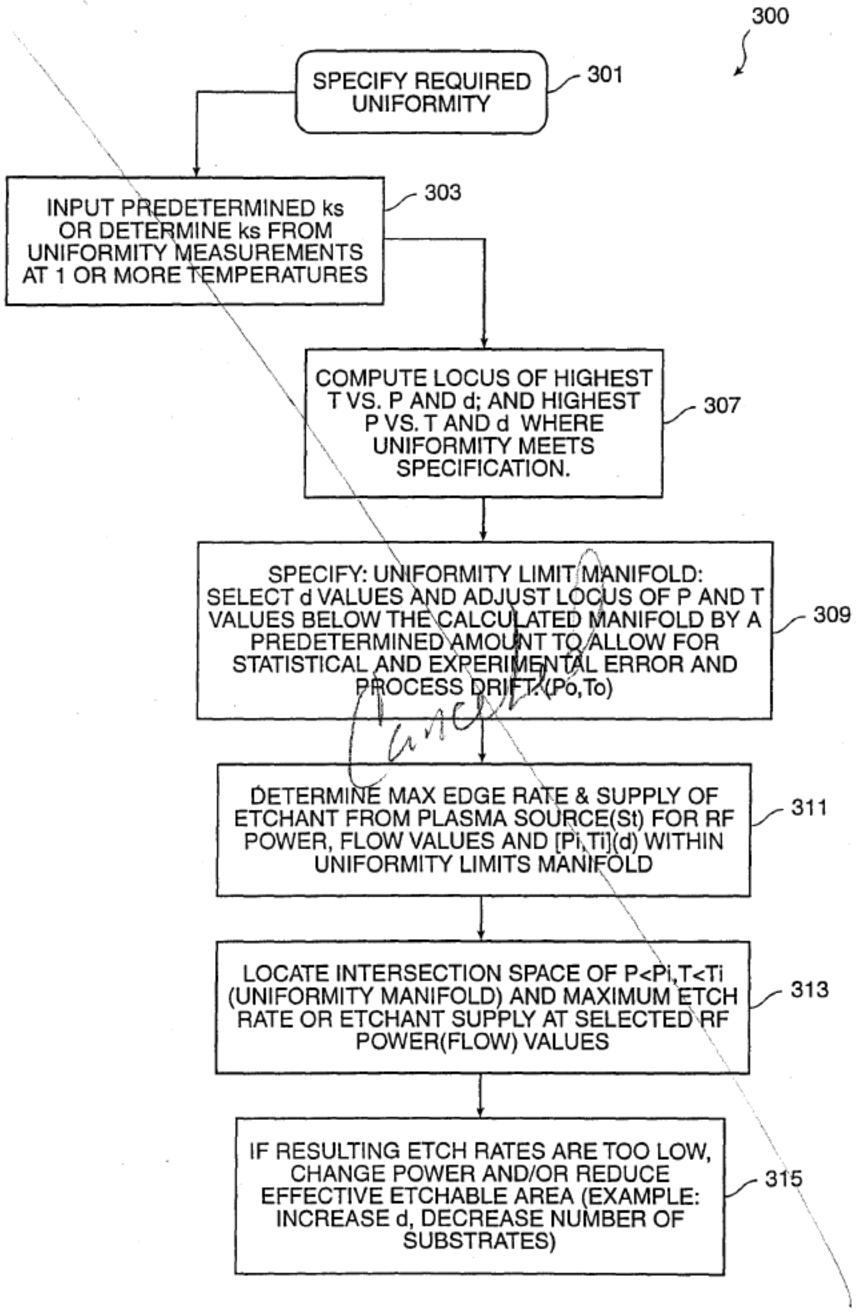
FIG. 4


300
SPECIFY REQUIRED UNIFORMITY
301
INPUT PREDETERMINED ks OR DETERMINE ks FROM UNIFORMITY MEASUREMENTS AT 1 OR MORE TEMPERATURES
303
COMPUTE LOCUS OF HIGHEST T VS. P AND d; AND HIGHEST P VS. T AND d WHERE UNIFORMITY MEETS SPECIFICATION.
307
SPECIFY: UNIFORMITY LIMIT MANIFOLD: SELECT d VALUES AND ADJUST LOCUS OF P AND T VALUES BELOW THE CALCULATED MANIFOLD BY A PREDETERMINED AMOUNT TO ALLOW FOR STATISTICAL AND EXPERIMENTAL ERROR AND PROCESS DRIFT. (Po,To)
309
DETERMINE MAX EDGE RATE & SUPPLY OF ETCHANT FROM PLASMA SOURCE(St) FOR RF POWER, FLOW VALUES AND [Pi,Ti](d) WITHIN UNIFORMITY LIMITS MANIFOLD
311
LOCATE INTERSECTION SPACE OF P<Pi,T<Ti (UNIFORMITY MANIFOLD) AND MAXIMUM ETCH RATE OR ETCHANT SUPPLY AT SELECTED RF POWER(FLOW) VALUES
313
IF RESULTING ETCH RATES ARE TOO LOW, CHANGE POWER AND/OR REDUCE EFFECTIVE ETCHABLE AREA (EXAMPLE: INCREASE d, DECREASE NUMBER OF SUBSTRATES)
315

Cancel

FIG. 5

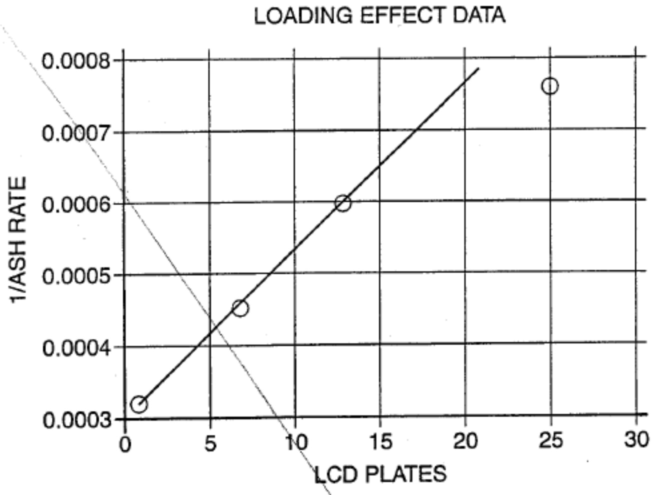


FIG. 6

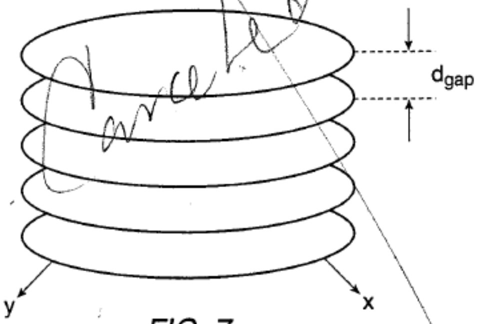


FIG. 7

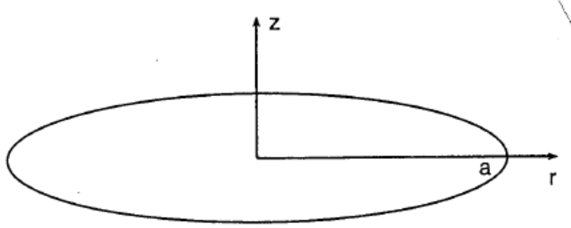


FIG. 8

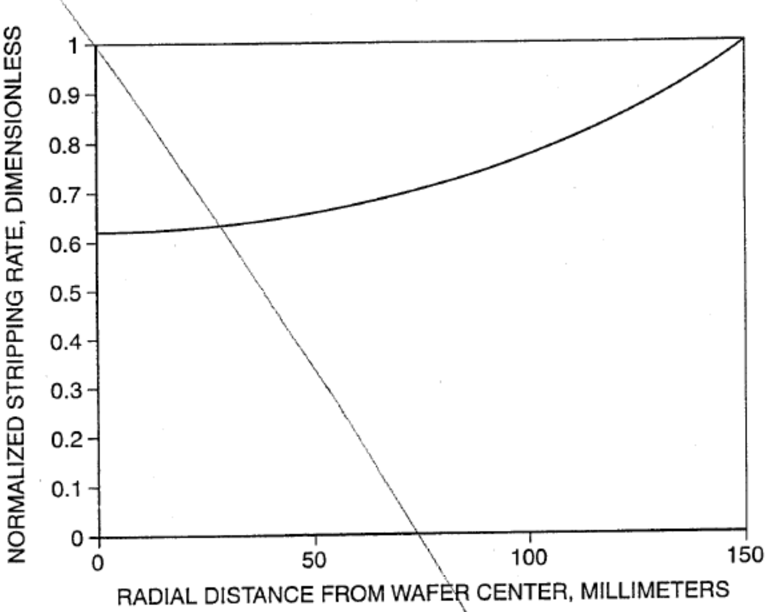


FIG. 9

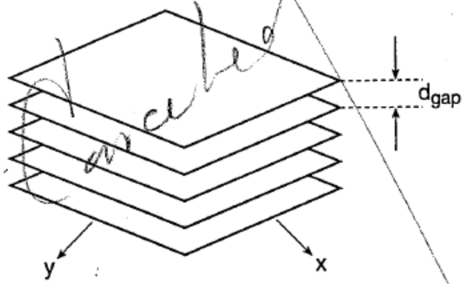


FIG. 10

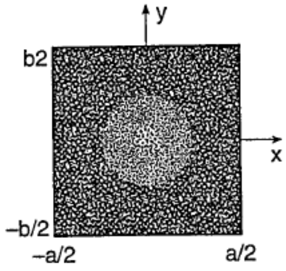


FIG. 11

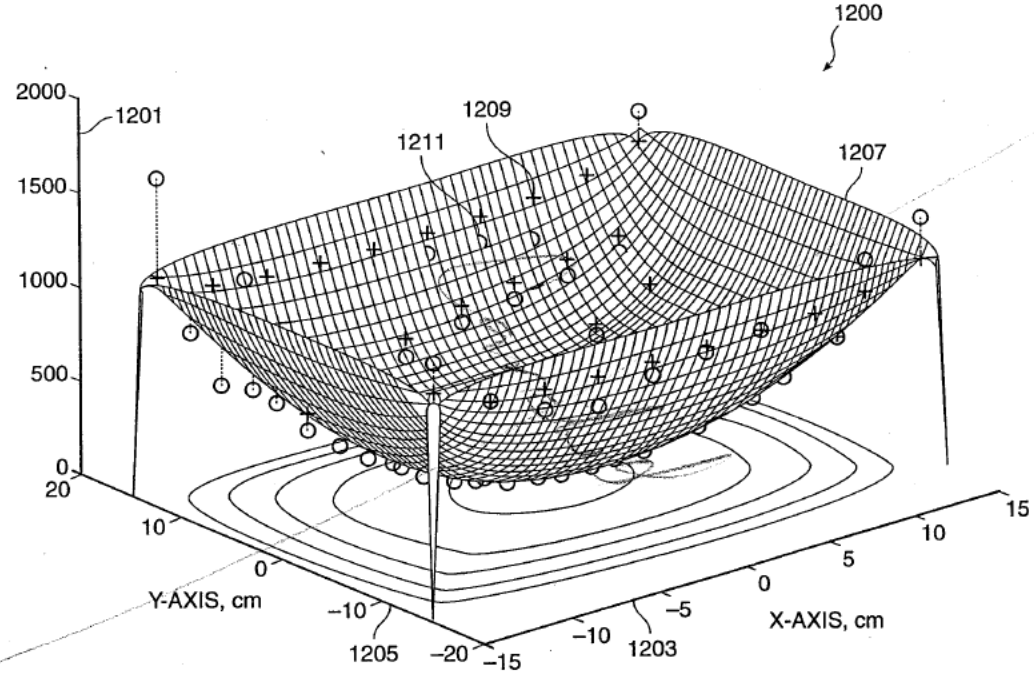

1200
2000
1500
1000
500
0
1201
1211
1209
1207
20
10
0
Y-AXIS, cm
−10
1205
−20
−15
−10
1203
−5
0
5
10
15
X-AXIS, cm

FIG. 12

PART B—ISSUE FEE TRANSMITT

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Street Address
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CO-INVENTOR'S NAME
Street Address
City, State and Zip Code
☐ Check if additional changes are enclosed

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

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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 INVENTION PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

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)

Townsend and Townsend and Crew LLP
Two Embarcadero Center, 8th Floor
San Francisco, CA 94111-3834

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.

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 perviously submitted to the PTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

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☒ 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.

(Authorized Signature) (Date) 9/9/97
Richard T. Ogawa, Reg. No. 37,692

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Washington, D.C. 20231

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

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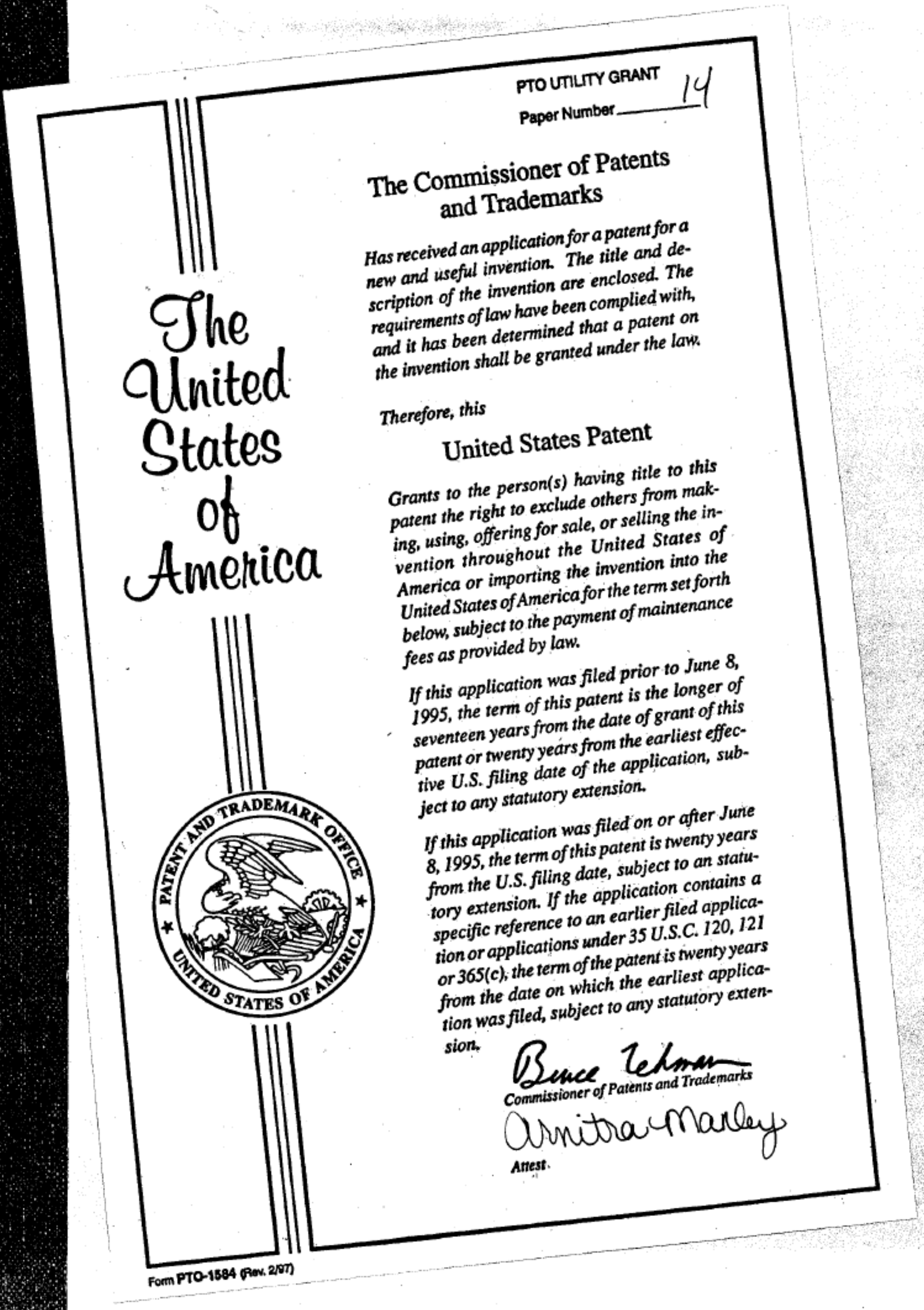
Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

[redacted]



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 any 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.

Bruce Lehman
Commissioner of Patents and Trademarks

Arnitra Marley
Attest

The United States of America

Form PTO-1584 (Rev. 2/97)

(RIGHT INSIDE)

7560 GAU 1113

Amendment Transmittal

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

Atty. Docket No. 55-000100 $

OIPE
OCT 2 7 1997
C30
PATENT & TRADEMARK OFFICE

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

Serial No. 08/4[illegible]3,623

Filed: May [illegible], 1995

Group Art Unit: 1113

For: PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING

Express Mail Label No.: EM140585555US

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Date: 10/27/97

J. Liebeschuetz

and I also hereby certify that this correspondence is being sent by facsimile transmission to:
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Fax No: 1-703-305-359
Assistant Commissioner for Patents, Washington, D.C. 20231, on 10/27/97

By Diane Elgrige

ASSISTANT COMMISSIONER FOR PATENTS
Washington, D.C. 20231

Sir:

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

[X] Amendment After Payment of Issue Fee Under 37 CFR 1.312(b).
[X] Petition for Amendment After Payment of Issue Fee Under 37 CFR 1.312(b).
[X] 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	OR	+250=	$
					TOTAL ADDIT. FEE	$0.00		TOTAL	$

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

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*** 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. Aka
Gary T. Aka
Reg. No.: 29,038
Attorneys for Applicant

16655\1-312.trn

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on 10/27/97
Express Mail Label No. EM140585555US
TOWNSEND and TOWNSEND and CREW LLP
By______

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

<u>PATENT</u>

Attorney Docket No. 16655-000100

15/1/8/4

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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

Assistant Commissioner for Patents
Washington, D.C. 20231

OK to Enter
MA
12/4/97

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.

12/04/1997 TSTOKES 00000120 DA#:201430 08433623
01 FC:122 130.00 CH

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

Gary T. Aka
Reg. No. 29,038

TOWNSEND and TOWNSEND and CREW LLP
Two Embarcadero Center, 8th Floor
San Francisco, California 94111-3834
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Group Director - Theodore Morris
Fax No: 1-703-305-3599
Assistant Commissioner for Patents, Washington, D.C. 20231, on 10/27/97
By

PATENT

Attorney Docket No. 16655-000100

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 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 --,--.

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 "ϖ".

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 --; and I_o is a modified Bessel function of the first kind--.

B1

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_o" and insert --R_{os}--; please delete "k_{vo}" and insert --k_s--.

At page 11, line 25, please delete "R_o" 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_o" and insert --R_{os}--.

At page 13, line 11, please delete "R_o" 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 --

$$[1-\frac{R_{MAX}-R_{MIN}}{2\sum_{i=1}^{m} \frac{R_i}{m}}]$$ --.

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_o" and insert --R_{os}--.

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_w" and insert --A_{eff}--.

At page 19, line 9, before etching rates, please insert --when etching uniformity is high the--.

At page 19, line 16, please delete "k_e" and insert --k_s--.

At page 19, in the equation after line 20, please delete "k_o" and insert --k_s--.

At page 19, in the equation after line 20, please delete "A_w" and insert --A_{eff}--.

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 $D\nabla n_o$ and insert --)-- after $D\nabla n_o$.

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_d/n_{o0}--.

At page 23, line 9, please delete "9" and insert --10--.

At page 23, line 26, please delete "where λ_x is given by".

At page 24, between the first and second equation on the page, please insert --where λ_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, "*St*" is replaced by "S^T". 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 replace with "one". As discussed with respect to Fig. 4, in box 309, "*St*" is replaced by "S^T". 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 $k_i(T)$ 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, "St" is replaced by "S^T" 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.

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 show 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

Gary T. Aka
Reg. No. 29,038

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16655-1

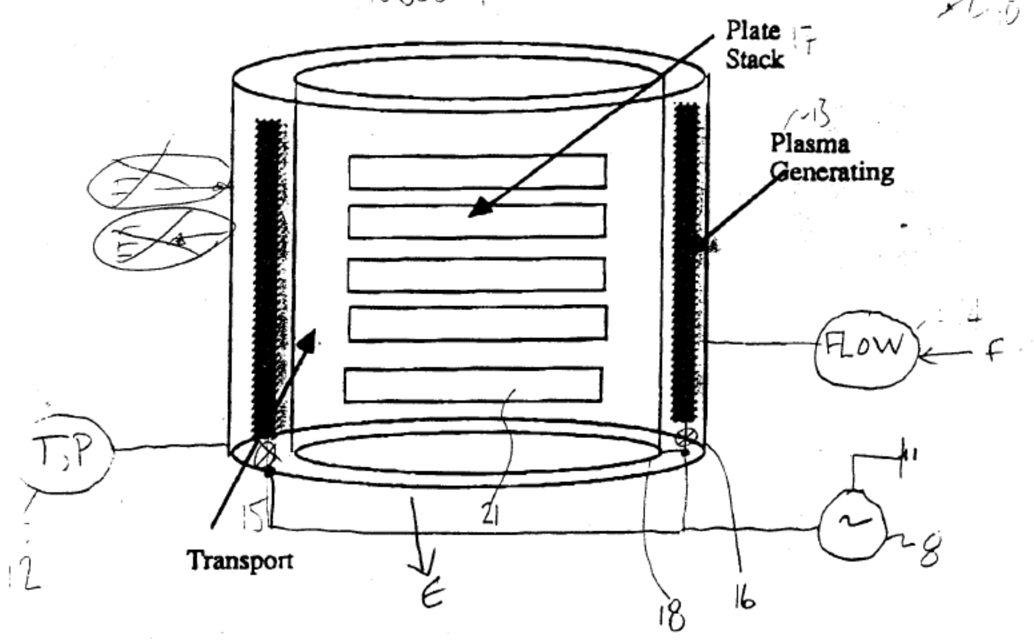


FIG. 1

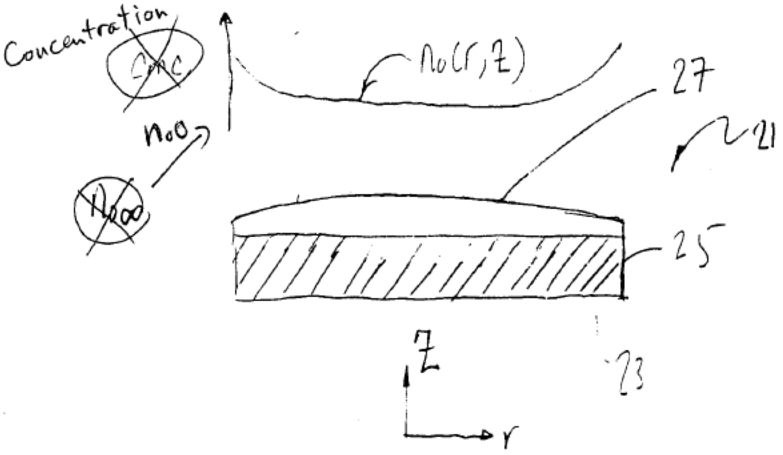


FIG. 1A

0055-1

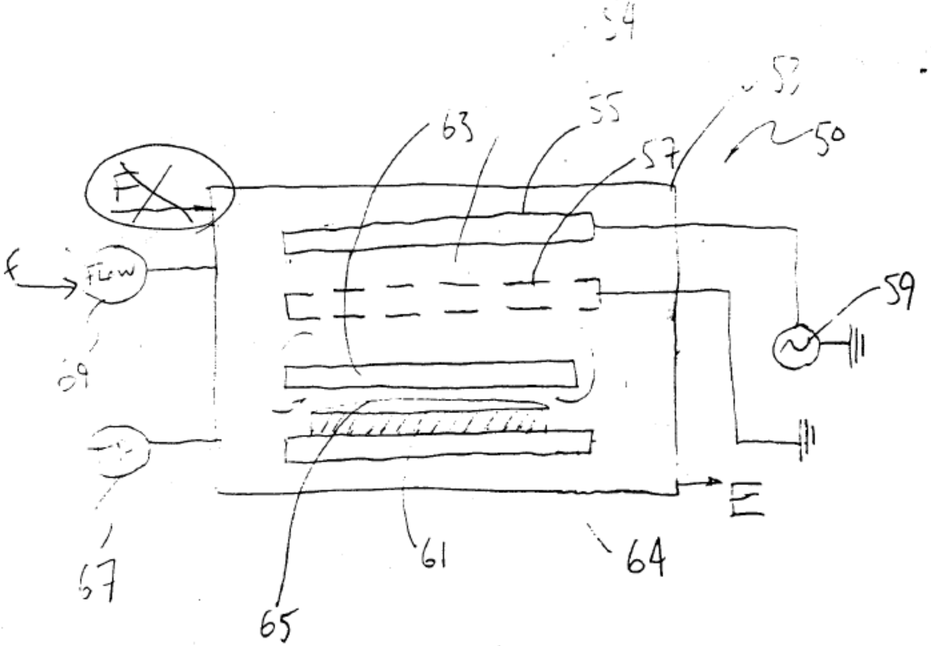


FIG. 2

16655-1

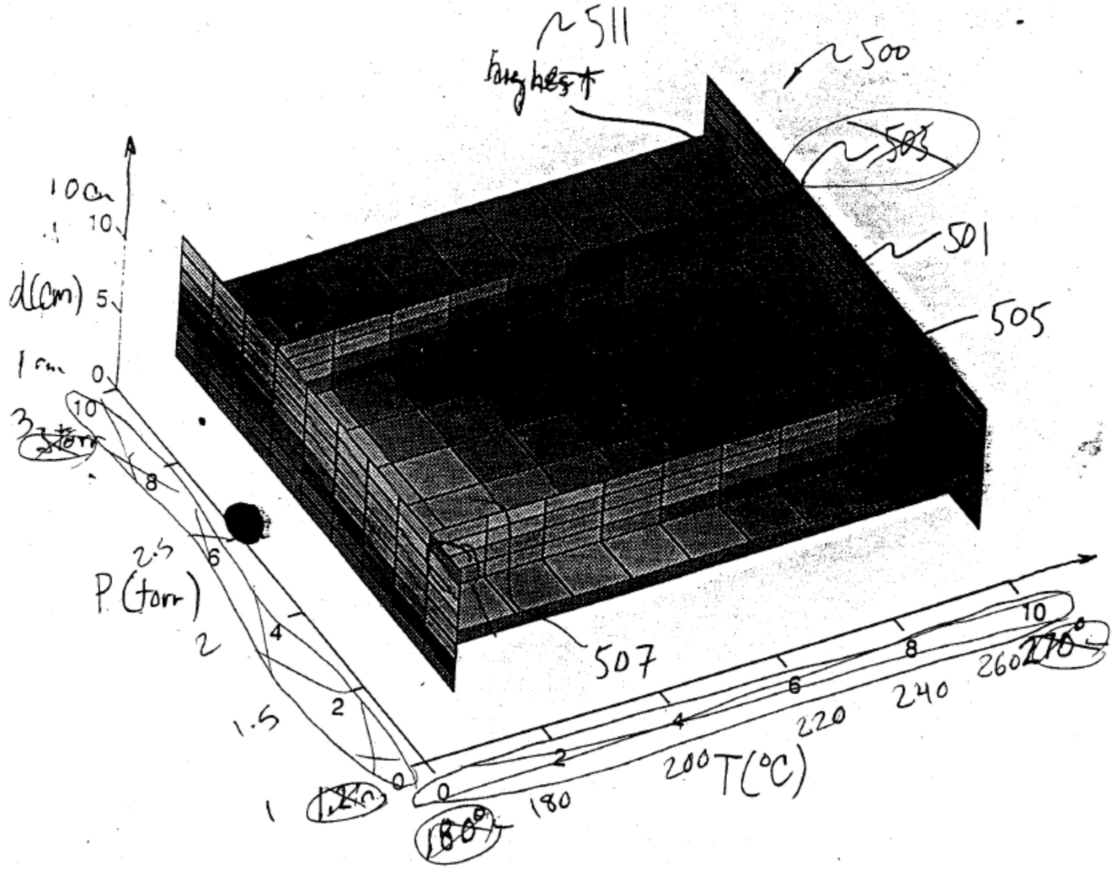


FIG. 5A

16655-1

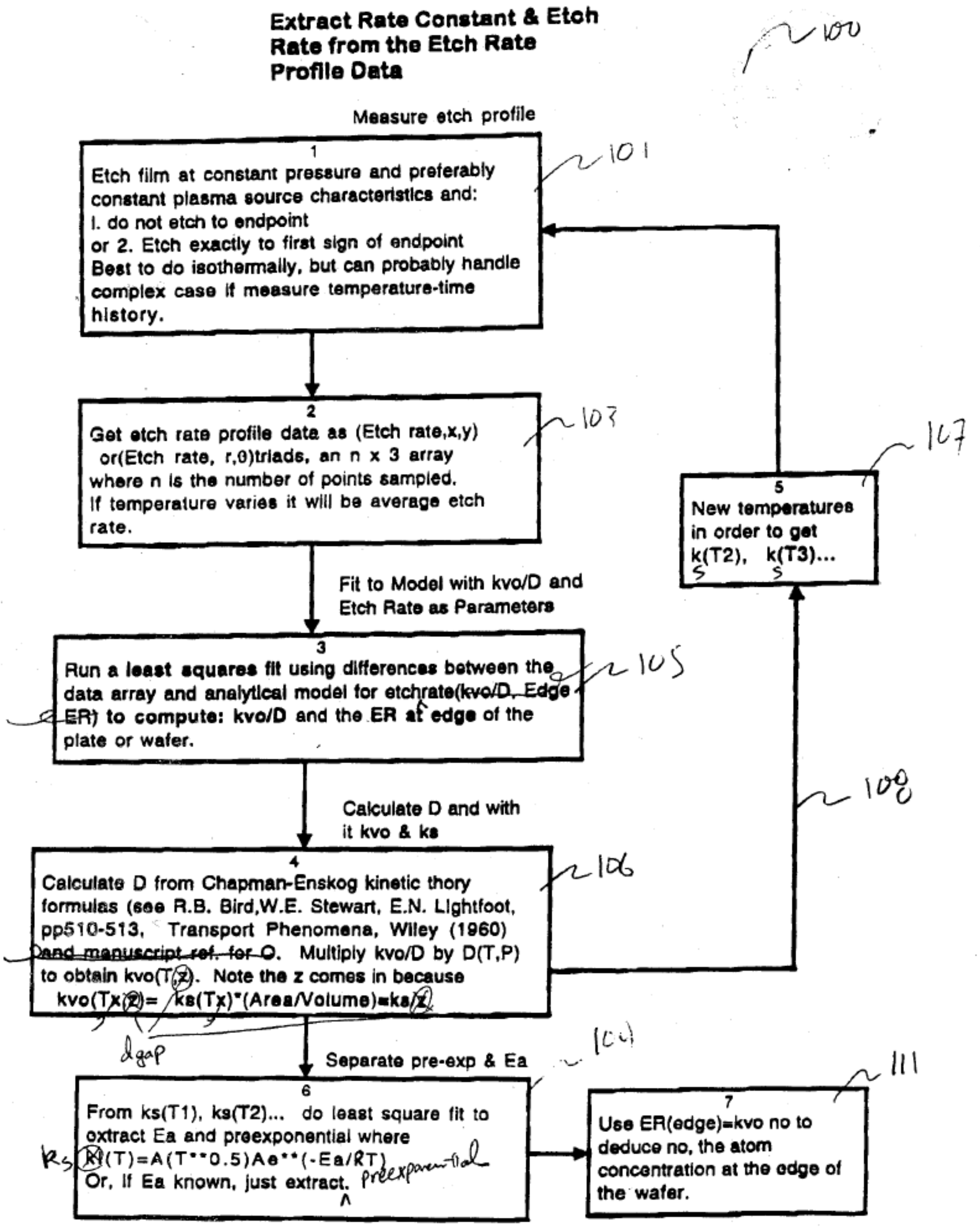
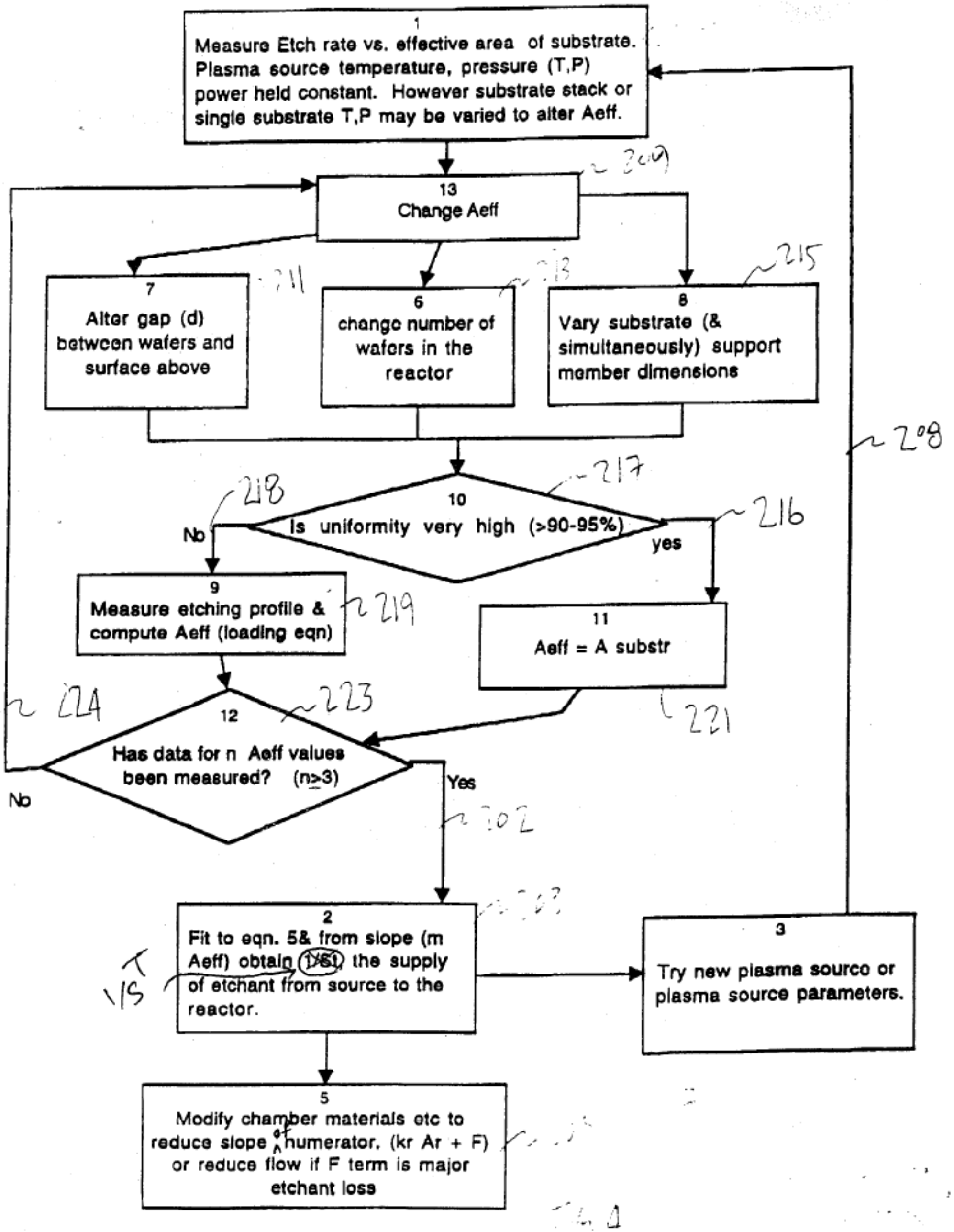

Extract Rate Constant & Etch Rate from the Etch Rate Profile Data
100
Measure etch profile
1
Etch film at constant pressure and preferably constant plasma source characteristics and:
I. do not etch to endpoint
or 2. Etch exactly to first sign of endpoint
Best to do isothermally, but can probably handle complex case if measure temperature-time history.
101
2
Get etch rate profile data as (Etch rate,x,y) or(Etch rate, r,θ)triads, an n x 3 array where n is the number of points sampled.
If temperature varies it will be average etch rate.
103
Fit to Model with kvo/D and Etch Rate as Parameters
3
Run a least squares fit using differences between the data array and analytical model for etchrate(~~kvo/D, Edge ER~~) to compute: kvo/D and the ER at edge of the plate or wafer.
105
Calculate D and with it kvo & ks
4
Calculate D from Chapman-Enskog kinetic thory formulas (see R.B. Bird,W.E. Stewart, E.N. Lightfoot, pp510-513, Transport Phenomena, Wiley (1960) ~~and manuscript ref. for O~~. Multiply kvo/D by D(T,P) to obtain kvo(T,z). Note the z comes in because
kvo(Tx,z)= ks(Tx)*(Area/Volume)=ks/z
s s
dgap
106
5
New temperatures in order to get
k(T2), k(T3)...
s s
107
108
Separate pre-exp & Ea
109
6
From ks(T1), ks(T2)... do least square fit to extract Ea and preexponential where
ks k(T)=A(T**0.5)Ae**(-Ea/RT)
Or, If Ea known, just extract. preexponential
7
Use ER(edge)=kvo no to deduce no, the atom concentration at the edge of the wafer.
111

FIG. 3

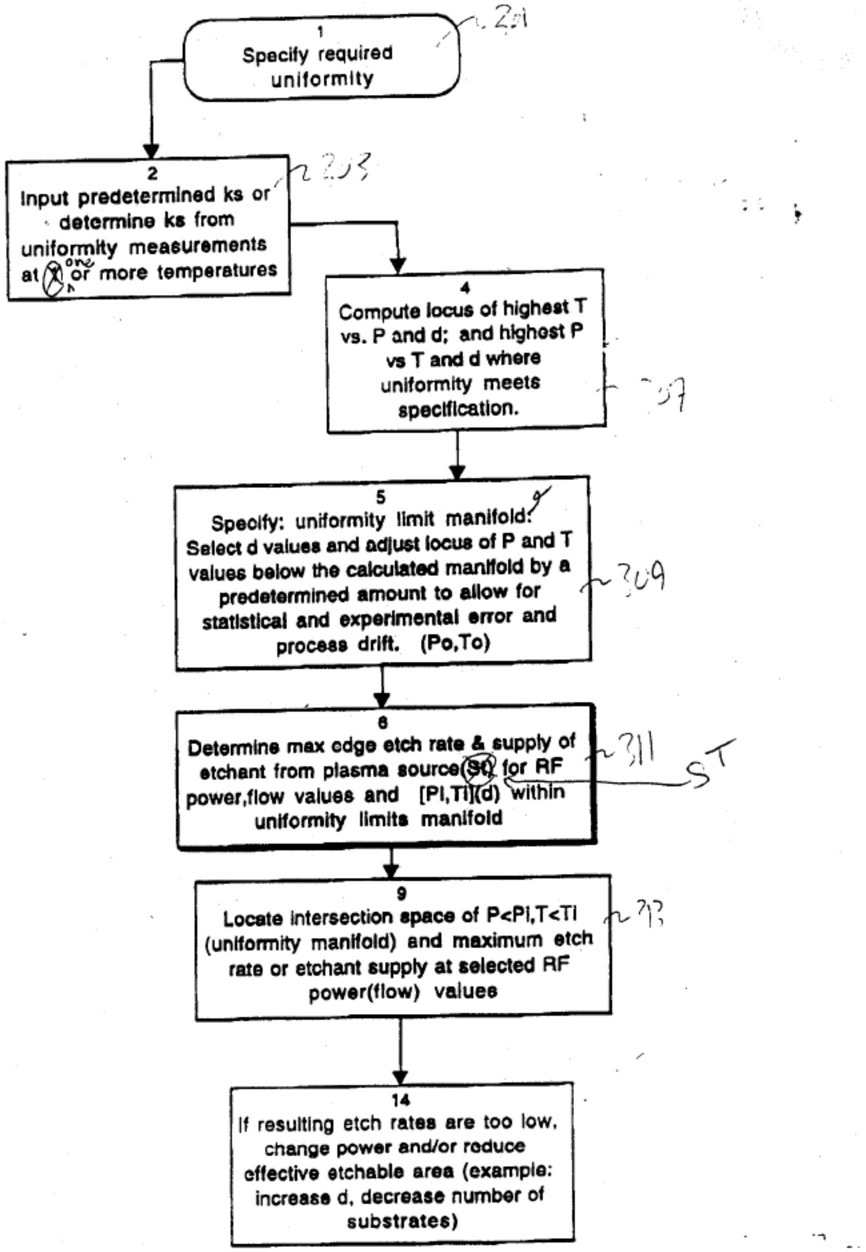
16655-1

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

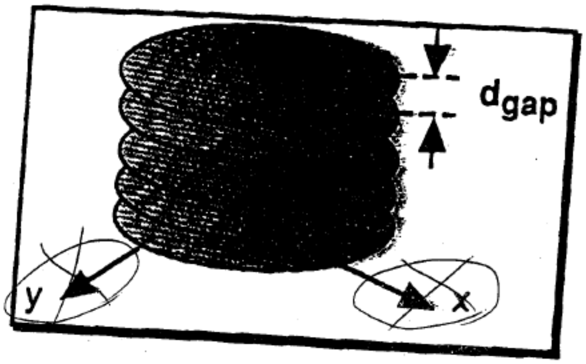


FIG. 7

433623

5711849 9

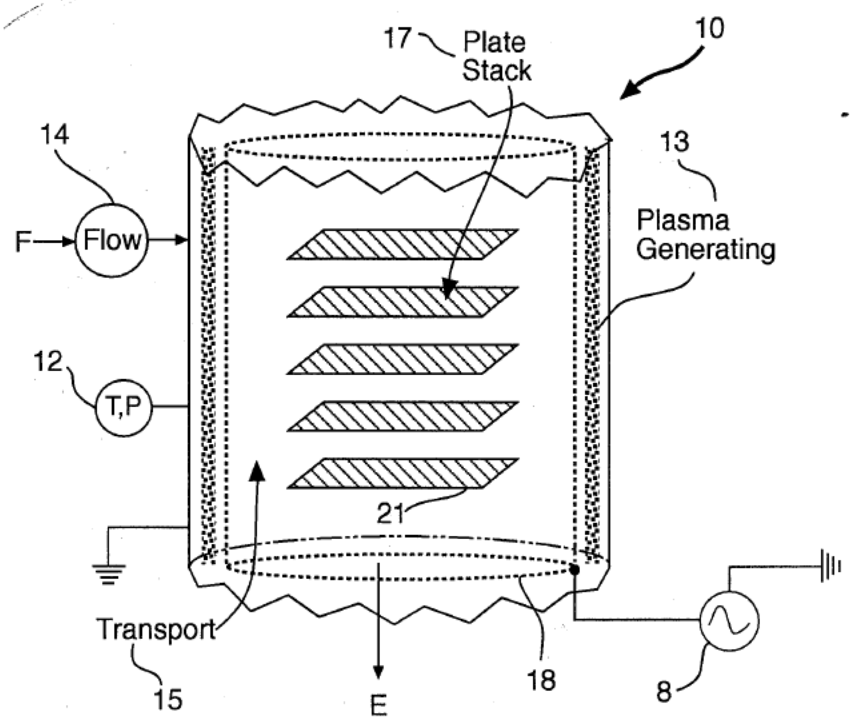


FIG. 1

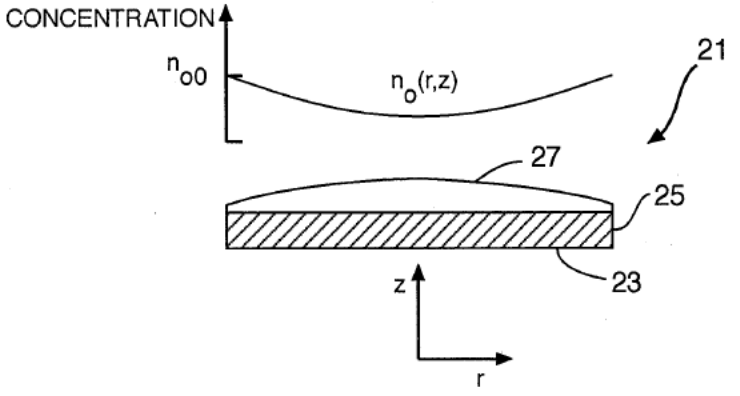


FIG. 1A

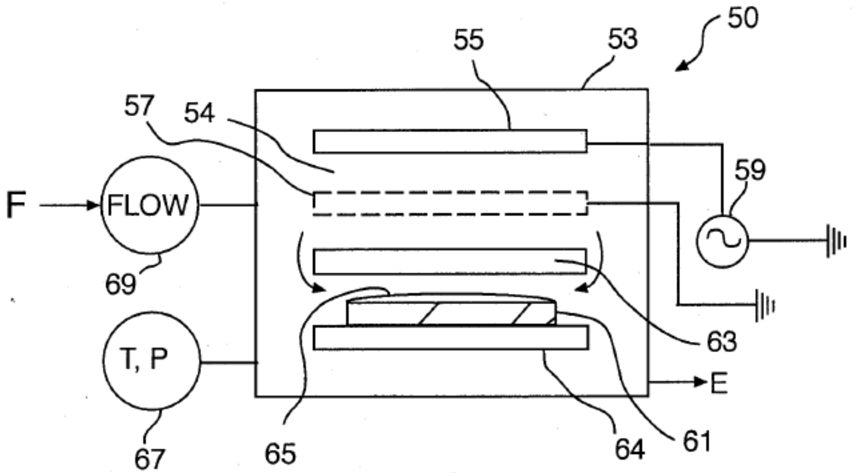

50
55
53
57
54
59
F
FLOW
69
T, P
67
63
E
65
64
61

FIG. 2

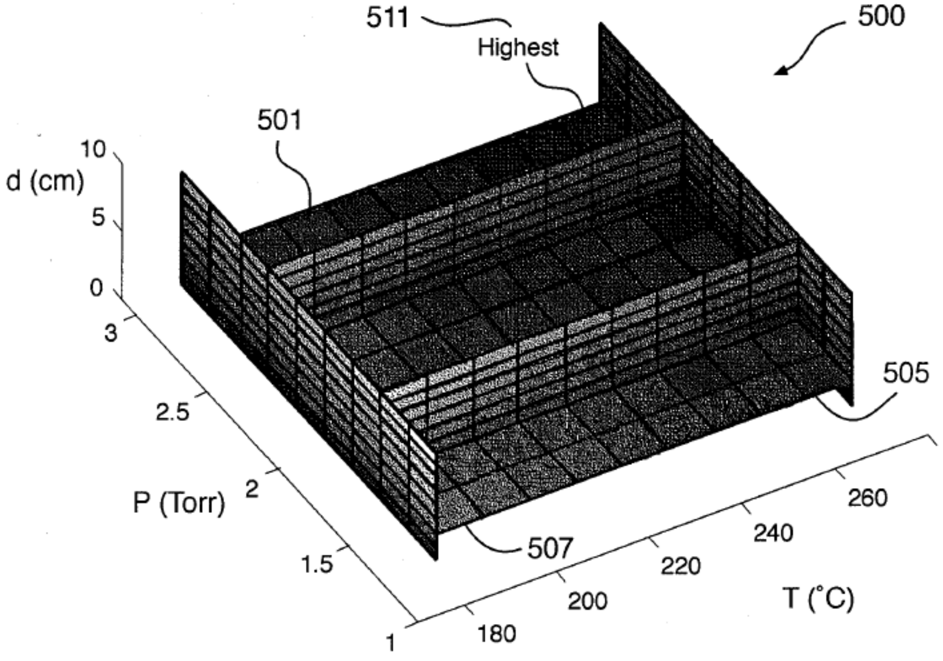

511
Highest
500
501
d (cm)
10
5
0
3
2.5
2
1.5
1
P (Torr)
505
507
180
200
220
240
260
T (°C)

FIG. 5A

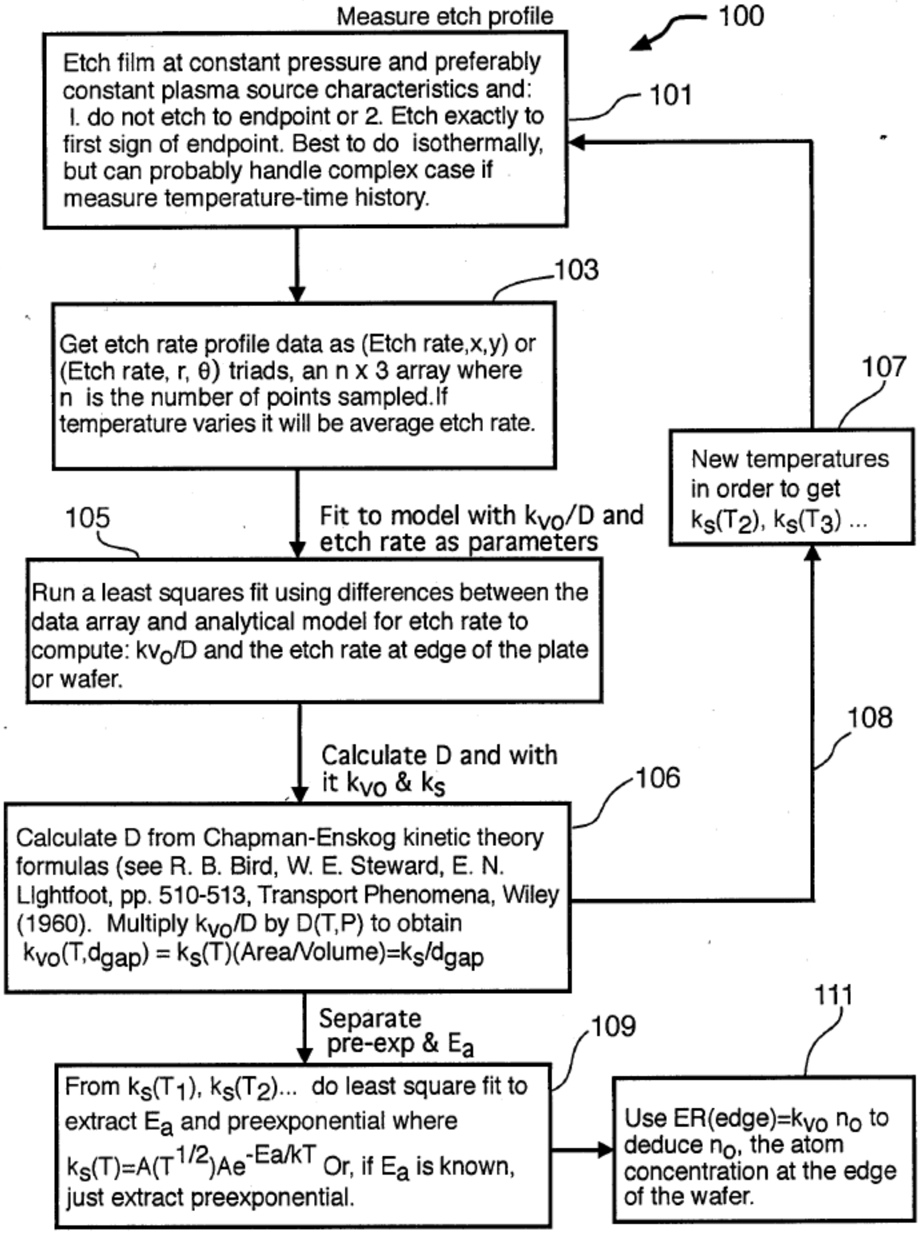

Measure etch profile
100
101
Etch film at constant pressure and preferably constant plasma source characteristics and: I. do not etch to endpoint or 2. Etch exactly to first sign of endpoint. Best to do isothermally, but can probably handle complex case if measure temperature-time history.
103
Get etch rate profile data as (Etch rate,x,y) or (Etch rate, r, θ) triads, an n x 3 array where n is the number of points sampled. If temperature varies it will be average etch rate.
107
New temperatures in order to get $k_s(T_2)$, $k_s(T_3)$ ...
105
Fit to model with k_{vo}/D and etch rate as parameters
Run a least squares fit using differences between the data array and analytical model for etch rate to compute: kv_o/D and the etch rate at edge of the plate or wafer.
108
Calculate D and with it k_{vo} & k_s
106
Calculate D from Chapman-Enskog kinetic theory formulas (see R. B. Bird, W. E. Steward, E. N. Lightfoot, pp. 510-513, Transport Phenomena, Wiley (1960). Multiply k_{vo}/D by D(T,P) to obtain $k_{vo}(T,d_{gap}) = k_s(T)(\text{Area/Volume})=k_s/d_{gap}$
111
Separate pre-exp & E_a
109
From $k_s(T_1)$, $k_s(T_2)$... do least square fit to extract E_a and preexponential where $k_s(T)=A(T^{1/2})Ae^{-Ea/kT}$ Or, if E_a is known, just extract preexponential.
Use $ER(edge)=k_{vo}\,n_o$ to deduce n_o, the atom concentration at the edge of the wafer.

FIG. 3

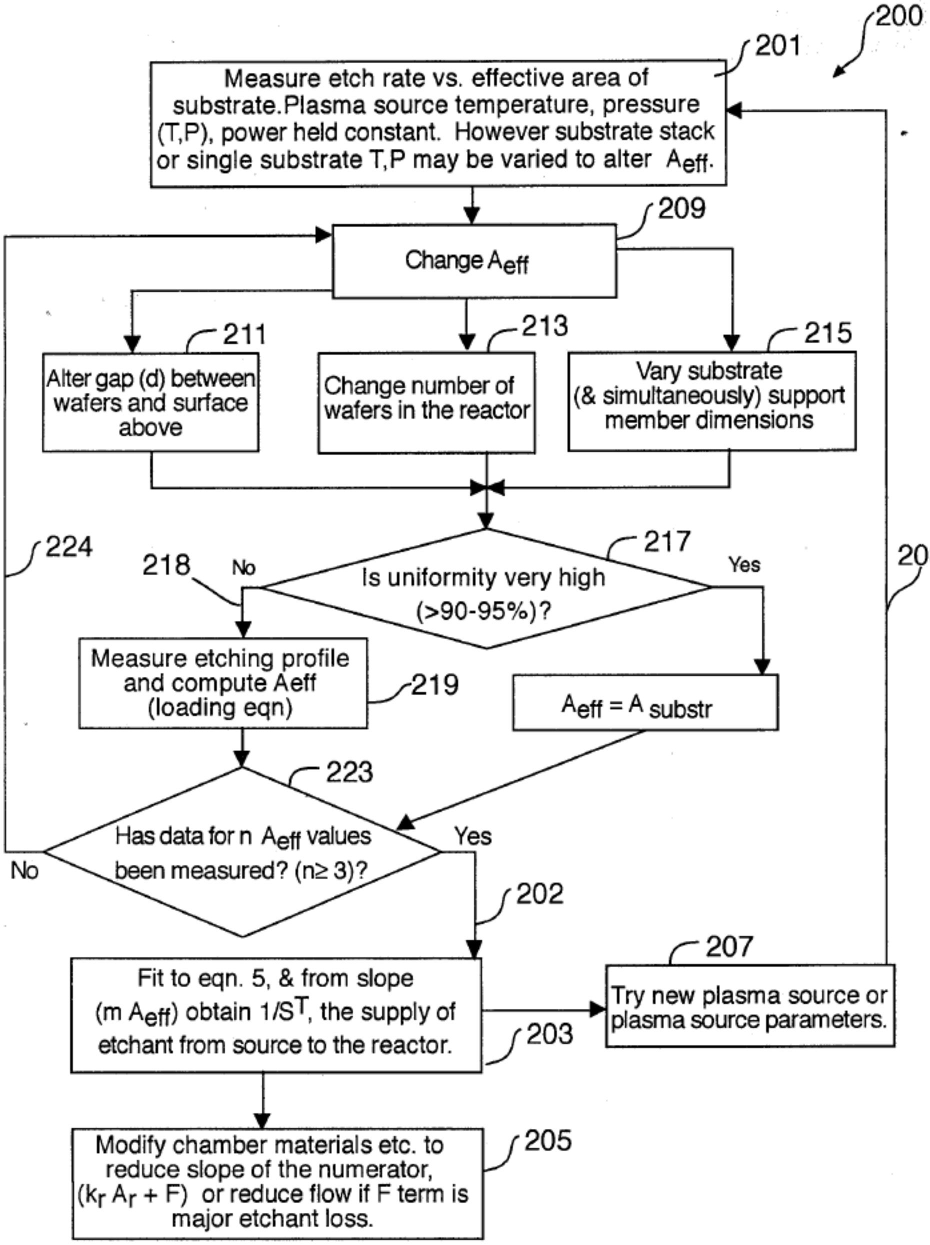

200
201
Measure etch rate vs. effective area of substrate. Plasma source temperature, pressure (T,P), power held constant. However substrate stack or single substrate T,P may be varied to alter A_{eff}.
209
Change A_{eff}
211
Alter gap (d) between wafers and surface above
213
Change number of wafers in the reactor
215
Vary substrate (& simultaneously) support member dimensions
224
218
No
217
Is uniformity very high (>90-95%)?
Yes
208
Measure etching profile and compute Aeff (loading eqn)
219
$A_{eff} = A_{substr}$
223
Has data for n A_{eff} values been measured? ($n \geq 3$)?
No
Yes
202
207
Fit to eqn. 5, & from slope (m A_{eff}) obtain $1/S^T$, the supply of etchant from source to the reactor.
203
Try new plasma source or plasma source parameters.
205
Modify chamber materials etc. to reduce slope of the numerator, ($k_r A_r + F$) or reduce flow if F term is major etchant loss.

FIG. 4

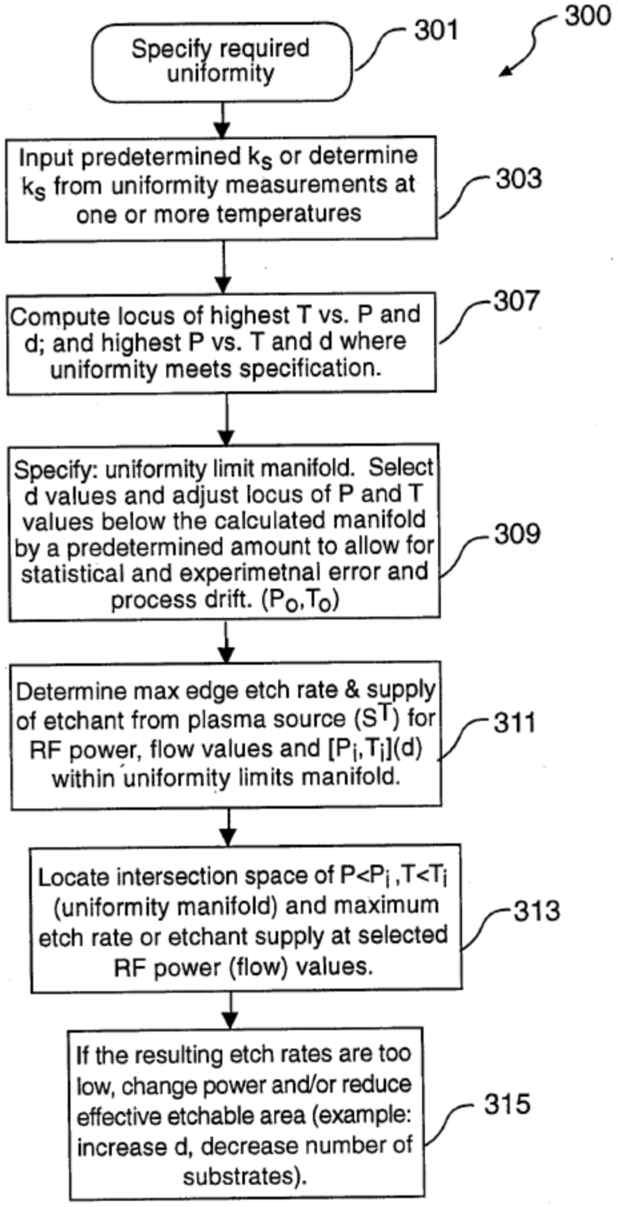

300
Specify required uniformity
301
Input predetermined k_S or determine k_S from uniformity measurements at one or more temperatures
303
Compute locus of highest T vs. P and d; and highest P vs. T and d where uniformity meets specification.
307
Specify: uniformity limit manifold. Select d values and adjust locus of P and T values below the calculated manifold by a predetermined amount to allow for statistical and experimetnal error and process drift. (P_O,T_O)
309
Determine max edge etch rate & supply of etchant from plasma source (S^T) for RF power, flow values and [P_i,T_i](d) within uniformity limits manifold.
311
Locate intersection space of $P<P_i$,$T<T_i$ (uniformity manifold) and maximum etch rate or etchant supply at selected RF power (flow) values.
313
If the resulting etch rates are too low, change power and/or reduce effective etchable area (example: increase d, decrease number of substrates).
315

FIG. 5

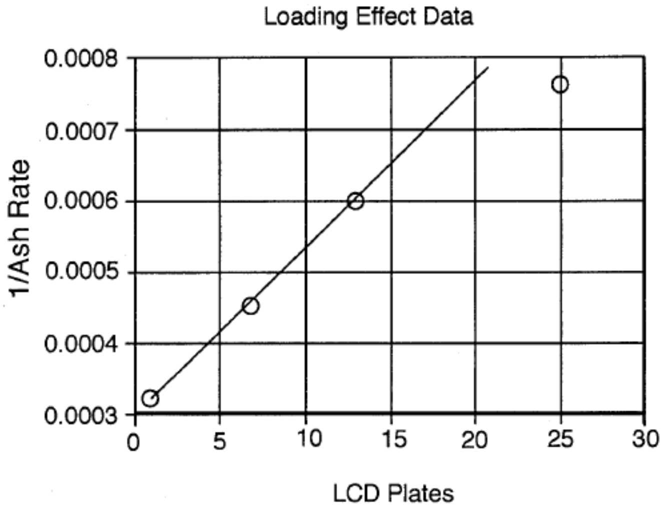


FIG. 6

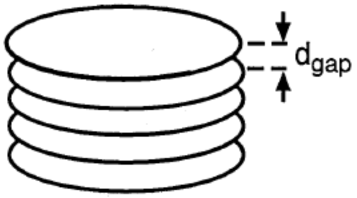


FIG. 7

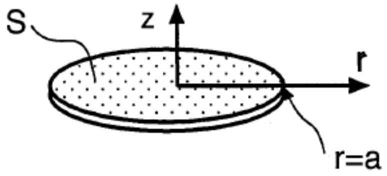


FIG. 8

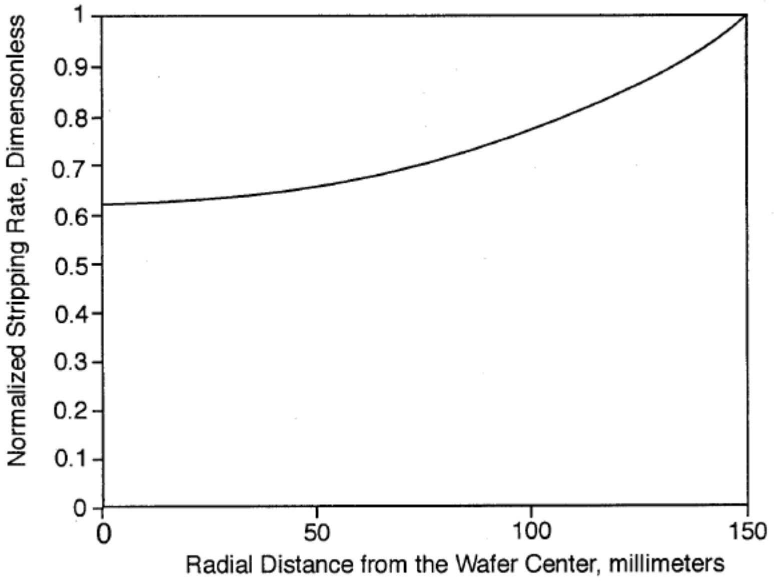


FIG. 9

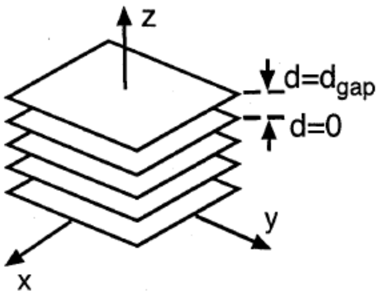


FIG. 10

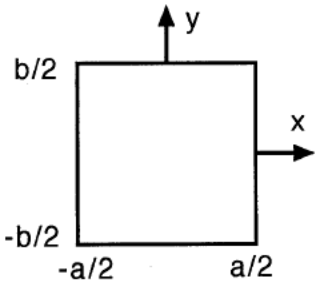


FIG. 11

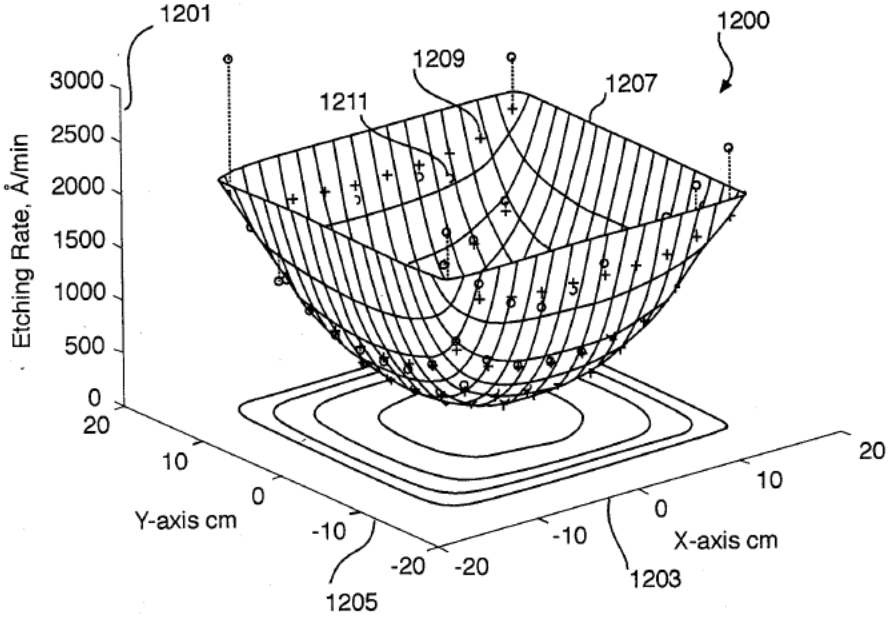

1201
1200
1209
1207
1211
3000
2500
2000
1500
1000
500
0
Etching Rate, Å/min
20
10
0
-10
-20
Y-axis cm
1205
-20
-10
0
10
20
X-axis cm
1203

FIG. 12

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Atty Docket No. 16655-000100

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Group Art Unit 1113

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CERTIFICATION OF FACSIMILE TRANSMISSION

I hereby certify that the following Communication and copies of Amendment Transmittal; 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); Serial No. 08/433,623, Filed: May 3, 1995 for PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING is being facsimile transmitted to the Patent and Trademark Office on the date shown below.

Number of pages being transmitted, including this page: 29

Dated: October 27, 1997

Diane Elzingre
Diane Elzingre

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16655\1-pto.fax

Amendment Transmittal

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San Francisco, CA 94111-3834
(650) 326-2400

Atty. Docket No. 16655-000100

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

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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

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

By

ASSISTANT COMMISSIONER FOR PATENTS
Washington, D.C. 20231

Sir:
Transmitted herewith is an amendment in the above-identified application.
[X] Amendment After Payment of Issue Fee Under 37 CFR 1.312(b).
[X] Petition for Amendment After Payment of Issue Fee Under 37 CFR 1.312(b).
[X] 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: <u>See</u> claim 28, which is counted as three claims					+125=	$0.00	OR	+250=	$
					TOTAL ADDIT. FEE	$0.00		TOTAL	$

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

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*** 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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Gary T. Aka
Reg. No.: 29,038
Attorneys for Applicant

16655\1-312.tm

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PATENT

Attorney Docket No. 16655-000100

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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

PETITION FOR 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), 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.

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

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Attorney Docket No. 16655-000100

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Daniel L. Flamm	Examiner: M. Angebranndt
Application No.: 08/433,623	Art Unit: 1113
Filed: May 3, 1995	
For: PROCESS OPTIMIZATION IN GAS PHASE DRY ETCHING	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 --,--.

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 --; and I_o 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_o" and insert --R_{os}--; please delete "k_{vo}" and insert --k_s--.

At page 11, line 25, please delete "R_o" 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_o" and insert --R_{os}--.

At page 13, line 11, please delete "R_o" 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 --

$[1-\frac{R_{MAX}-R_{MIN}}{2\sum_{i=1}^{m}\frac{R_i}{m}}]$--.

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_o" and insert --R_{os}--.

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_w" and insert --A_{eff}--.

At page 19, line 9, before etching rates, please insert --when etching uniformity is high the--.

At page 19, line 16, please delete "k_e" and insert --k_s--.

At page 19, in the equation after line 20, please delete "k_o" and insert --k_s--.

At page 19, in the equation after line 20, please delete "A_w" and insert --A_{eff}--.

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 $D\nabla n_o$ and insert --)-- after $D\nabla n_o$.

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_o/n_{o0}--.

At page 23, line 9, please delete "9" and insert --10--.

At page 23, line 26, please delete "where λ_x is given by".

At page 24, between the first and second equation on the page, please insert --where λ_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 $k_l(T)$ 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_l 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, "*St*" is replaced by "S^T". 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 replace with "one". As discussed with respect to Fig. 4, in box 309, "*St*" is replaced by "S^T". 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 $k_i(T)$ 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, "St" is replaced by "S^T" 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.

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 show 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
Gary T. Aka
Reg. No. 29,038

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H:\WORK\16655\000100\312V2.AMD

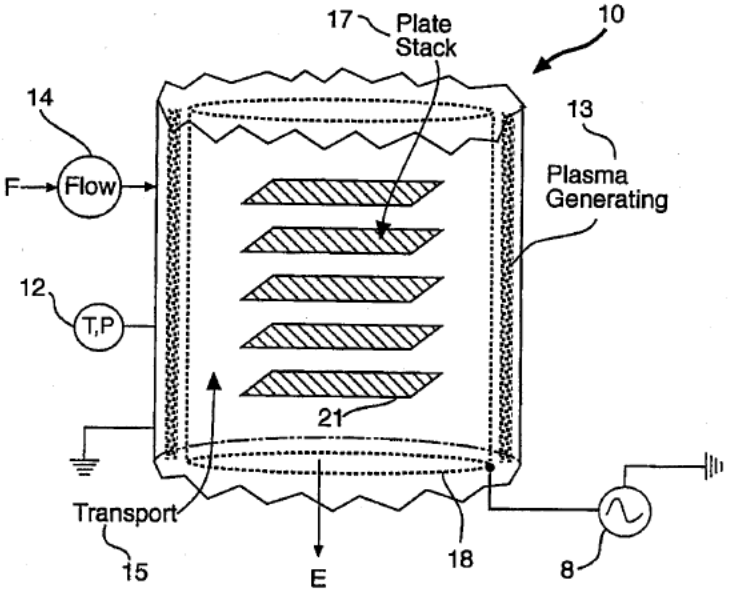

17
Plate Stack
10
14
13
F
Flow
Plasma Generating
12
T,P
21
Transport
15
E
18
8

FIG. 1

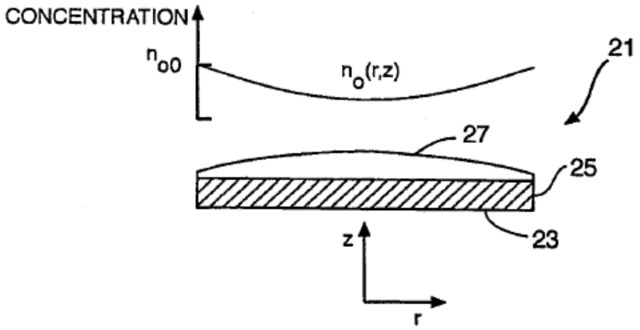

CONCENTRATION
n_{o0}
$n_o(r,z)$
21
27
25
23
z
r

FIG. 1A

2/8

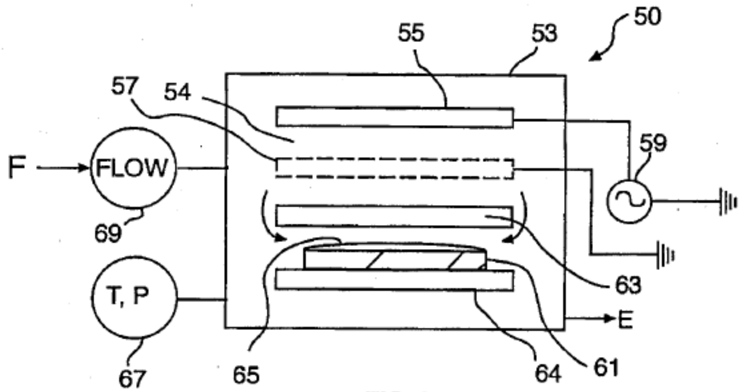


FIG. 2

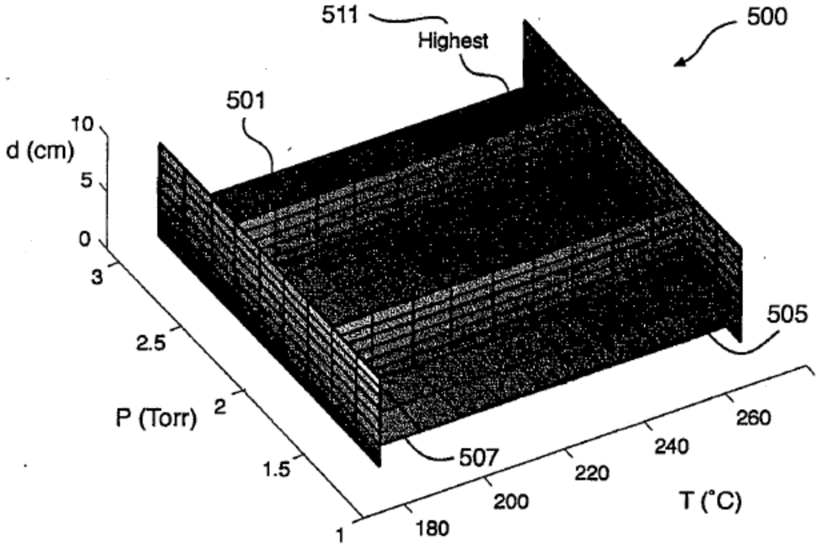


FIG. 5A

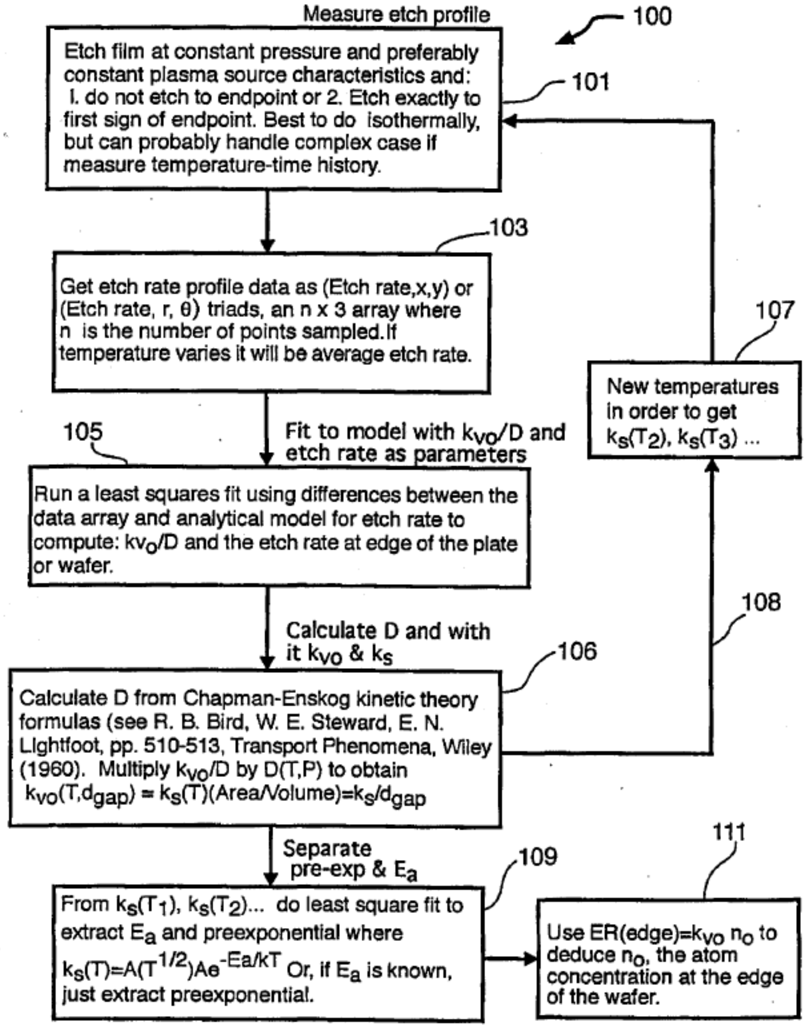

Measure etch profile
100
Etch film at constant pressure and preferably constant plasma source characteristics and: I. do not etch to endpoint or 2. Etch exactly to first sign of endpoint. Best to do isothermally, but can probably handle complex case if measure temperature-time history.
101
103
Get etch rate profile data as (Etch rate,x,y) or (Etch rate, r, θ) triads, an n x 3 array where n is the number of points sampled. If temperature varies it will be average etch rate.
107
New temperatures in order to get $k_s(T_2)$, $k_s(T_3)$ ...
105
Fit to model with k_{vo}/D and etch rate as parameters
Run a least squares fit using differences between the data array and analytical model for etch rate to compute: kv_o/D and the etch rate at edge of the plate or wafer.
108
Calculate D and with it k_{vo} & k_s
106
Calculate D from Chapman-Enskog kinetic theory formulas (see R. B. Bird, W. E. Steward, E. N. Lightfoot, pp. 510-513, Transport Phenomena, Wiley (1960). Multiply k_{vo}/D by D(T,P) to obtain $k_{vo}(T,d_{gap}) = k_s(T)(Area/Volume)=k_s/d_{gap}$
Separate pre-exp & E_a
109
111
From $k_s(T_1)$, $k_s(T_2)$... do least square fit to extract E_a and preexponential where $k_s(T)=A(T^{1/2})Ae^{-Ea/kT}$ Or, if E_a is known, just extract preexponential.
Use $ER(edge)=k_{vo}\ n_o$ to deduce n_o, the atom concentration at the edge of the wafer.

FIG. 3

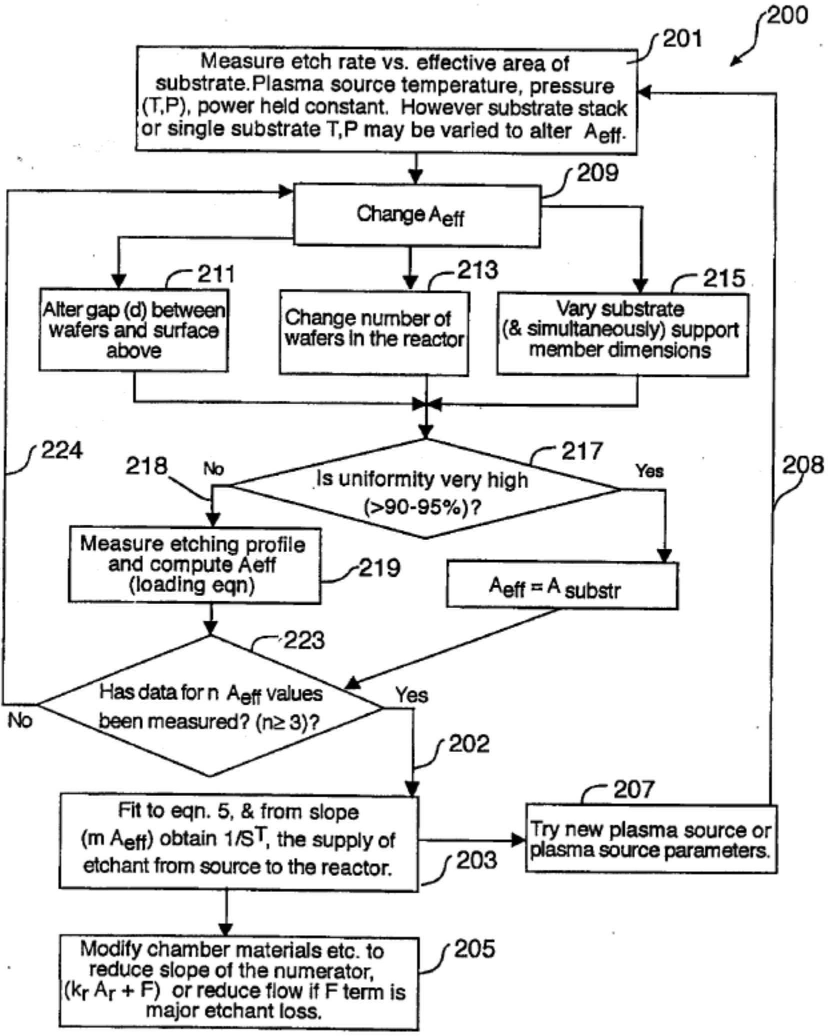
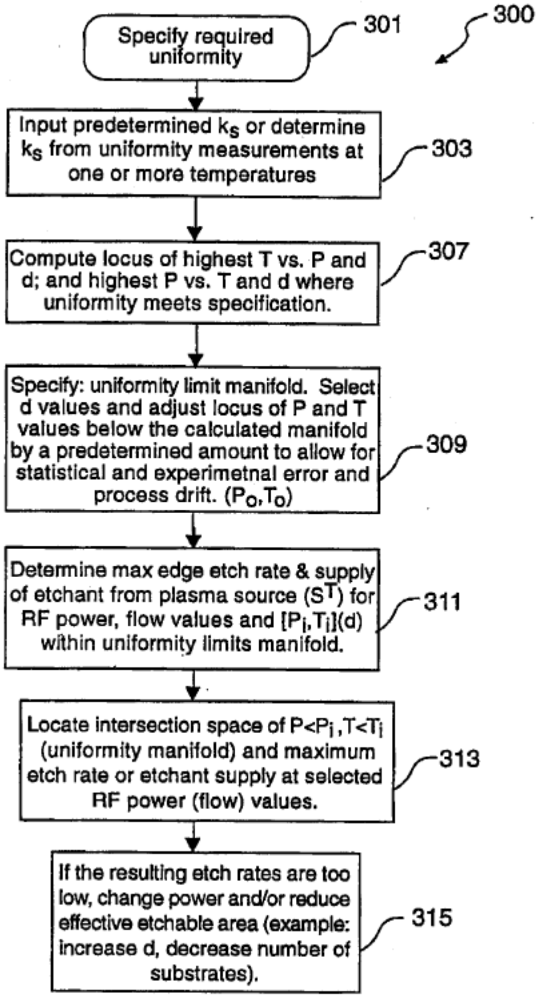

200
201
Measure etch rate vs. effective area of substrate. Plasma source temperature, pressure (T,P), power held constant. However substrate stack or single substrate T,P may be varied to alter A_eff.
209
Change A_eff
211
Alter gap (d) between wafers and surface above
213
Change number of wafers in the reactor
215
Vary substrate (& simultaneously) support member dimensions
224
218
No
217
Is uniformity very high (>90-95%)?
Yes
208
Measure etching profile and compute Aeff (loading eqn)
219
A_eff = A_substr
223
Has data for n A_eff values been measured? (n≥ 3)?
No
Yes
202
207
Fit to eqn. 5, & from slope (m A_eff) obtain 1/S^T, the supply of etchant from source to the reactor.
Try new plasma source or plasma source parameters.
203
Modify chamber materials etc. to reduce slope of the numerator, (k_r A_r + F) or reduce flow if F term is major etchant loss.
205

FIG. 4

5/8



Specify required uniformity
301
300
Input predetermined k_s or determine k_s from uniformity measurements at one or more temperatures
303
Compute locus of highest T vs. P and d; and highest P vs. T and d where uniformity meets specification.
307
Specify: uniformity limit manifold. Select d values and adjust locus of P and T values below the calculated manifold by a predetermined amount to allow for statistical and experimetnal error and process drift. (P_o,T_o)
309
Determine max edge etch rate & supply of etchant from plasma source (S^T) for RF power, flow values and [P_i,T_i](d) within uniformity limits manifold.
311
Locate intersection space of $P<P_i$, $T<T_i$ (uniformity manifold) and maximum etch rate or etchant supply at selected RF power (flow) values.
313
If the resulting etch rates are too low, change power and/or reduce effective etchable area (example: increase d, decrease number of substrates).
315

FIG. 5

6/8

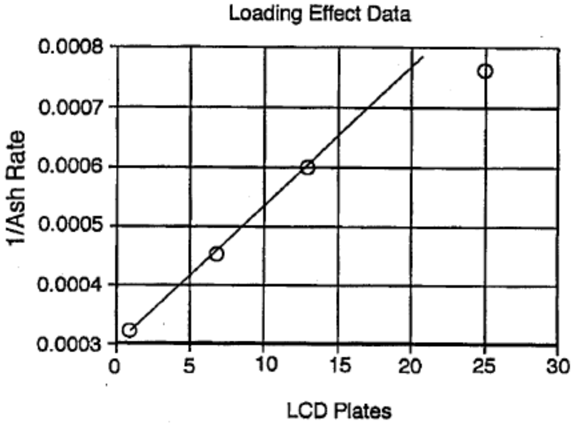


FIG. 6

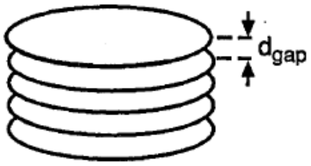


FIG. 7

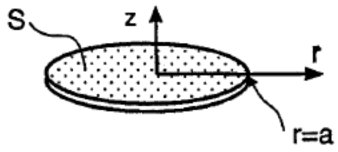


FIG. 8

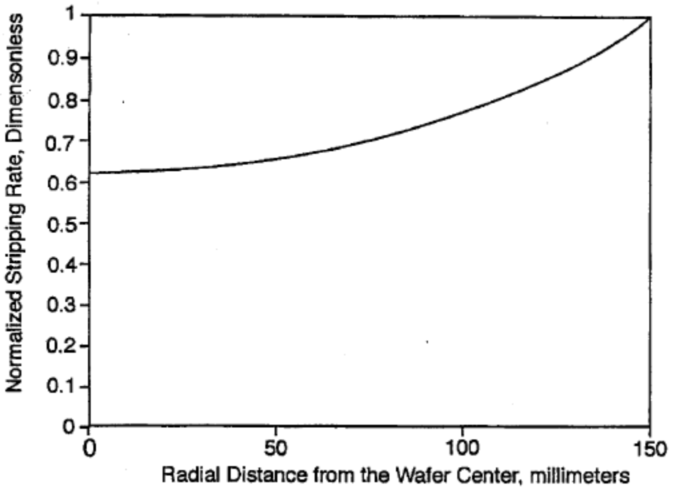


FIG. 9

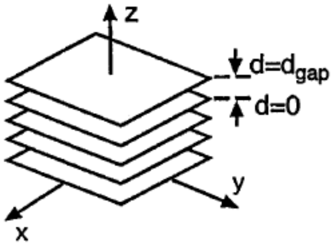


FIG. 10

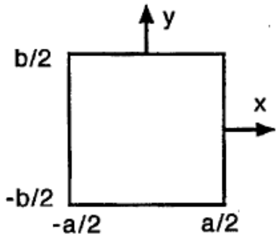


FIG. 11

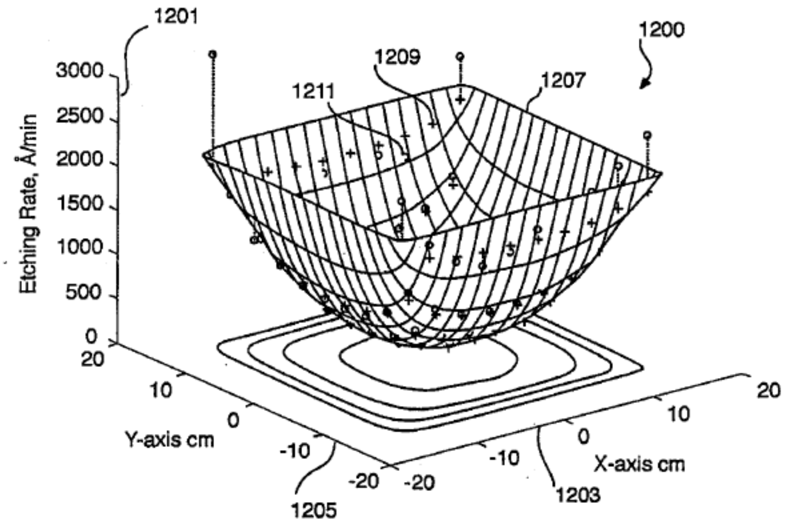

1201
1200
1209
1211
1207
3000
2500
2000
1500
1000
500
0
Etching Rate, Å/min
20
10
0
-10
-20
Y-axis cm
-20
-10
0
10
20
X-axis cm
1205
1203

FIG. 12

Received Event (Event Succeeded)

Date:	10/27/97	**Time:**	6:09 PM	
Pages:	29	**Sender:**	415 326 2422	
Fax Number:		**Subject:**		
Company:	OCT 27 '97 06:15PM TTC PALO ALTO 415 326 2422	**Type:**	Fax	P.20

6655-1

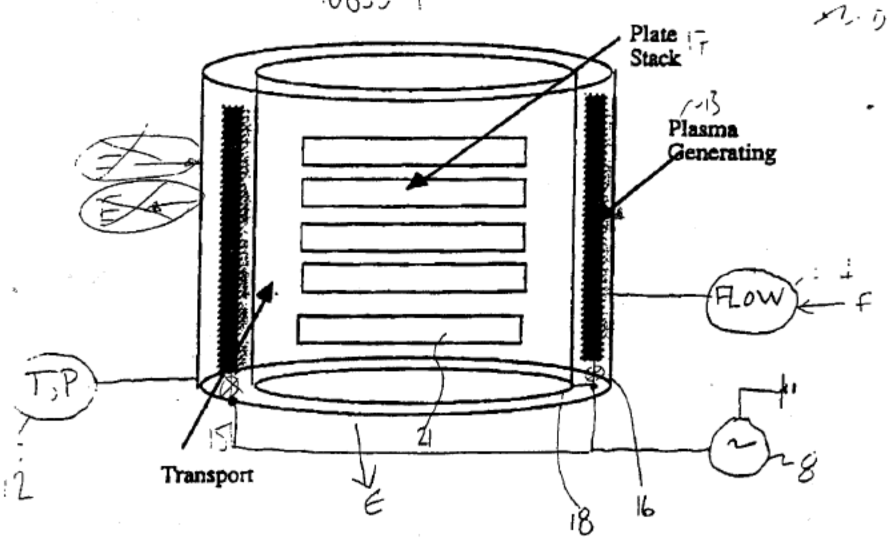


FIG. 1

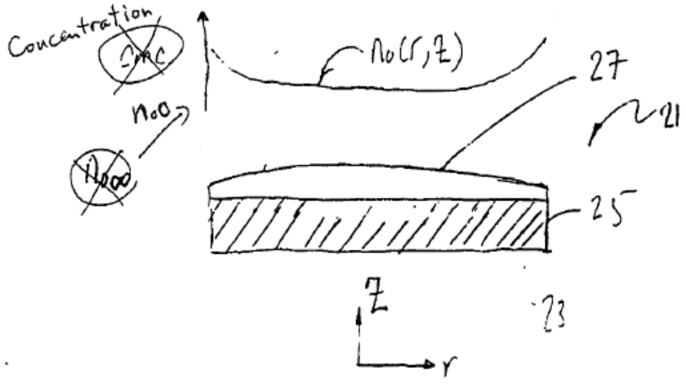


FIG. 1A

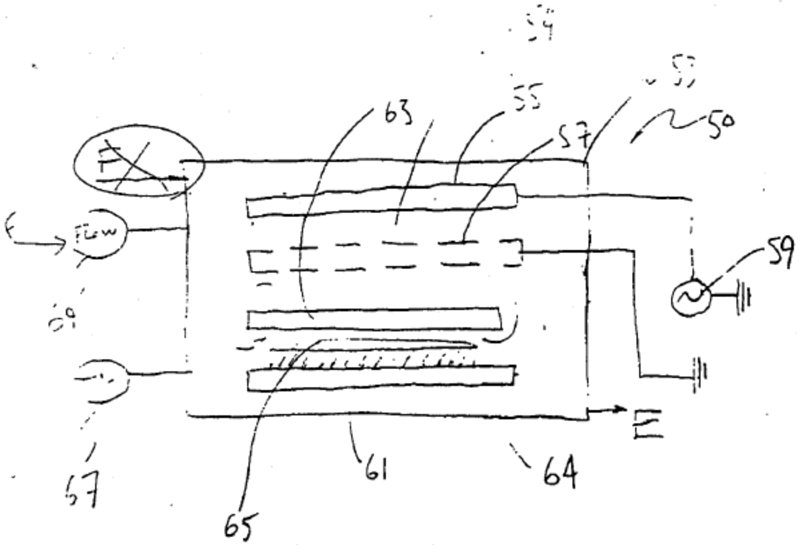


FIG. 2

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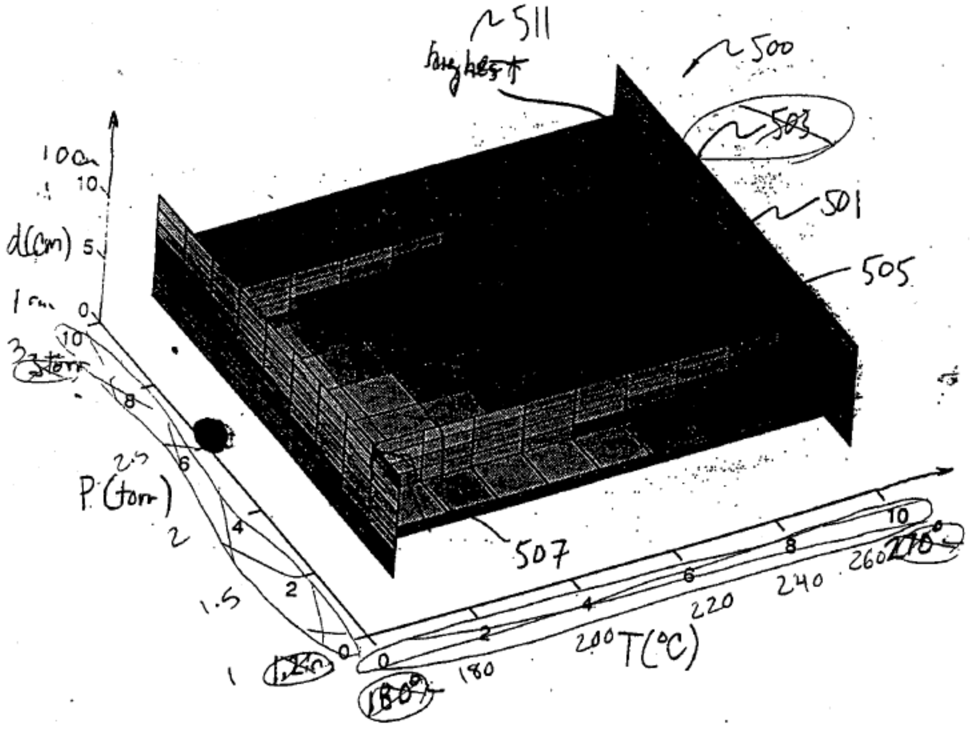

FIG. 5A

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

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

11M1/1208

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SAN FRANCISCO CA 94111-3834

EXAMINER	
ANGEBRANNDT, M	
ART UNIT	**PAPER NUMBER**
1113	17

DATE MAILED: 12/08/97

Please find below and/or attached an Office communication concerning this application or proceeding.

Commissioner of Patents and Trademarks

PTO-90C (Rev. 2/95)

1- File Copy

Response to Rule 312 Communication

Application No. 08/433,623	Applicant(s) Flamm
Examiner Martin J. Angebranndt	Group Art Unit 1113

☒ 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

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. ANGEBRANNDT
PRIMARY EXAMINER
ART UNIT 1113

U. S. Patent and Trademark Office
PTO-271 (Rev. 5-95) **Response to Rule 312 Communication** Part of Paper No. 16

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Washington, D.C. 20231

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CHANGE OF ADDRESS/POWER OF ATTORNEY

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:

TOWNSEND AND TOWNSEND AND CREW
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)

TO: **Mail Stop 8** **Director of the U.S. Patent & Trademark Office** **P.O. Box 1450** **Alexandria, VA 22313-1450**	**REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK**

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 ☐ Amendment ☐ Answer ☐ Cross Bill ☐ 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

CLERK	(BY) DEPUTY CLERK	DATE
Richard W. Wieking	Sheila Rash	March 19, 2015

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

PATENT APPLICATION FEE DETERMINATION RECORD

Effective October 1, 1994

Application or Docket Number 433623

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
FOR	NUMBER FILED	NUMBER EXTRA	RATE	FEE		RATE	FEE
BASIC FEE				365.00	OR		730.00
TOTAL CLAIMS	23 minus 20 =	* 3	x$11=	33.	OR	x$22=	~~66~~
INDEPENDENT CLAIMS	4 minus 3 =	* 1	x38=	38.	OR	x76=	~~76~~
MULTIPLE DEPENDENT CLAIM PRESENT			+120=		OR	+240=	
			TOTAL	436	OR	TOTAL	872

* If the difference in column 1 is less than zero, enter "0" in column 2

CLAIMS AS AMENDED - PART II

AMENDMENT A

	(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
Total	* 25	Minus	** 23	= 2	x$11=	22 pd	OR	x$22=	
Independent	* 5	Minus	~~3~~ 4	= 1	x38=	39 pd	OR	x76=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+120=		OR	+240=	
					TOTAL ADDIT. FEE	61.00 PAID	OR	TOTAL ADDIT. FEE	

AMENDMENT B

	(Column 1)		(Column 2)	(Column 3)					
	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	OR	x$22=	
Independent	* 6	Minus	*** 5	= 1	x38=	39.00	OR	x76=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+120=		OR	+240=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	(Column 1)		(Column 2)	(Column 3)					
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
Total	*	Minus	**	=	x$11=		OR	x$22=	
Independent	*	Minus	***	=	x38=		OR	x76=	
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM					+120=		OR	+240=	
					TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* 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.

FORM PTO-875
(Rev. 10/94)

Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

Form PTO 1130
(REV 2/94)

PACE DATA ENTRY CODING SHEET

U.S. DEPARTMENT OF COMMERCE
Patent and Trademark Office

1ST EXAMINER	DSTay	DATE	5-19-95
2ND EXAMINER	Dill	DATE	8/4/95

APPLICATION NUMBER	TYPE APPL	FILING DATE MONTH DAY YEAR	SPECIAL HANDLING	GROUP ART UNIT	CLASS	SHEETS OF DRAWING
57479 U.S. PTO 08433623 05/03/95	1	050395	0	1109	437	13

TOTAL CLAIMS	INDEPENDENT CLAIMS	SMALL ENTITY?	FILING FEE	FOREIGN LICENSE	ATTORNEY DOCKET NUMBER
23	4	1	0501	Y	16655-000100

CONTINUITY DATA

CONT CODE	STATUS CODE	PARENT APPLICATION SERIAL NUMBER	PCT APPLICATION SERIAL NUMBER	PARENT PATENT NUMBER	PARENT FILING DATE MONTH DAY YEAR
			PCT/ /		
			PCT/ /		
			PCT/ /		
			PCT/ /		
			PCT/ /		

PCT/FOREIGN APPLICATION DATA

FOREIGN PRIORITY CLAIMED	COUNTRY CODE	PCT/FOREIGN APPLICATION SERIAL NUMBER	FOREIGN FILING DATE MONTH DAY YEAR

☆U.S.G.P.O.: 1994 - 384-021

MULTIPLE DEPENDENT CLAIM FEE CALCULATION SHEET
(FOR USE WITH FORM PTO-875)

SERIAL NO. 08/433,623

FILING DATE 5/3/95

APPLICANT(S) FIAMM

CLAIMS

	AS FILED		AFTER 1st AMENDMENT		AFTER 2nd AMENDMENT	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
1	1		1		1	
2		1		1		1
3		1		1		1
4		1		1		1
5		1		1		1
6		1		1		1
7		1		1		1
8		1		1		1
9	1		1		1	
10		1		1		1
11		1		1		1
12		1		1		1
13		1		1		1
14		1		1		1
15		1		1		1
16		1		1		1
17		1		1		1
18		1		1		1
19	1		1		1	
20	1		1		1	
21		1		1		1
22		1		1		1
23		1		1		1
24				1		1
25			1		1	
26						1
27						1
28						3
29					1	
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50						
TOTAL IND.	4		5		6	
TOTAL DEP.	19		20		25	
TOTAL CLAIMS	23		25		31	

	*		*		*	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
51						
52						
53						
54						
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99						
100						
TOTAL IND.						
TOTAL DEP.						
TOTAL CLAIMS						

PTO-1360 (3-78)

*MAY BE USED FOR ADDITIONAL CLAIMS OR AMENDMENTS

U.S. DEPARTMENT of COMMERCE
Patent and Trademark Office

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=> 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
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=> 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
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