United States Patent [19]
Mahawili

[11] **Patent Number:** **5,059,770**
[45] **Date of Patent:** **Oct. 22, 1991**

[54] MULTI-ZONE PLANAR HEATER ASSEMBLY AND METHOD OF OPERATION

[75] Inventor: **Imad Mahawili,** Sunnyvale, Calif.

[73] Assignee: **Watkins-Johnson Company,** Palo Alto, Calif.

[21] Appl. No.: **409,125**

[22] Filed: **Sep. 19, 1989**

[51] **Int. Cl.**^{5} **F27B 5/14**
[52] **U.S. Cl.** **219/391;** 219/390; 219/464
[58] **Field of Search** 219/391, 395, 390, 405, 219/411, 464, 465, 466, 468

[56] **References Cited**

U.S. PATENT DOCUMENTS

1,706,015	3/1929	Wiegand	219/465
3,536,892	10/1970	Walther	219/439
3,836,751	9/1974	Anderson	219/411
3,842,794	10/1974	Ing	219/390
4,002,883	1/1977	Hurko	219/464
4,101,759	7/1978	Anthony	219/405
4,292,276	9/1981	Enomoto	219/390
4,503,807	3/1985	Nakayama	219/405
4,545,327	10/1985	Campbell	219/405
4,859,832	8/1989	Uehara	219/411

Primary Examiner—Teresa J. Walberg
Attorney, Agent, or Firm—John A. Bucher

[57] ABSTRACT

A heater assembly and method of operation for use in processing of a substrate such as a semiconductor wafer, for example in a chemical vapor deposition (CVD) reactor chamber, the heater assembly including a dielectric heater base, radially spaced apart and circumferentially extending heater element segments being arranged on the heater base, operation of the plurality of heater elements being independently regulated, a heater shroud being arranged in spaced apart relation over the heater elements while supporting the substrate for maintaining a blanket of inert gas between the heater elements and the heater shroud. Inert gas is preferably introduced through a central opening in the heater base and is selectively regulated for facilitating processing of the substrate.

25 Claims, 2 Drawing Sheets

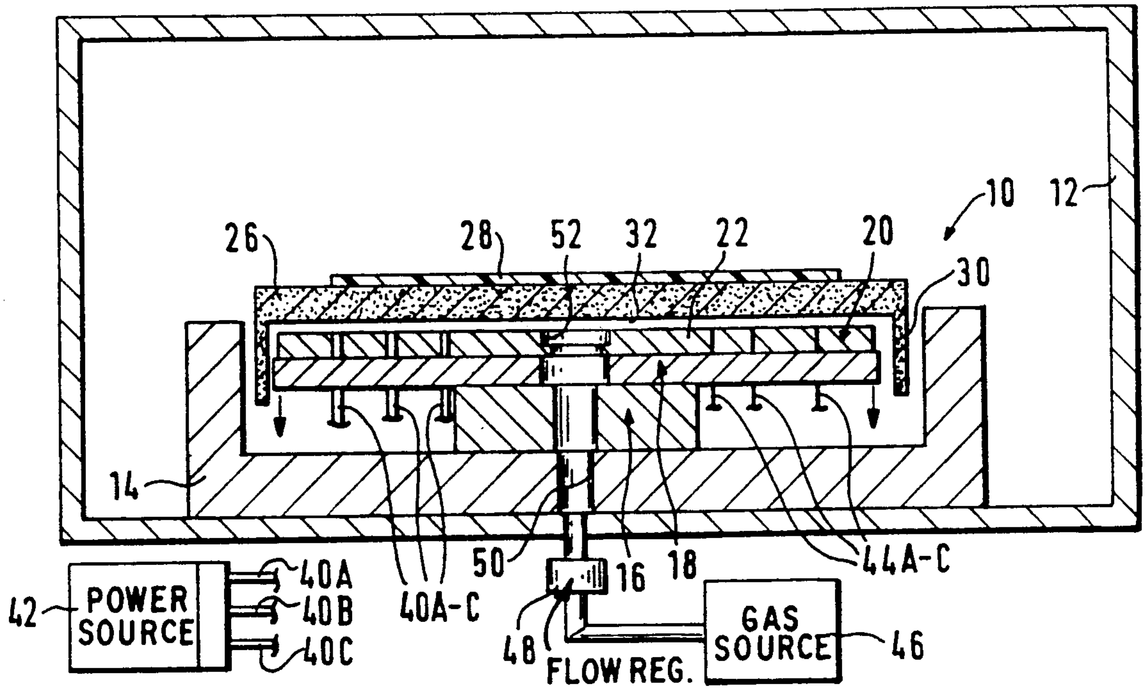
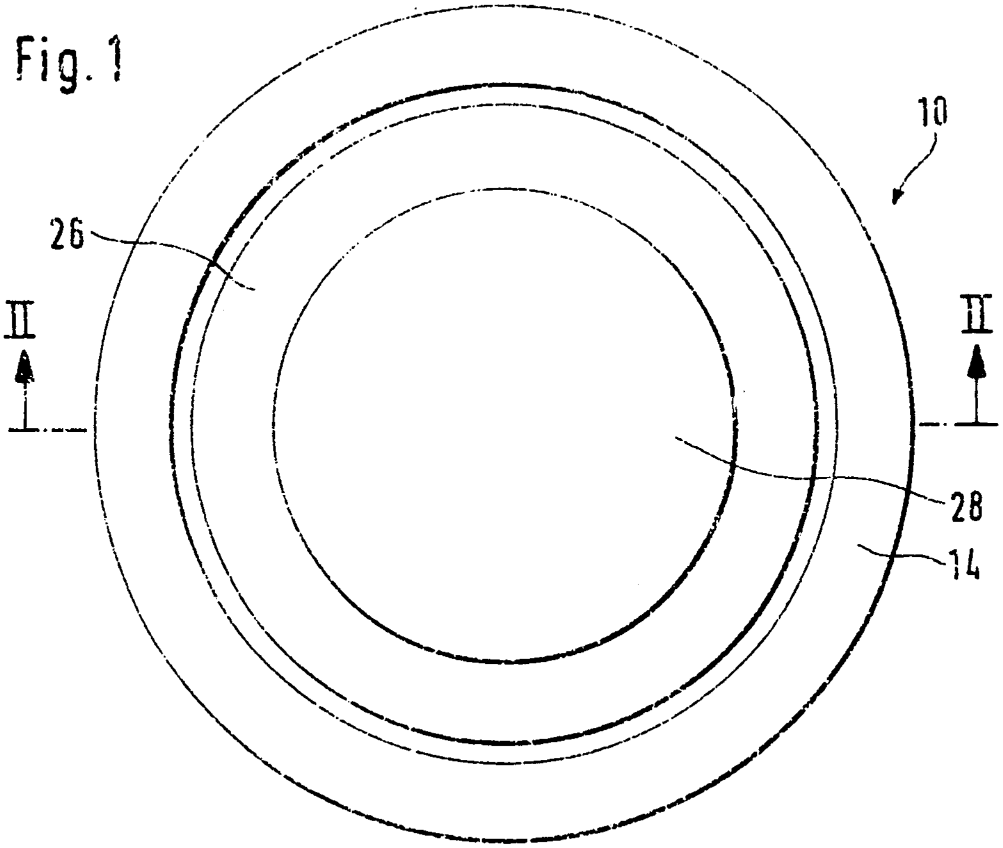


Fig. 1



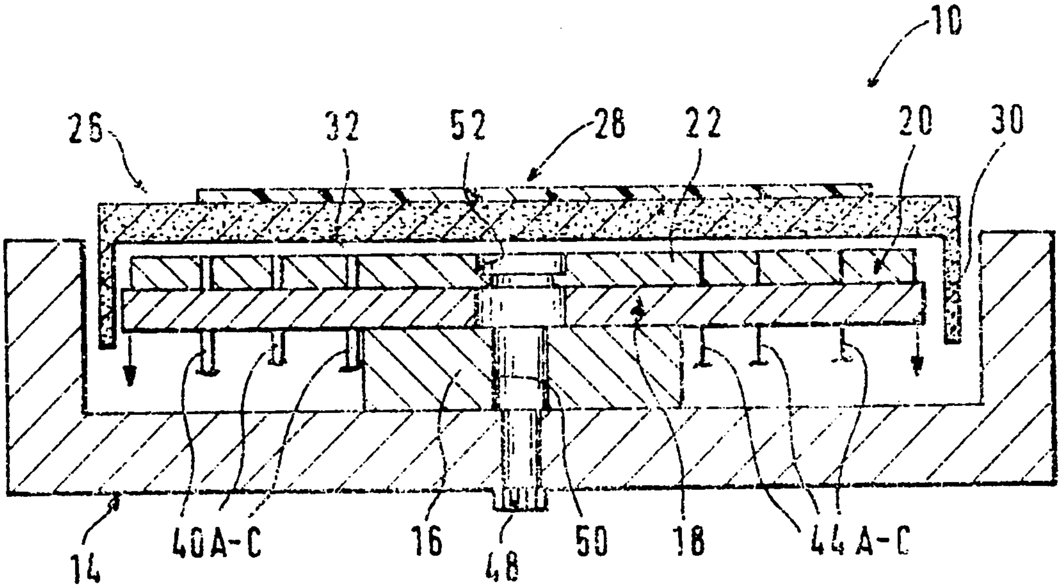
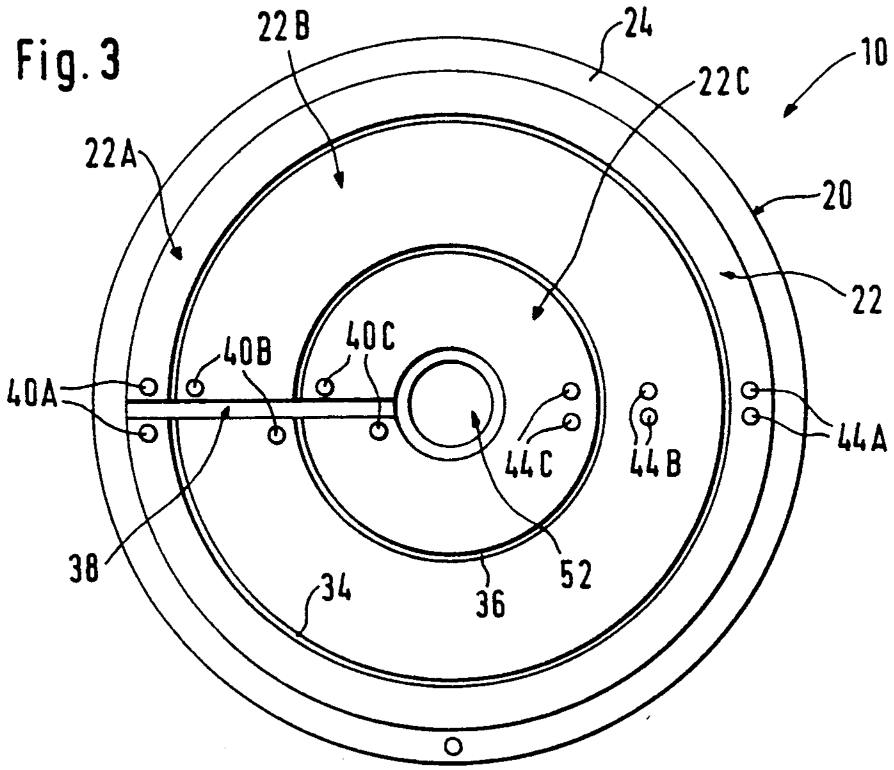


Fig. 2

Fig. 3


22B
24
10
22C
22A
20
22
40C
40B
40A
44A
44C
44B
38
52
34
36

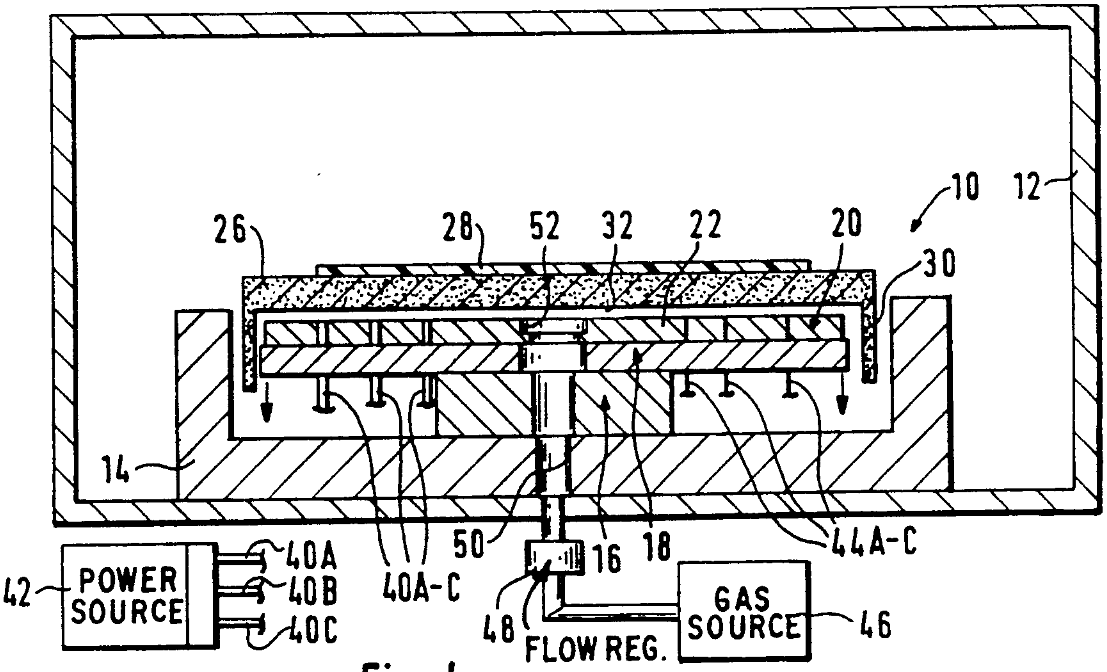

26
28
52
32
22
20
10
12
30
14
50
16
18
44A-C
42
POWER SOURCE
40A
40B
40C
40A-C
48
FLOW REG.
GAS SOURCE
46

Fig. 4

MULTI-ZONE PLANAR HEATER ASSEMBLY AND METHOD OF OPERATION

FIELD OF THE INVENTION

The present invention relates to a heater assembly and method of its operation for use in processing a substrate such as a semiconductor wafer and more particularly to such a heater assembly and method of operation for use in a chemical vapor deposition (CVD) reactor.

BACKGROUND OF THE INVENTION

In semiconductor wafer processing, for example, CVD, and similar methods, substrates such as silicon wafers are typically heated to various temperatures in order to carry out different thin film deposition or etch operations. Various techniques have been employed in the prior art for heating these thin substrates, including: (1) infrared heating; (2) visible light source heating; (3) radio frequency coupled heaters; and (4) hot plate heaters.

In the first type of heater, the substrate was physically rotated past an array of infrared lamps in an effort to achieve required uniform temperatures throughout the silicon wafer. However, the physical rotation step tended to interfere with distribution of gas flow over and onto the wafer, thus resulting in processing limitations.

In the second heating method, temperature uniformity was attempted by employing very complex and expensive optical reflectors. Stability and uniformity of temperatures were determined by complex radiative interaction of the various surfaces according to their respective emissivities.

The third method, while also complex and expensive, has been commonly employed particularly for processing temperatures in the range of 1,000–1,200 degrees centigrade (°C.). However, this method has offered sub-optimal temperature uniformity on the substrate while being very difficult to manipulate in order to achieve even a moderate level of temperature uniformity.

The fourth method has typically been employed for low temperature applications, for example below 500° C. Such hot plate heaters have commonly consisted of an embedded resistance wire in a ceramic or dielectric plate or a high thermally conductive metal such as aluminum. While satisfactory temperature uniformity has been achieved by this method, it has not been found suitable for use in high temperature processing due, for example, to limits established by metal melting points, bonding materials employed and the emission of contaminants from the heating element and the metals particularly at such higher temperatures.

SUMMARY OF THE INVENTION

Accordingly, there has been found to remain a need for an improved heater assembly and method of operation for use in such techniques. Generally, semiconductor wafer processing techniques such as those described above require temperature uniformity across the entire wafer area, typically with a variation of no more than ±2° C. in order to achieve uniform film processing (deposition or etch, for example) on the wafer or substrate. Such temperature uniformity is required in processes which may be carried out in a temperature range of typically 250°–1,250° C.

Semiconductor processing techniques are further complicated by the requirement for heating of the wafers or substrates from one side only in order to allow a gas delivery system (on the other side of the substrate) to be at a different temperature for optimal chemical processing. A fundamental problem arises in such heating techniques in that heat losses in central portions of the substrate tend to be very different from heat losses in edge portions. Thus, if a substrate is uniformly heated across its area, heat loss characteristics of the substrate normally cause it to assume a temperature profile which, when viewed in diametric cross-section, will be relatively low at the diametric edges and relatively high midway between those diametric extremities. Furthermore, relative heat losses and the temperature profile referred to above vary at different temperature levels and at different pressures. Thus, as processing temperatures are increased for a substrate, there will be a corresponding increase in the temperature profile, that is, a greater contrast between maximum and minimum temperatures in different areas of the substrate. In addition, the temperature profile is also affected by processing pressure. This is due in part to the fact that, at pressures below about 5 Torr, the heat transfer mechanism is mostly by radiation whereas, above about 10 Torr, the heat transfer mechanism involves a combination of radiation and convection.

In any event, the preceding discussion is set forth in order to further emphasize the difficulties in maintaining uniform surface temperatures throughout a substrate, particularly where the substrate is being processed at a variety of temperatures and/or pressures.

It is therefore an object of the invention to provide an improved heater assembly and method of operation for the heater assembly in the processing of substrates or wafers in order to overcome one or more problems as discussed above.

More specifically, it is an object of the invention to provide a heater assembly for use in the processing of substrates or wafers in order to develop and maintain a uniform elevated temperature throughout the substrate, the heater assembly including a dielectric heater base having a generally circular surface, a plurality of heater elements forming radially spaced and circumferentially extending segments which substantially cover the circular surface of the heater base, a heater shroud arranged in spaced apart relation from the heater element segments and intermediate the heater elements and the substrate, separate means for operating the plurality of heater elements and means for maintaining a blanket of inert gas adjacent the heater element segments.

Such a combination provides a multi-zone planar heater assembly and method of operation therefor permitting modification in heating patterns for the substrate in order to eliminate or minimize temperature profile effects as discussed above. In particular, the heater assembly may be provided with any number of heater element segments which are preferably radially separated and circumferentially extending in configuration. With such a heater configuration, the different heater element segments can be adjusted to achieve different heating temperatures in order to either compensate for or substantially eliminate temperature variations throughout the substrate.

The heater element segments are preferably formed from electrically conductive material or metal capable of resistance heating. The dielectric heater base is then preferably formed from a dielectric material having a similar coefficient of thermal expansion as the heater element segments while also being selected to resist separation from the heater elements and to remain dimensionally stable during rapid and extensive temperature variations. A particularly preferred combination of materials is a heater base formed from boron nitride with the heater element segments being formed from pyrolytic graphite.

In a preferred method of construction, the conductive material for the heater elements is uniformly deposited upon the heater base, circumferential regions of the conductive material then being removed, for example by machining, to define the radially spaced apart heater element segments. Each heater element segment is also preferably interrupted by a radially extending line or region so that electric contact can be made on opposite end portions of each heater segment for causing resistance heating.

It is yet a further object of the invention to provide a heater assembly and method of operation including means for maintaining an inert gas blanket over the heater element, for example, to prevent oxidation, etc. Preferably, a central opening in the heater base forms an inlet for the inert gas so that it flows radially outwardly over the heater elements. The inert gas can then be exhausted about the periphery of the heater shroud.

Preferably, the heater assembly is adapted for use in reactor chambers, more particularly in a CVD reactor chamber. For example, the heater assembly of the present invention is contemplated for use in a CVD deposition method as disclosed in a copending U.S. patent application Ser. No. 07/370,331 filed June 22, 1989 by the present inventor and entitled METHOD OF DEPOSITING SILICON DIOXIDE FILM AND PRODUCT. In addition, the heater assembly of the present invention is also contemplated for use within a CVD reactor chamber of the type disclosed in another copending U.S. patent application Ser. No. 07/386,903 filed July 28, 1989 by the present inventor and entitled CHEMICAL VAPOR DEPOSITION REACTOR AND METHOD OF OPERATION. Those two copending applications are accordingly incorporated herein by reference as though set forth in their entirety in order to assure a more complete understanding of the present invention.

It is a further related object of the invention to provide a method of operation for a heater assembly as summarized above. In both the heater assembly design and method of operation, it is contemplated that the means for regulating operation of the multiple heating elements and also the means for regulating flow of inert gas can be varied in order to facilitate processing of the wafer. In particular, by adjusting the heating effect of the different heater elements, temperature variations occurring diametrically across a substrate can readily be substantially eliminated or reduced to a satisfactory level, even for a wide variety of operating temperatures and/or pressures. Furthermore, heating capacities of the respective heating elements are selected in order to permit rapid heating of the substrate to greatly elevated temperatures in a very short period of time. For example, it is contemplated that the heater assembly of the present invention may be employed to heat a substrate or semiconductor wafer from ambient to a desired processing temperature, typically 1,000°-1,100° C., over a time interval of about one minute.

At the same time, the ability to adjust the flow rate and/or the type of inert gas even further enhances versatility of the heater assembly. For example, in addition to preventing oxidation, increased inert gas flow may be provided, for example, between processing operations in order to more rapidly cool down both the heater assembly and the substrate to facilitate interchange of substrates where sequential operations are contemplated.

Additional objects and advantages of the invention are made apparent in the following description having reference to the accompany drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a plan view of the heater assembly with a substrate or silicon wafer in the form of a cylindrical disk being mounted thereupon.

FIG. **2** is a side view, with parts in section, taken along section line II—II of FIG. **1** in order better illustrate internal construction of the heater assembly.

FIG. **3** is a plan view of the heater assembly, similar to FIG. **1** but with the substrate and heater shroud removed to better illustrate a plurality of heating element segments.

FIG. **4** is a schematic representation of the heater assembly, generally in side view, arranged within a CVD reactor.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings and particularly FIGS. **1-3**, a heater assembly constructed according to the present invention is generally indicated at **10**. The heater assembly **10** is preferably adapted for use within a reactor such as that schematically indicated at **12** in FIG. **4**. The CVD reactor **12** may, for example, be of a type contemplated and described in greater detail within either of the copending references noted above. Accordingly, no further description of the CVD reactor or its general mode of operation is believed necessary within the scope of the present invention.

Referring particularly to FIG. **2**, the heater assembly **10** includes a water cooled, heater support monolith **14** capable of being mounted within a reactor chamber as illustrated in FIG. **4**.

A tubular riser **16** is centrally secured to the monolith with a heater support point **18** being mounted thereupon. Both the tubular riser **16** and heater support point **18** are preferably formed from nickel plated stainless steel in order to withstand contemplated high temperatures and to avoid introducing contaminants thereinto.

A disk-shaped heater base **20** formed from a suitable dielectric material as described in greater detail below is mounted upon the support plate **18** with a plurality of heater elements, collectively indicated at **22**, being arranged on a generally circular surface **24** of the heater base. Construction of the heater base **20** and heater elements **22** is described in greater detail below.

As for the overall construction of the heater assembly, a cover or shroud **26** is also supported by the monolith **14** in spaced apart relation from the heater elements **22**. Preferably, the shroud **26** is formed from a material such as quartz and includes means for supporting a substrate or silicon wafer **26** on its upper surface directly above the heater elements **22**.

The shroud **26** includes a flange or skirt extending downwardly in spaced apart relation about both the heater base **20** and support plate **18**. The skirt **30** is also

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.

WHAT WILL YOU BUILD? | **sales@docketalarm.com** | **1-866-77-FASTCASE**

Smarter legal research.