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(54) **INTERFEROMETER ENDPOINT MONITORING DEVICE**

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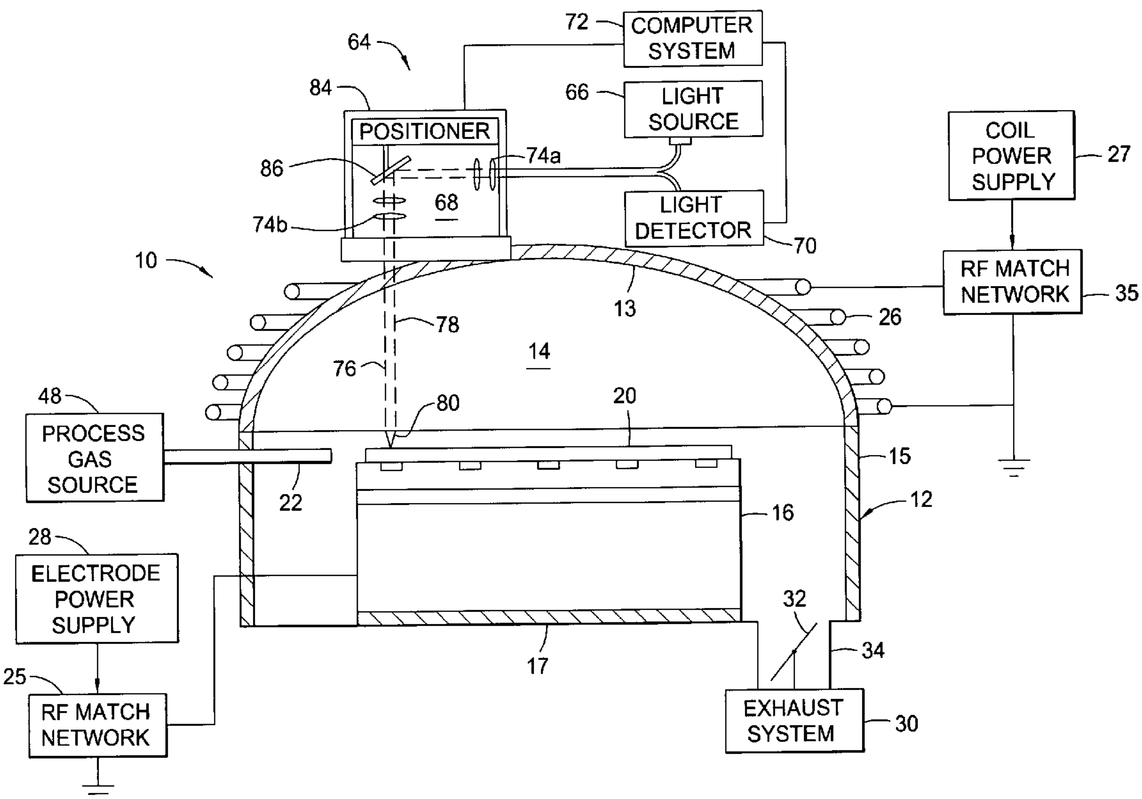
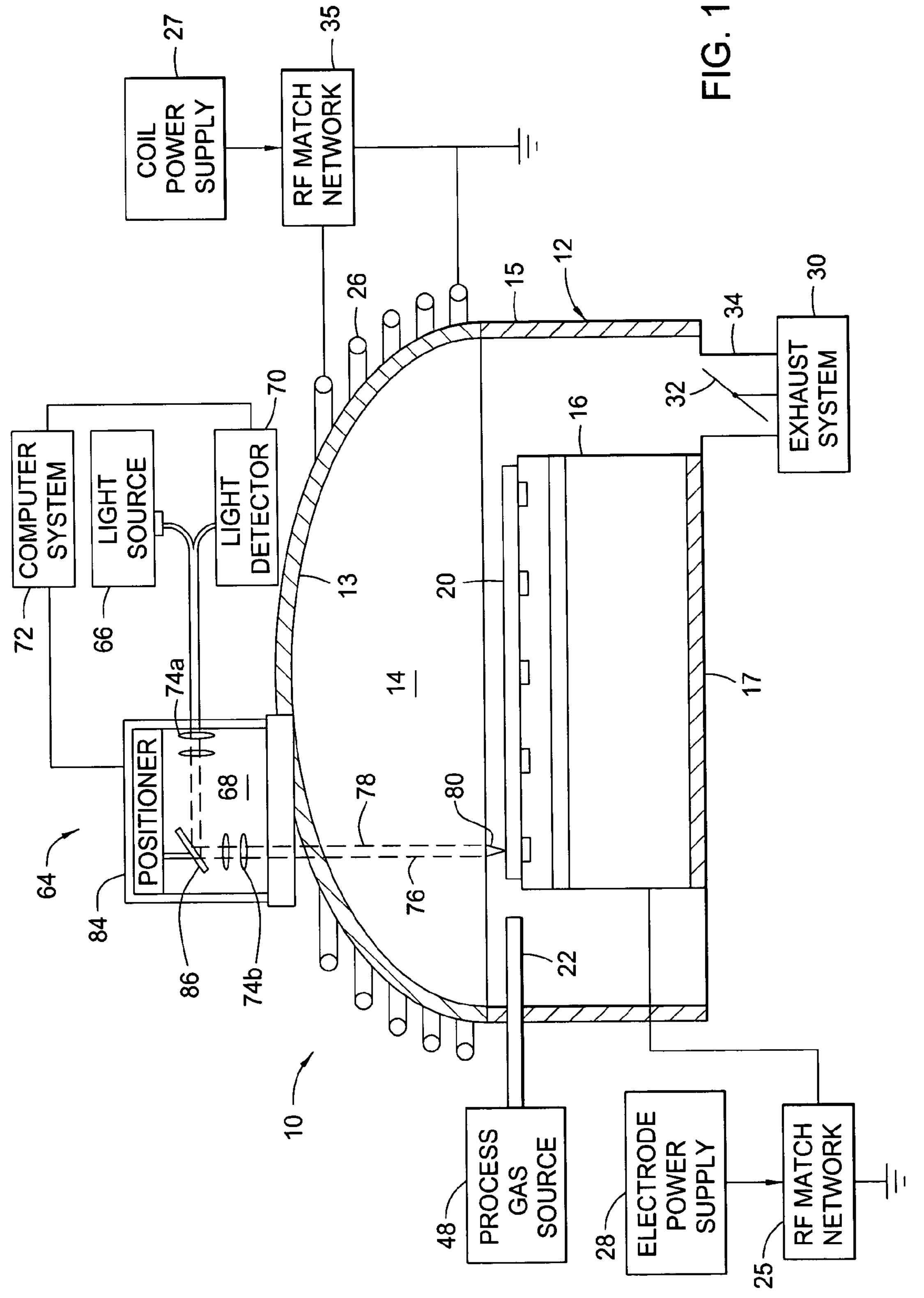
(57) **ABSTRACT**

A photomask etch chamber, which includes a substrate support member disposed inside the chamber. The substrate support member is configured to support a photomask substrate. The chamber further includes a ceiling disposed on the chamber and an endpoint detection system configured to detect a peripheral region of the photomask substrate.




COIL POWER SUPPLY
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RF MATCH NETWORK
35
COMPUTER SYSTEM
LIGHT SOURCE
LIGHT DETECTOR
70
72
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74a
POSITIONER
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74b
78
80
76
13
14
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26
15
12
16
17
22
32
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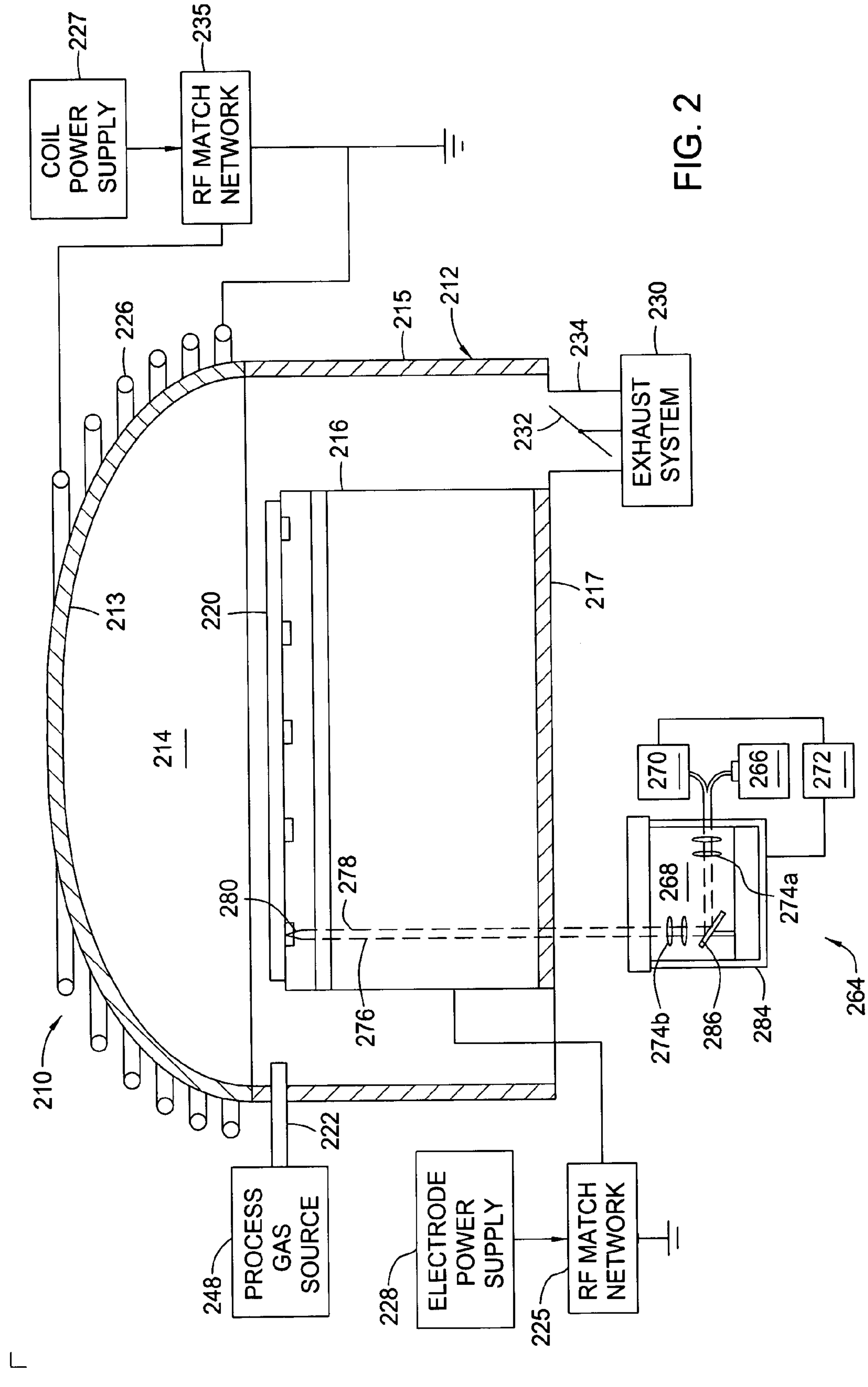
EXHAUST SYSTEM
30
10
PROCESS GAS SOURCE
48
ELECTRODE POWER SUPPLY
28
RF MATCH NETWORK
25

FIG. 1


COIL POWER SUPPLY
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RF MATCH NETWORK
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274a
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PROCESS GAS SOURCE
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ELECTRODE POWER SUPPLY
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RF MATCH NETWORK
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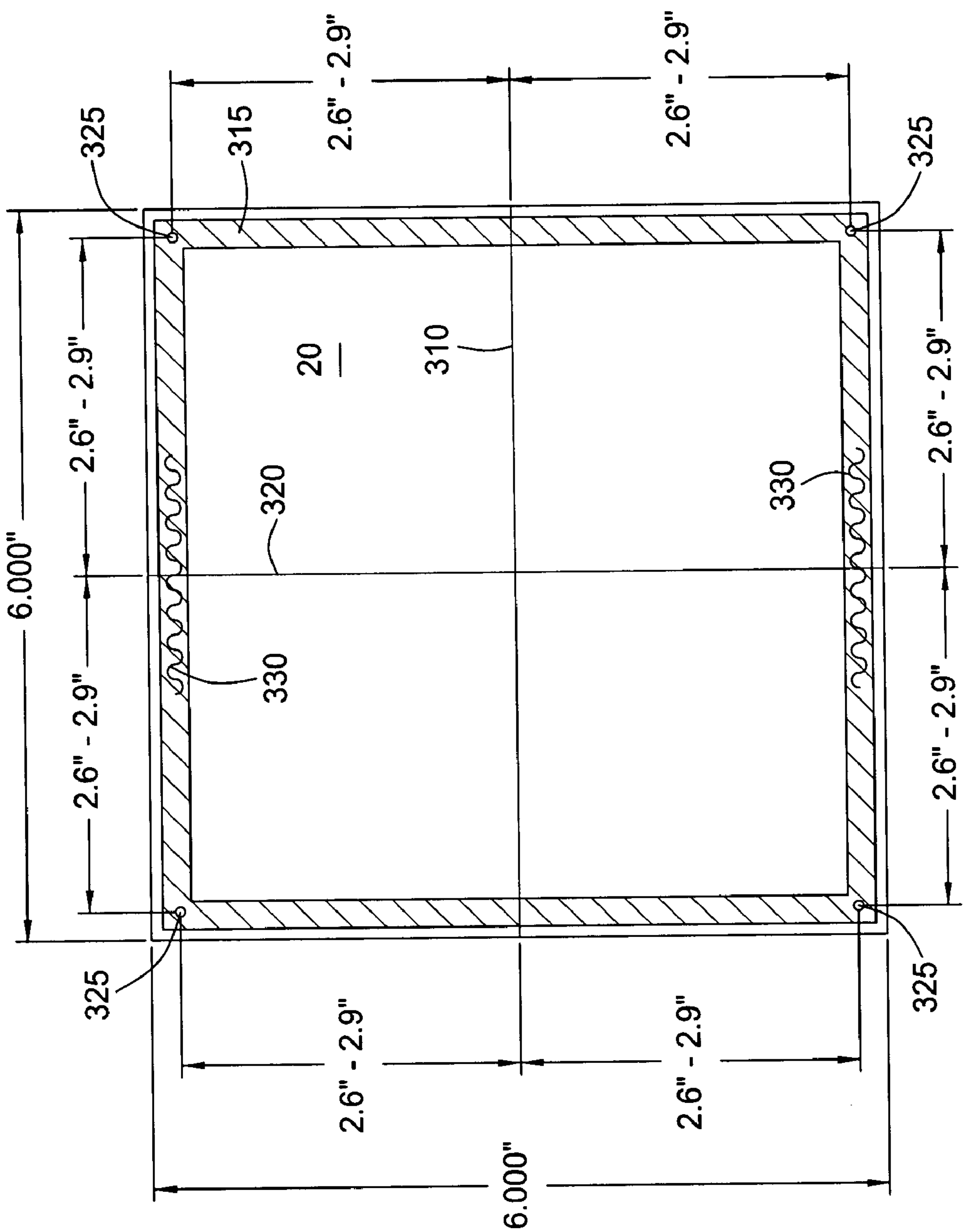
FIG. 2


325
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2.6" - 2.9"
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325
2.6" - 2.9"
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6.000"

FIG. 3

INTERFEROMETER ENDPOINT MONITORING DEVICE

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] Embodiments of the present invention generally relate to the fabrication of integrated circuits and to the fabrication of photomasks useful in the manufacture of integrated circuits.

[0003] b 2. Description of the Related Art

[0004] Semiconductor device geometries have dramatically decreased in size since such devices were first introduced several decades ago. Since then, integrated circuits have generally followed the two year/half-size rule (often called Moore's Law), which means that the number of devices on a chip doubles every two years. Today's fabrication plants are routinely producing devices having 0.15 μm and even 0.13 μm feature sizes, and tomorrow's plants soon will be producing devices having even smaller geometries.

[0005] The increasing circuit densities have placed additional demands on processes used to fabricate semi-conductor devices. For example, as circuit densities increase, the widths of vias, contacts and other features, as well as the dielectric materials between them, decrease to sub-micron dimensions, whereas the thickness of the dielectric layers remains substantially constant, with the result that the aspect ratios for the features, i.e., their height divided by width, increases. Reliable formation of high aspect ratio features is important to the success of sub-micron technology and to the continued effort to increase circuit density and quality of individual substrates.

[0006] High aspect ratio features are conventionally formed by patterning a surface of a substrate to define the dimensions of the features and then etching the substrate to remove material and define the features. To form high aspect ratio features with a desired ratio of height to width, the dimensions of the features are required to be formed within certain parameters, which are typically defined as the critical dimensions of the features. Consequently, reliable formation of high aspect ratio features with desired critical dimensions requires precise patterning and subsequent etching of the substrate.

[0007] Photolithography is a technique used to form precise patterns on the substrate surface. The patterned substrate surface is etched to form the desired device or features. Photolithography techniques use light patterns and resist materials deposited on a substrate surface to develop the patterns on the substrate surface prior to the etching process. In conventional photolithographic processes, a resist is applied on the layer to be etched, and the features to be etched in the layer, such as contacts, vias, or interconnects, are defined by exposing the resist to a pattern of light through a photolithographic reticle having a photomask layer disposed thereon. The photomask layer corresponds to the desired configuration of features. A light source emitting ultraviolet (UV) light or low X-ray light, for example, may be used to expose the resist to alter the composition of the resist. Generally, the exposed resist material is removed by a chemical process to expose the underlying substrate material. The exposed underlying substrate material is then etched to form the features in the substrate surface while the retained resist material remains as a protective coating for the unexposed underlying substrate material.

[0008] Photolithographic reticles typically include a substrate made of an optically transparent material, such as quartz (i.e., silicon dioxide, SiO2), having an opaque light-shielding layer of metal, typically chromium, disposed on the surface of the substrate. The light-shielding layer is patterned to correspond to the features to be transferred to the substrate. Generally, conventional photolithographic reticles are fabricated by first depositing a thin metal layer on a substrate comprising an optically transparent material, such as quartz, and depositing a resist layer on the thin metal layer. The resist is then patterned using conventional laser or electron beam patterning equipment to define the critical dimensions to be transferred to the metal layer. The metal layer is then etched to remove the metal material not protected by the patterned resist, thereby exposing the underlying material and forming a patterned photomask layer. Photomask layers allow light to pass therethrough in a precise pattern onto the substrate surface.

[0009] During processing, endpoint data from the patterns disposed on the photolithographic reticles may be used to determine whether the process meets the desired recipe. Each photolithographic reticle generally has its own set of patterns. Consequently, different photolithographic reticles operating under the same recipe generally yield different endpoint data, thereby making it difficult to determine whether the processing conditions in the chamber meet the desired recipe.

[0010] Therefore, a need exists in the art for an improved apparatus and method for generating endpoint data that would be consistent for each photolithographic reticle.

SUMMARY OF THE INVENTION

[0011] Embodiments of the present invention are generally directed to a photomask etch chamber, which includes a substrate support member disposed inside the chamber. The substrate support member is configured to support a photomask substrate. The chamber further includes a ceiling disposed on the chamber and an endpoint detection system configured to detect a peripheral region of the photomask substrate.

[0012] In one embodiment, the endpoint detection system is disposed through a peripheral region of the ceiling and positioned directly above the peripheral region of the photomask substrate.

[0013] In another embodiment, the endpoint detection system is disposed through a peripheral region of the substrate support member and positioned directly below the peripheral region of the photomask substrate.

[0014] In yet another embodiment, the endpoint detection system is an interferometer endpoint detection system.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] So that the manner in which the above recited features, advantages and objects of the invention are attained and can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

[0016] It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0017] **FIG. 1** illustrates a schematic cross sectional view of an inductively coupled plasma etch chamber in accordance with one embodiment of the invention.

[0018] **FIG. 2** illustrates an endpoint detection system in accordance with another embodiment of the invention.

[0019] **FIG. 3** illustrates a top view of a substrate in accordance with one embodiment of the invention.

[0020] While the invention is described herein by way of example for several embodiments and illustrative drawings, those skilled in the art will recognize that the invention is not limited to the embodiments or drawings described. It should be understood, that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the intention is to cover all modifications, equivalents and alternatives falling within the spirit and scope of the present invention as defined by the appended claims. The headings used herein are for organizational purposes only and are not meant to be used to limit the scope of the description or the claims.

DETAILED DESCRIPTION

[0021] **FIG. 1** is a schematic cross sectional view of an inductively coupled plasma etch chamber **10** in accordance with one embodiment of the invention. Suitable inductively coupled plasma etch chambers include the ETEC Tetra™ II photomask etch chamber available from ETEC of Hayward, Calif., or optionally, the Decoupled Plasma Source (DPS™) chamber available from Applied Materials, Inc., of Santa Clara, Calif. Other process chambers may be used in connection with embodiments of the invention, including, for example, capacitive coupled parallel plate chambers and magnetically enhanced ion etch chambers, as well as inductively coupled plasma etch chambers of different designs.

[0022] The processing chamber **10** generally includes a cylindrical sidewall or chamber body **12**, an energy transparent dome ceiling **13** mounted on the body **12**, and a chamber bottom **17**. The ceiling **13** may be flat, rectangular, arcuate, conical, dome or multi-radius shaped. An inductive coil **26** is disposed around at least a portion of the dome **13**. The chamber body **12** and the chamber bottom **17** of the processing chamber **10** can be made of a metal, such as anodized aluminum, and the ceiling **13** can be made of an energy transparent material such as a ceramic or other dielectric material.

[0023] A substrate support member **16** is disposed in the processing chamber **10** to support a substrate **20** during processing. The support member **16** may be a conventional mechanical or electrostatic chuck with at least a portion of the support member **16** being electrically conductive and capable of serving as a process bias cathode. While not shown, a reticle adapter may be used to secure the reticle on the support member **16**. The reticle adapter generally includes a lower portion milled to cover an upper portion of the support member and a top portion having an opening that is sized and shaped to hold a reticle. A suitable reticle adapter is disclosed in U. S. Pat. No. 6,251,217, issued on Jun. 26, 2001, which is incorporated herein by reference to the extent not inconsistent with aspects and claims of the invention.

[0024] Processing gases are introduced into the processing chamber **10** from a process gas source **48** through a gas distributor **22** peripherally disposed about the support member **16**. Mass flow controllers (not shown) for each processing gas, or alternatively, for mixtures of the processing gas, are disposed between the processing chamber **10** and the process gas source **48** to regulate the respective flow rates of the process gases.

[0025] A plasma zone **14** is defined by the process chamber **10**, the substrate support member **16** and the ceiling **13**. A plasma is formed in the plasma zone **14** from the processing gases using a coil power supply **27** which supplies power to the inductor coil **26** to generate an electromagnetic field in the plasma zone **14** through an RF match network **35**. The support member **16** may include an electrode disposed therein, which is powered by an electrode power supply **28** and generates a capacitive electric field in the processing chamber **10** through an RF match network **25**. Typically, RF power is applied to the electrode in the support member **16** while the body **12** is electrically grounded. The capacitive electric field is transverse to the plane of the support member **16**, and influences the directionality of charged species more normal to the substrate **20** to provide more vertically oriented anisotropic etching of the substrate **20**.

[0026] Process gases and etchant byproducts are exhausted from the process chamber **10** through an exhaust system **30**. The exhaust system **30** may be disposed in the bottom **17** of the processing chamber **10** or may be disposed in the body **12** of the processing chamber **10** for removal of processing gases. A throttle valve **32** is provided in an exhaust port **34** for controlling the pressure in the processing chamber **10**.

[0027] **FIG. 1** further illustrates an endpoint detection system **64** connected to the processing chamber **10** in accordance with one embodiment of the invention. The endpoint detection system **64** may be an interferometer endpoint (IEP) detection system. The endpoint detection system **64** is positioned through the peripheral portion of the ceiling **13**, i.e., over a peripheral portion of the substrate. In this manner, the endpoint detection system **64** has a direct line of sight to detect the peripheral region **315** of the substrate surface (shown in **FIG. 3**).

[0028] The endpoint detection system **64** generally comprises a light source **66** for emitting a light beam, a focusing assembly **68** for focusing an incident light beam **76**, which illuminates an area or spot **80** on the surface of substrate **20**, and a light detector **70** that measures the intensity of a reflected light beam **78**, which is reflected from the beam spot **80** on substrate **20** surface. A computer **72** calculates portions of the real-time measured waveform spectra of light reflected from the beam spot **80** on substrate **20** and compares these with a stored characteristic waveform pattern.

[0029] The light source **66** comprises a monochromatic or polychromatic light source that generates an incident light beam **76**, which illuminates a beam spot **80** on substrate **20**.

When the layer onto which the illuminated spot **80** is directed has a sufficient thickness, a reflected light beam **78** is reflected from beam spot **80**. The intensity of the incident light beam **76** is selected to be sufficiently high to provide a reflected light beam **78** which has a measurable intensity. In one version, the light source **66** provides polychromatic light, such as an Hg—Cd lamp, which generates an emission spectrum of light in wavelengths from about 200 nm to about 600 nm. The polychromatic light source **66** can be filtered to provide an incident light beam **76** having selected frequencies. Color filters can be placed in front of the light detector **70** to filter out all wavelengths except for the desired wavelength of light, prior to measuring the intensity of the reflected light beam **78** entering the light detector **70**. The light source **66** can also comprise a flash lamp or a monochromatic light source that provides a selected wavelength of light, for example, an He—Ne or ND-YAG laser.

[**0030**] One or more convex focusing lenses **74***a*, **74***b* may be used to focus an incident light beam **76** from the light source **66** to form a beam spot **80** on the substrate surface, and to focus the reflected light beam **78** back on the active surface of light detector **70**. The size or area of the beam spot **80** should be sufficiently large to compensate for variations in surface topography of the substrate **20** and device design features. This enables detection of etch endpoints for high aspect ratio features having small openings, such as vias or deep narrow trenches, which may be densely present or more isolated. The area of the reflected light beam should be sufficiently large to activate a large portion of the active light-detecting surface of the light detector **70**. The incident and reflected light beams **76**, **78** are directed through a transparent window **82** in the process chamber **10** that allows the light beams to pass in and out of the processing environment.

[**0031**] The diameter of the beam spot **80** is generally about 2 mm to about 10 mm. However, if the beam spot **80** encompasses large isolated areas of the substrate, containing only a small number of etched features, it may be necessary to use a larger beam spot in order to encompass a greater number of etched features. The size of the beam spot can therefore be optimized, depending on the design features for a particular device.

[**0032**] Optionally, a light beam positioner **84** may be used to move the incident light beam **76** across the substrate **20** to locate a suitable portion of the substrate surface on which to position the beam spot **80** to monitor an etching process. The light beam positioner **84** may include one or more primary mirrors **86** that rotate at small angles to deflect the light beam from the light source **66** onto different positions of the substrate surface. Additional secondary mirrors may be used (not shown) to intercept the reflected light beam **78** that is reflected from the substrate **20** surface and focus the reflected light beam **78** on the light detector **70**. The light beam positioner **84** may also be used to scan the light beam in a raster pattern across the substrate **20** surface. In this version, the light beam positioner **84** comprises a scanning assembly consisting of a movable stage (not shown), upon which the light source **66**, the focusing assembly **68** and the detector **70** are mounted. The movable stage can be moved through set intervals by a drive mechanism, such as a stepper motor, to move the beam spot **80** across the substrate **20** surface.

[**0033**] The light detector **70** comprises a light-sensitive electronic component, such as a photovoltaic cell, photodiode, or phototransistor, which provides a signal in response to a measured intensity of the reflected light beam **78** that is reflected from the substrate **20** surface. The signal can be in the form of a change in the level of a current passing through an electrical component or a change in a voltage applied across an electrical component. The reflected light beam **78** undergoes constructive and/or destructive interference which increases or decreases the intensity of the light beam, and the light detector **70** provides an electrical output signal in relation to the measured intensity of the reflected light beam **78**. The electrical output signal is plotted as a function of time to provide a waveform spectra having numerous waveform patterns corresponding to the varying intensity of the reflected light beam **78**.

[**0034**] A computer program on a computer system **72** compares the shape of the measured waveform pattern of the reflected light beam **78** to a stored characteristic waveform pattern and determines the endpoint of the etching process when the measured waveform pattern is the same as the characteristic waveform pattern. As such, the period of interference signal may be used to calculate the depth and etch rate. The program may also operate on the measured waveform to detect a characteristic waveform, such as, an inflection point. The operations can be simple mathematic operations, such as evaluating a moving derivative to detect an inflection point.

[**0035**] The endpoint detection system **64** is configured to detect patterns disposed in any region of the substrate surface. In one embodiment of the invention, the endpoint detection system **64** is used to detect the endpoint of one or more test patterns **330** disposed on the peripheral region **315** of the substrate surface or on the corners **325** of the substrate surface. As such, the endpoint detection system **64** may be disposed directly above the peripheral region **315** or corner regions **325** of the substrate surface. For example, in detecting a 6 inch by 6 inch substrate, the endpoint detection system **64** may be disposed about 2.6-2.9 inches from a horizontal center line **310** of the substrate **20** and about 2.6-2.9 inches from a vertical center line **320** of the substrate **20**, as illustrated in **FIG. 3**.

[**0036**] The light beams reflected from each substrate having the same test patterns are configured to have the same waveform patterns when detected by the endpoint detection system **64**. In this manner, the waveform patterns derived from the same test patterns may be used to determine whether the chamber is operating according to a particular recipe.

[**0037**] **FIG. 2** illustrates an endpoint detection system **264** in accordance with another embodiment of the invention. The endpoint detection system **264** is disposed through the substrate support member **216**. The endpoint detection system **264** comprises a light source **266** for emitting a light beam, a focusing assembly **268** for focusing an incident light beam **276**, which illuminates an area or spot **280** on the bottom surface of substrate **220**, and a light detector **270** that measures the intensity of a reflected light beam **278** that is reflected from the beam spot **280** on substrate bottom surface. A computer **272** calculates portions of the real-time measured waveform spectra of light reflected from the beam spot **280** on substrate **220** and compares these with a stored characteristic waveform pattern. Detailed description of the light source **66**, the focusing assembly **68**, the light detector **70**, the computer **72**, and other components of the endpoint detection system **64** may also apply to the light source **266**, the focusing assembly **268**, the light detector **270**, the computer **272**, and other components of the endpoint detection system **264**.

[**0038**] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A photomask etch chamber, comprising:

a substrate support member disposed inside the chamber, wherein the substrate support member is configured to support a photomask substrate;

a ceiling disposed on the chamber; and

an endpoint detection system configured to detect a peripheral region of the photomask substrate.

2. The chamber of claim 1, wherein the endpoint detection system is disposed through a peripheral region of the ceiling and positioned directly above the peripheral region of the photomask substrate.

3. The chamber of claim 1, wherein the endpoint detection system is disposed through a peripheral region of the substrate support member and positioned directly below the peripheral region of the photomask substrate.

4. The chamber of claim 1, wherein the endpoint detection system is an interferometer endpoint detection system.

5. A photomask etch chamber, comprising:

a substrate support member disposed inside the chamber, wherein the substrate support member is configured to support a photomask substrate;

a ceiling disposed on the chamber; and

an interferometer endpoint detection system disposed through a peripheral region of the ceiling.

6. The chamber of claim 5, wherein the interferometer endpoint detection system is disposed directly above a corner region of the photomask substrate.

7. The chamber of claim 5, wherein the photomask substrate is about 6 inches wide and about 6 inches long and the interferometer endpoint detection system is disposed about 2.8 inches from a horizontal center line and about 2.8 inches from a vertical center line of the photomask substrate.

8. The chamber of claim 5, wherein the interferometer endpoint detection system is disposed directly above a peripheral region of the photomask substrate.

9. The chamber of claim 5, wherein the interferometer endpoint detection system is configured to detect a peripheral region of the photomask substrate.

10. The chamber of claim 5, wherein the interferometer endpoint detection system is configured to detect one or more test patterns disposed on a peripheral region of the photomask substrate.

11. The chamber of claim 5, wherein the interferometer endpoint detection system is configured to detect one or more test patterns disposed on a corner region of the photomask substrate.

12. The chamber of claim 5, wherein the interferometer endpoint detection system comprises:

a light source for sending a light beam to a surface of the substrate; and

a light detector for measuring the intensity of the light beam reflected from the substrate surface.

13. The chamber of claim 5, wherein the interferometer endpoint detection system further comprises a focusing assembly for focusing the light beam to a spot on the substrate surface.

14. The chamber of claim 5, wherein the interferometer endpoint detection system further comprises a computer for calculating at least a portion of the waveform spectra of the reflected light beam.

15. The chamber of claim 14, wherein the computer is configured to compare the waveform spectra of the reflected light beam with a stored characteristic waveform spectra pattern.

16. A photomask etch chamber, comprising:

a substrate support member disposed inside the chamber, wherein the substrate support member is configured to support a photomask substrate; and

an interferometer endpoint detection system disposed through a peripheral region of the substrate support member.

17. The chamber of claim 16, wherein the interferometer endpoint detection system is disposed directly below a corner region of the photomask substrate.

18. The chamber of claim 16, wherein the photomask substrate is about 6 inches wide and about 6 inches long and the interferometer endpoint detection system is disposed about 2.8 inches from a horizontal center line and about 2.8 inches from a vertical center line of the photomask substrate.

19. The chamber of claim 16, wherein the interferometer endpoint detection system is disposed directly below a peripheral region of the photomask substrate.

20. The chamber of claim 16, wherein the interferometer endpoint detection system is configured to detect a peripheral bottom region of the photomask substrate.

21. The chamber of claim 16, wherein the interferometer endpoint detection system is configured to detect one or more test patterns disposed on a peripheral region of the photomask substrate.

22. The chamber of claim 16, wherein the interferometer endpoint detection system is configured to detect one or more test patterns disposed on a corner region of the photomask substrate.

* * * * *