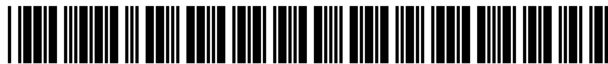
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Ouyang et al.

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(54) **LASER ANNEALING AND ELECTRIC FIELD**

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(51) **Int. Cl.**
H01L 21/027 (2006.01)
G03F 7/20 (2006.01)
G03F 7/16 (2006.01)

(52) **U.S. Cl.**
CPC ***G03F 7/2053*** (2013.01); ***G03F 7/168*** (2013.01)

(58) **Field of Classification Search**
CPC G03F 7/70691; G03F 7/3007; H01L 21/67225
USPC 430/328, 327
See application file for complete search history.

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(57) **ABSTRACT**

A method and apparatus for exposing a photoresist in the presence of an electric field using a high power continuous wave source as a radiation source is disclosed herein. In one embodiment, a processing region includes a stage, a translation mechanism, a continuous wave electromagnetic module, and plurality of electrode assemblies. The continuous wave electromagnetic module includes a continuous wave electromagnetic radiation source in the form of a high power continuous wave electromagnetic laser. An electric field is applied to the surface of the substrate using the plurality of electrode assemblies while the continuous wave electromagnetic radiation source selectively irradiates the surface of the substrate.

20 Claims, 9 Drawing Sheets

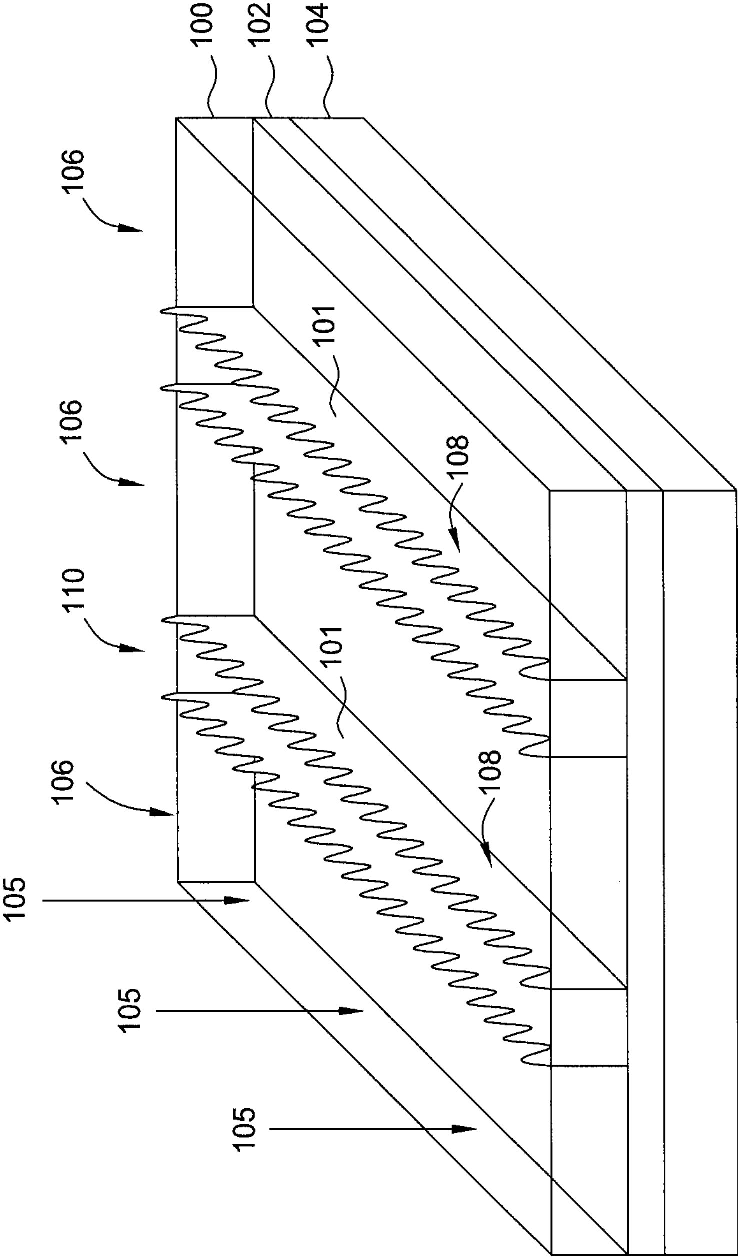

FIG. 1
(PRIOR ART)

200
202
201
232
208
201
232
236
212
224
218
220
222
210
214
238
204
230
216
230
234
206
206
228
236
234

FIG. 2A

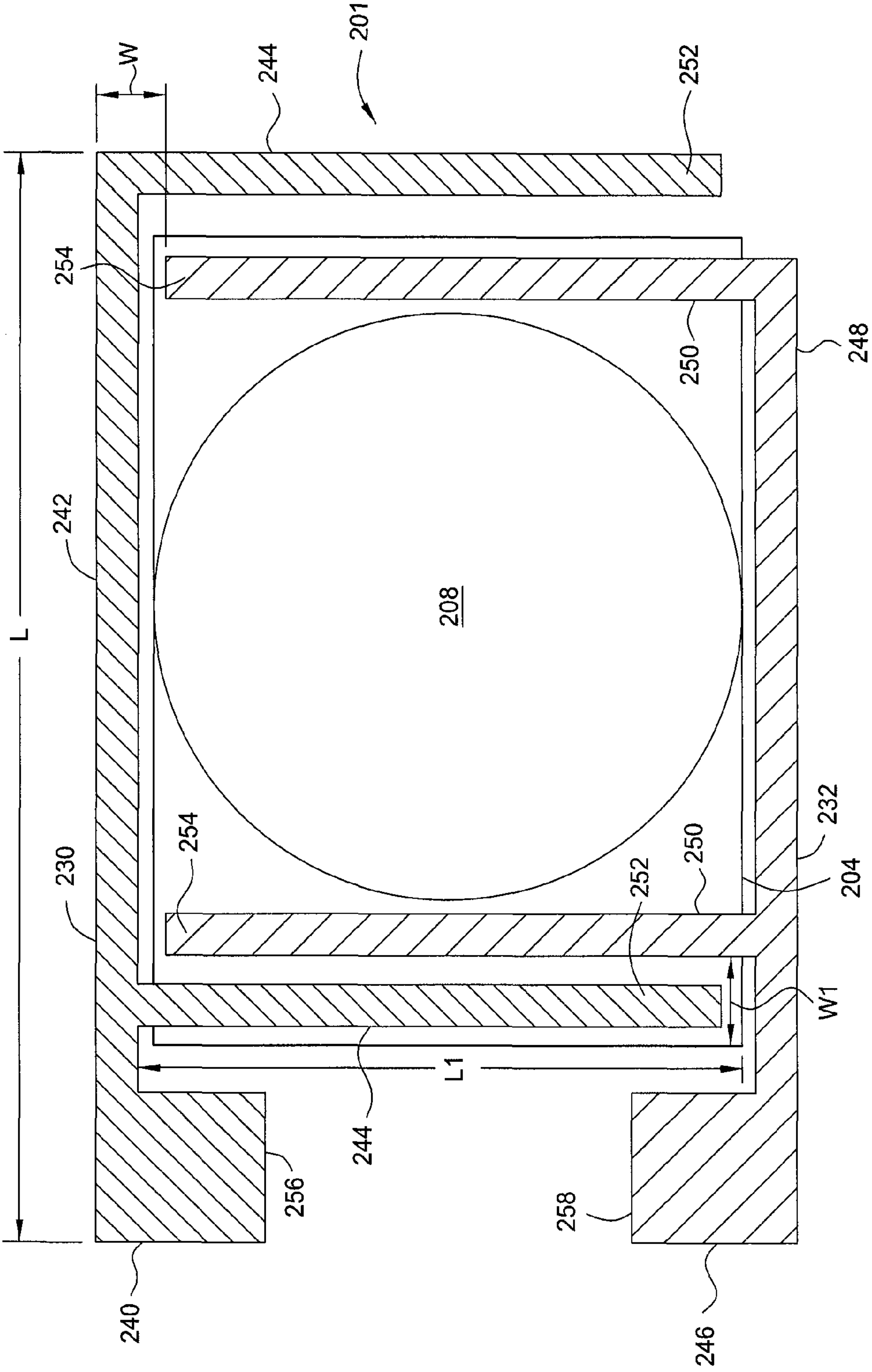

FIG. 2B

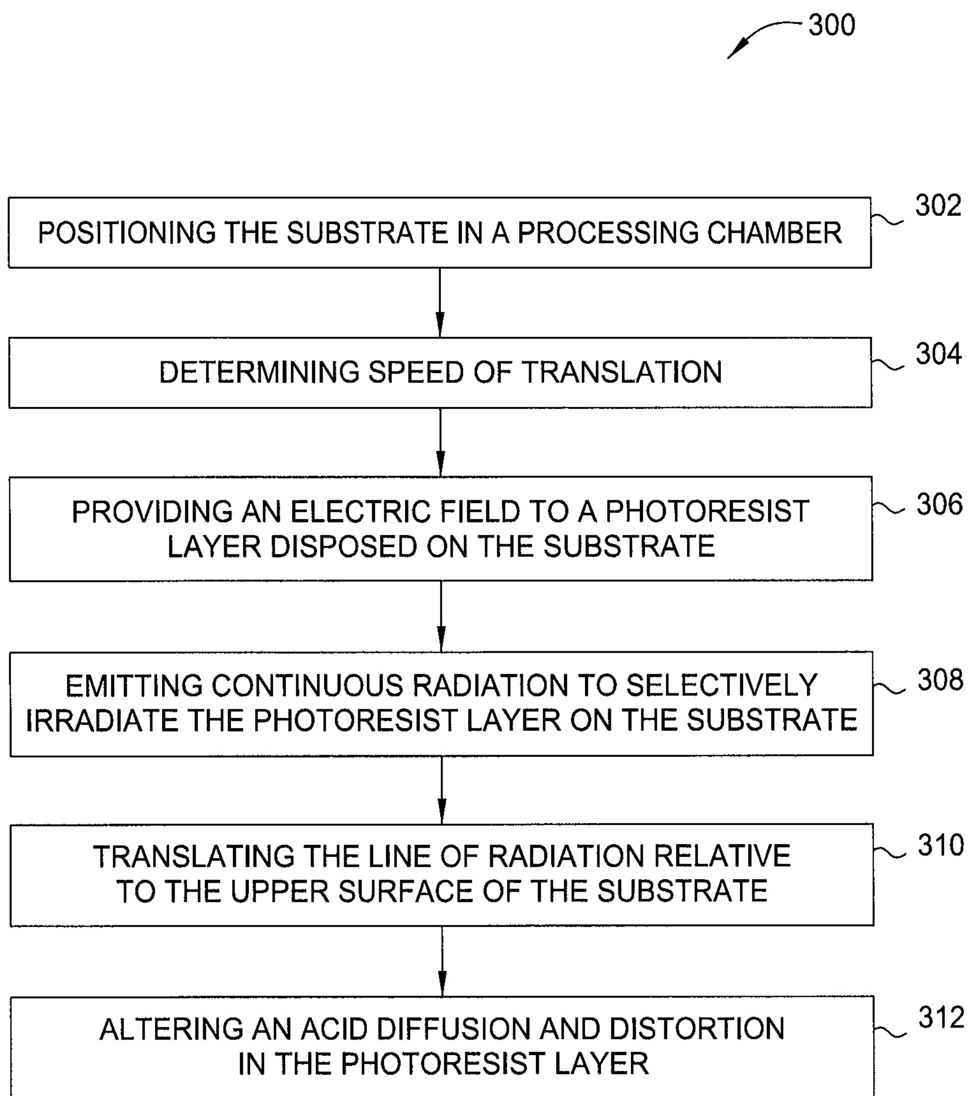

FIG. 3

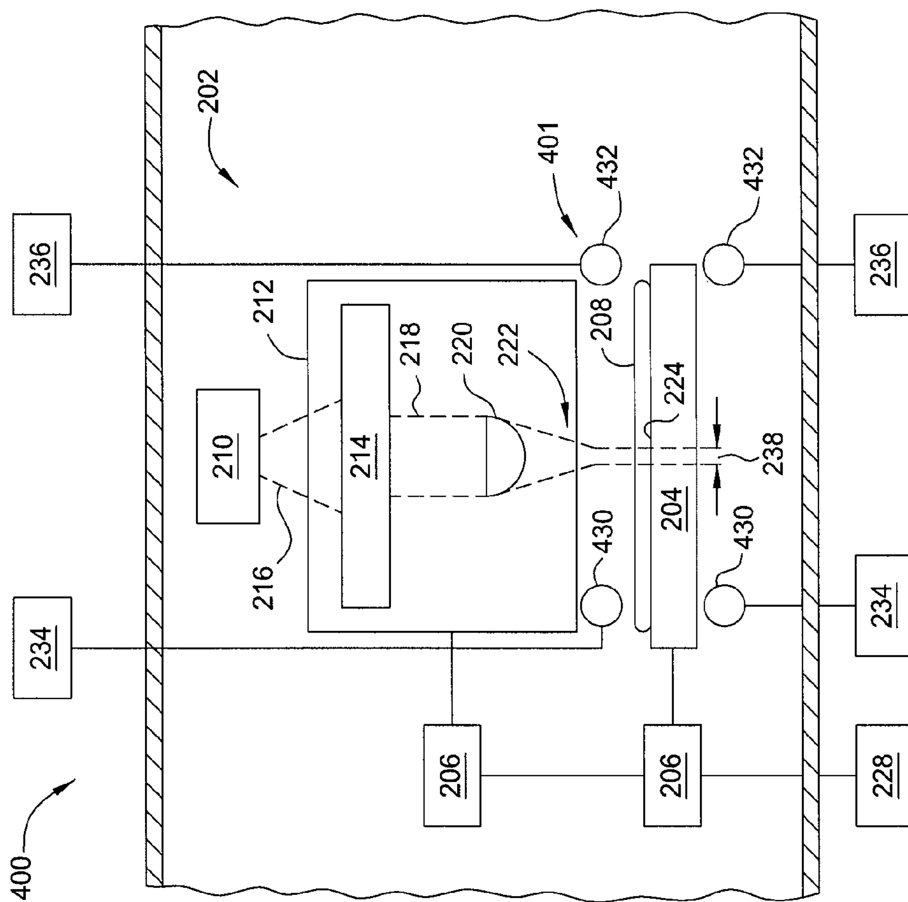

FIG. 4

FIG. 5

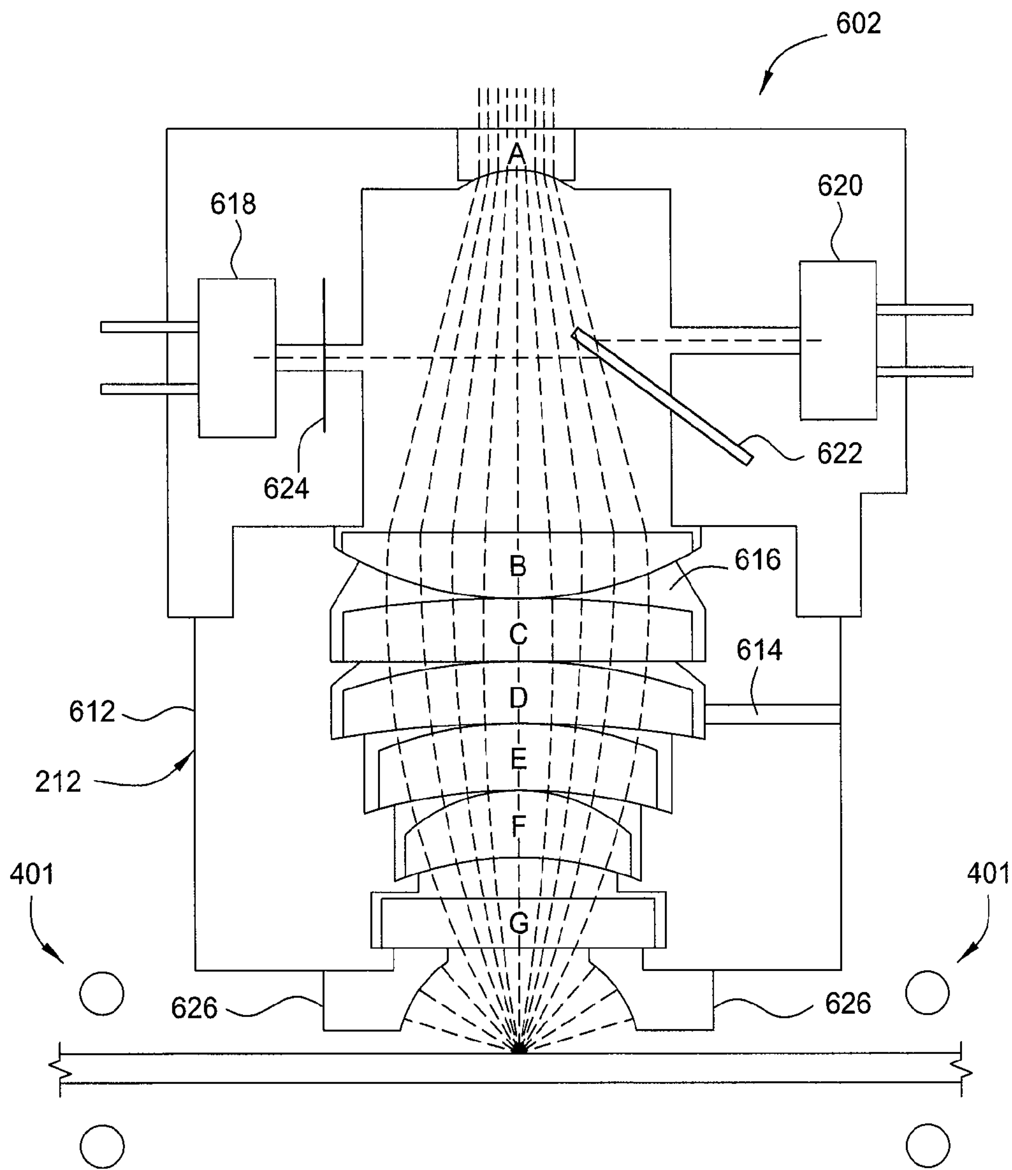

FIG. 6

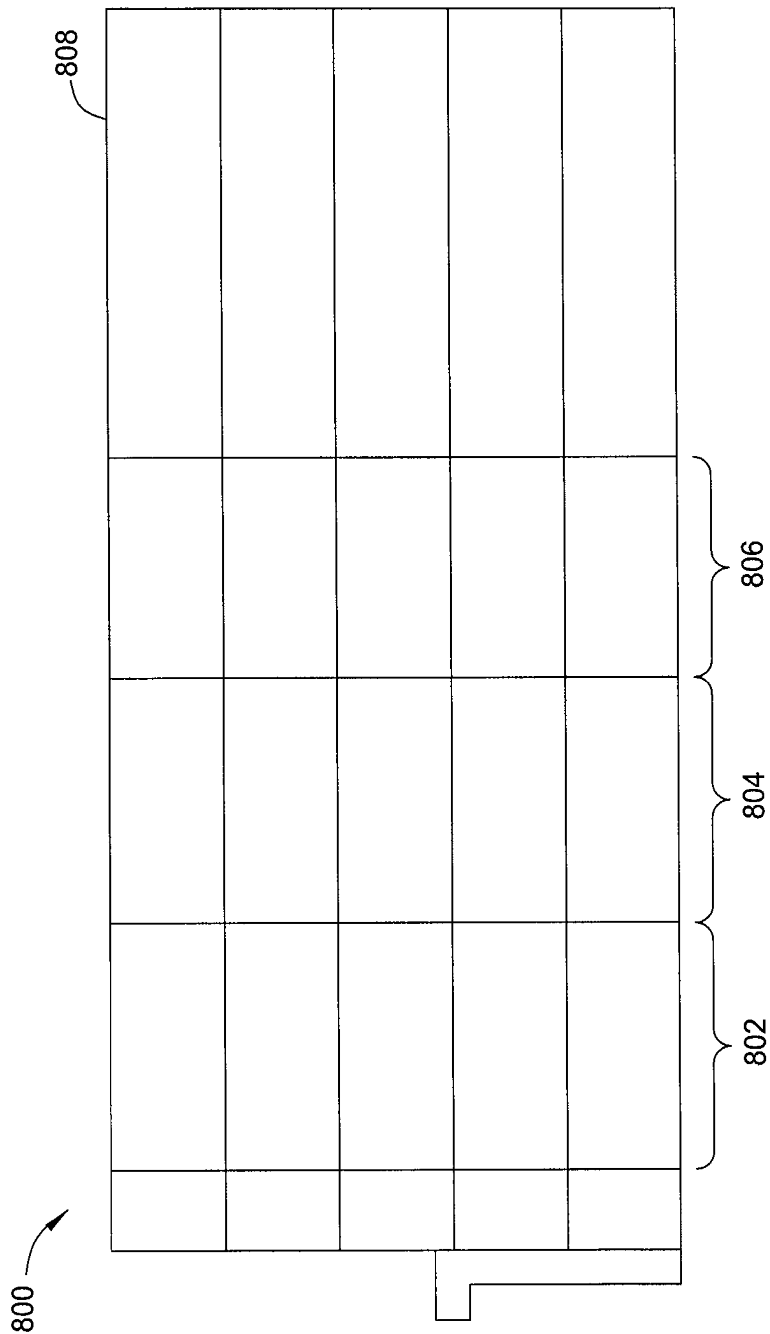

FIG. 8

LASER ANNEALING AND ELECTRIC FIELD

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority from U.S. Provisional Application Ser. No. 62/144,173, filed Apr. 7, 2015, which is hereby incorporated by reference in its entirety.

FIELD

The present disclosure generally relates to a method and apparatus for processing a substrate. Specifically, the present disclosure relates to a method and apparatus for controlling line width variability in a photoresist patterning process.

BACKGROUND

Integrated circuits have evolved into complex devices that can include millions of components (e.g., transistors, capacitors, and resistors) on a single chip. Photolithography may be used to form components on a chip. Generally the process of photolithography involves a few basic stages. Initially, a photoresist layer is formed on a substrate. The photoresist layer may be formed by, for example, spin-coating. A chemically amplified photoresist may include a resist resin and a photoacid generator. The photoacid generator, upon exposure to electromagnetic radiation in the subsequent exposure stage, alters the chemistry of the exposed portion of the photoresist, for example solubility or chemical reactivity, in the development process. The electromagnetic radiation may have any suitable wavelength, such as a wavelength in the extreme ultra violet region. The electromagnetic radiation may be from any suitable source, such as, for example, a 193 nm ArF laser, an electron beam, an ion beam, or other source. Excess solvent used during the coating process may be removed in a pre-exposure bake process.

FIG. **1** depicts a photoresist layer **100** on a material layer **102** formed on a substrate **104** during a prior art photolithography exposure process. Photoacid **108** is generated in an irradiated region **106** when a photoacid generator is exposed to a radiation **105**. The radiation **105** has an effect of forming latent image lines **101** in the photoresist layer **100**.

The photoacid **108** is primarily generated in the first region **106** of the photoresist layer **100** during light exposure processing. During the post exposure bake process, movement of the photoacid is generally random and the interface between areas within the photoresist layer **100** that include the generated photoacid **108** and areas that do not include the generated photoacid comprise an unclear boundary. For example, the random movement may result in at least a portion of the photoacid **108** diffusing into a second region **110** that may not be irradiated. The unintended diffusion may create undesired wiggling and/or an undesired roughness profile. As a result, the unintended diffusion may result in inaccurate feature transfer to the target material, which may lead to device failure and/or loss.

Therefore, there is a need for a method and apparatus to control edge straightness in latent image lines in the photoresist layer.

SUMMARY

In one embodiment, a processing chamber for processing a substrate is disclosed herein. The processing chamber includes a stage, a translation mechanism, a continuous wave electromagnetic module, and a plurality of electrode assemblies. The stage includes a substrate support surface. The translation mechanism is configured to translate the stage or the continuous wave electromagnetic radiation source. The continuous wave electromagnetic module is configured to heat a surface of the substrate. The continuous wave electromagnetic module includes a continuous wave electromagnetic radiation source. The continuous wave electromagnetic radiation source is a continuous wave electromagnetic laser. The plurality of electrode assemblies is configured to surround the stage and create an electric field about the substrate support surface.

In another embodiment, a method of processing a substrate is disclosed herein. The method includes applying a photoresist layer to a substrate positioned in a processing chamber; providing an electric field to the photoresist layer disposed on the substrate; scanning a surface of the substrate with a continuous wave electromagnetic radiation source, wherein the continuous wave electromagnetic radiation source is a continuous wave electromagnetic laser; and selectively irradiating the surface of the substrate with the continuous wave electromagnetic radiation source.

In another embodiment, a processing chamber for processing a substrate is disclosed herein. The processing chamber includes a stage, a translation mechanism, a continuous wave electromagnetic module, and a plurality of electrode assemblies. The stage includes a substrate support surface. The translation mechanism is configured to translate the stage or the continuous wave electromagnetic radiation source. The continuous wave electromagnetic module is configured to heat a surface of the substrate. The continuous wave electromagnetic module includes a continuous wave electromagnetic radiation source and a focusing optic. The continuous wave electromagnetic radiation source is a continuous wave electromagnetic laser. The focusing optic is disposed between the continuous wave electromagnetic radiation source and the stage. The plurality of electrode assemblies is configured to surround the stage and create an electric field about the surface of the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

FIG. **1** illustrates a photoresist layer on a material layer formed on a substrate during a prior art photolithography exposure process.

FIG. **2**A is a diagrammatic side view of a processing chamber where a thermal exposure process may be performed, according to an embodiment of the invention.

FIG. **2**B is a diagrammatic top view of the substrate and the stage of FIG. **2**A.

FIG. **3** depicts a flow diagram of a method for controlling photoacid distribution/diffusion in a photoresist layer during a post-baking process.

FIG. **4** illustrates another embodiment of a processing chamber where a post exposure bake procedure may be formed.

FIG. **5** illustrates another embodiment of a processing chamber where a post exposure bake procedure may be formed.

FIG. **6** is a more detailed side view of the focusing optic and the detection module of FIG. **2**A.

FIG. **7** depicts a photoresist layer on a material layer formed on a substrate during a photolithography exposure process with an electric field applied thereto.

FIG. **8** depicts a track lithography tool, according to one embodiment of the invention.

For clarity, identical reference numerals have been used, where applicable, to designate identical elements that are common between figures. Additionally, elements of one embodiment may be advantageously adapted for utilization in other embodiments described herein.

DETAILED DESCRIPTION

FIG. **2**A is a diagrammatic side view of a processing chamber **200** where a thermal exposure process may be performed, according to an embodiment of the invention. Thermally processing a substrate means conducting any thermal process that requires the characteristics of the invention described below. Exemplary embodiments of such a thermal process include thermal annealing of substrates or thermal processes used in chemical vapor deposition (CVD).

The processing chamber **200** includes a continuous wave electromagnetic radiation module **202**, a stage **204**, at least one electrode assembly **201**, and a translation mechanism **206**. The stage **204** is configured to receive a substrate **208** thereon. The continuous wave electromagnetic radiation module **202** includes a continuous wave electromagnetic radiation source **210** and focusing optics **212**. The focusing optics **212** are disposed between the continuous wave electromagnetic radiation source **210** and the stage **204**.

In one embodiment, the substrate **208** is any suitable substrate, such as a single crystal silicon substrate; silicon on insulator (S**01**); silicon germanium or alloys thereof; glass or quartz substrate with a silicon layer thereon, as used for manufacturing thin film transistors (TFT); or the like. The substrate may be coated with a photoresist material.

The continuous wave electromagnetic radiation source **210** is capable of emitting "continuous waves" or rays of electromagnetic radiation, such as light. By "continuous wave" it is meant that the radiation source is configured to emit radiation continuously, i.e. not a burst, pulse, or flash of radiation. In one embodiment, the continuous wave electromagnetic radiation source **210** is a high power continuous wave electromagnetic laser source may be used. The laser source may be one emitter of laser light or a plurality of laser emitters. In another embodiment, the continuous wave electromagnetic radiation source **210** may be a plurality of light-emitting diodes. The emitters may be selected based on emissivity of the resist material to be patterned. In such embodiments, wavelengths produced by the continuous wave electromagnetic radiation sources may be strongly absorbed by the substrate.

The electromagnetic radiation source **210** may be a solid state laser. In one embodiment, the laser is a neodymium doped yttrium aluminum garnet (Nd:YAG laser) frequency-doubled pulsed laser. For example, the Nd:YAG laser may have a wavelength of approximately **532** nm. In another embodiment, the laser source is a solid state laser. In other embodiments of solid state lasers, a titanium-sapphire (Ti: sapphire) laser, a neodymium glass (Nd:glass) laser, an yttrium glass (Yt:glass) laser, an alexandrite laser, a uranium calcium fluoride (U:CaF) laser, or the like, may be used. In another embodiment, the laser is a diode laser. In yet another embodiment, the electromagnetic radiation source **210** is an excimer laser. For example, a xenon fluoride (XeF) laser having a wavelength of 351 nm or a xenon chloride (XeCl) having a wavelength of 308 nm. In yet another embodiment, the electromagnetic radiation source **210** is a semiconductor laser. for example, a gallium nitride (GaN) laser.

In one embodiment, the continuous wave electromagnetic radiation source **210** is capable of emitting radiation continuously for at least about 300 sec. In another embodiment, the continuous wave electromagnetic radiation source **210** includes multiple laser diodes arranged, for example, in an array. Each laser diode may produce light at a wavelength of 810 nm. The radiation emitted by the continuous wave electromagnetic radiation source **210** may have any desired coherence length, divergence, or modality, and optics such as diffusers, homogenizers, mode scramblers, and the like may be used to increase uniformity and/or decrease coherence of the light, if desired.

In general, the continuous wave electromagnetic radiation source **210** may emit electromagnetic radiation in wavelengths from the deep UV to infrared at a fluence or power level selected to cause a chemical or physical reaction in the substrate. In the embodiments described herein, the continuous wave electromagnetic radiation source **210** delivers power from about 1 W to about 1 kW, such as from about 10 W to about 500 W, for example about 200 W.

The focusing optics **212** may include one or more collimators **214**. The collimators **214** collimate radiation **216** from the continuous wave electromagnetic radiation source **210** into a substantially parallel beam **218**. The collimate radiation **216** is then focused by at least one lens **220** into a line of radiation **222** at an upper surface **224** of the substrate **208**.

Lens **220** is any suitable lens, or series of lenses, capable of focusing radiation into a line. In one embodiment, lens **220** is a cylindrical lens. Alternatively, lens **220** may be one or more concave lenses, convex lenses, plane mirrors, concave mirrors, convex mirrors, refractive lenses, diffractive lenses, Fresnel lenses, Fourier lenses, gradient index lenses, f-θ lenses, or the like. The focusing optics **212** is described in further detail in FIG. **6**.

The stage **204** is any platform or chuck capable of securely holding the substrate **208** during translation. In one embodiment, the stage **204** includes a mean for grasping the substrate **208**, such as frictional, gravitational, mechanical, or electrical system. Examples of suitable means for grasping the substrate **208** include mechanical clamps, electrostatic or vacuum chucks, or the like.

The processing chamber **200** further includes a translation mechanism **206**. The translation mechanism **206** is configured to translate the stage **204** and the line of radiation **222** relative to one another. In one embodiment, the translation mechanism **206** is coupled to the stage **204** to move the stage **204** relative to the continuous wave electromagnetic radiation source **210** and/or the focusing optics **212**. In another embodiment, the translation mechanism **206** is coupled to both the continuous wave electromagnetic radiation source **210** and the focusing optics **212** to move the continuous wave electromagnetic radiation source **210** and/or the focusing optics **212** relative to the stage **204**. In another embodiment, the translation mechanism **206** moves the continuous wave electromagnetic radiation source **210**, the focusing optics **212**, and the stage **204**. Any suitable translation mechanism may be used, such as a conveyor system, rack and pinion system, or the like.

The translation mechanism **206** is preferably coupled to a controller **228**. The controller **228** controls the scan speed at which the stage **204** and the line of radiation **222** move relative to one another. Additionally, translation of the stage **204** and the line of radiation **222** relative to one another are preferably along a path perpendicular to the line of radiation **222** and parallel to the upper surface **224** of the substrate **208**. In one embodiment, the translation mechanism **206** moves at a constant speed. Preferably, the constant speed is approximately, for example, between 5 mm/s and 300 mm/s. In another embodiment, the translation mechanism **206** moves at a variable speed, for example, between 5 mm/s and 300 mm/s. In another embodiment, the translation of the stage **204** and the line of radiation **222** relative to one another are not along a path perpendicular to the line of radiation **222**.

The electrode assembly **201** is configured to provide an electric field to the substrate **208** as the substrate **208** is being processed in the processing chamber **200**. The electrode assembly **201** includes at least a first electrode **230** and a second electrode **232**. The first electrode **230** is coupled to a power source **234**. The second electrode **232** is coupled to a power supply **236**. Electrode assemblies **201** are provided both above the stage **204** and below the stage **204** in order to provide a desired electric field configuration. Thus, the electrode assemblies **201** are both above and below the substrate **208**. The electrode assemblies **201** are configured to generate an electric field to the upper surface **224** of the substrate **208**.

The power source **234** and the power supply **236** may have various characteristics in order to provide the electric field, as described above. For example, the power source **234** and the power supply **236** may be configured to 0~+/−60 kV.

FIG. **2**B is a diagrammatic top view of the substrate **208** and the stage **204**. In one embodiment, the substrate **208** is a circular substrate with a diameter of 200 or 300 mm, and a thickness of 750 microns. The line of radiation **222** extends across the substrate **208**. The line of radiation **222** has a width **238** of between about 1 mm and about 50 mm, for example about 12 mm. The width **238** is measured at half the maximum intensity of the radiation. The length of the line of radiation **222** may be longer than its width **238**.

The electrode assembly **201**, as shown in FIG. **2**B, includes at least the first electrode **230** and the second electrode **232**. The first electrode **230** includes a first terminal **240**, a first support structure **242**, and one or more antennas **244**. The second electrode **232** includes a second terminal **246**, a second support structure **248**, and one or more antennas **250**. The first terminal **240**, the first support structure **242**, and the antennas **244** may form a unitary body. Alternatively, the first electrode **230** may include separate portions that may be coupled together. The second electrode **232** may similarly be unitary body or be comprised of separate detachable components. The first electrode **230** and the second electrode **232** may be prepared by any suitable means. For example, the first electrode **230** and the second electrode **232** may be fabricated by machining, casting, or additive manufacturing.

The first support structure **242** may be made from a conductive material, such as metal. For example, the first support structure **242** may be made of silicon, polysilicon, silicon carbide, molybdenum, aluminum, copper, graphite, silver, platinum, gold, palladium, zinc, or other suitable material. The first support structure **242** may have any desired dimensions. For example, the length L of the first support structure **242** may be between about 25 mm and about 450 mm, for example, between about 200 mm and about 300 mm. In another embodiment, the first support structure **242** has a length L approximately equal to a diameter of a standard semiconductor substrate.

The second support structure **248** may be made of the same materials as the first support structure **242**. The range of dimensions suitable for the first support structure **242** is also suitable for the second support structure **248**. In some embodiments, the first support structure **242** and the second support structure **248** are made of the same material. In another embodiment, the first support structure **242** and the second support structure **248** are made of different materials. The lengths L, widths W, and thicknesses of the first support structure **242** and the second support structure **248** may be the same or different.

The one or more antennas **244** of the first electrode **230** may also be made from a conductive material. The one or more antennas **244** may be made from the same materials as the first support structure **242**. The one or more antennas **244** of the first electrode **230** may have any desired dimensions. For example, a length L1 of the one or more antennas **244** may be between about 25 and about 450 mm, for example, between about 200 mm and about 300 mm. In some embodiments, the one or more antennas **244** may have a length L1 equal to the diameter of the substrate **208**.

Each of the antennas **244** may have the same dimensions. Alternatively, some of the one or more antennas **244** may have different dimensions than one or more of the other antennas **244**. Each of the one or more antennas **244** may be made of the same material. In another embodiment, some of the antennas **244** may be made of a different material than other antennas **244**.

The antennas **250** may be made of the same range of materials as the antennas **244**. The range of dimensions suitable for the antennas **244** is also suitable for the antennas **250**. In some embodiments, the antennas **244** and the antennas **250** are made of the same material. In other embodiments, the antennas **244** and the antennas **250** are made of different materials. The lengths L**1**, widths W**1**, and thicknesses of the antennas **244** and the antennas **250** may be the same or different.

Each of the antennas **244** has a terminal end **252**. Each of the antennas **250** has a terminal end **254**. In another embodiment, the first electrode **230** has a first terminal **256**, and the second electrode **232** has a second terminal **258**. The first terminal **256** may be a contact between the first electrode **230** and the power source **234**, the power supply **236**, or a ground. The second terminal **258** may be a contact between the second electrode **232** and the power source **234**, the power supply **236**, or a ground. The first terminal **256** and the second terminal **258** are shown as being at one end of the first electrode **230** and the second electrode **232**, respectively.

In operation, a voltage may be supplied from a power supply, such as the power source **234** or the power supply **236**, to the first terminal **256** or the second terminal **258**. The supplied voltage creates an electric field between each antenna of the one or more antennas **244** and each antenna of the one or more antennas **250**. The spatial relationship of the antennas **244**, **250** produces an electric field predominantly in a direction parallel to the plane defined by the surface of the stage **204**. To create an electric field predominantly in the direction parallel to the plane defined by the surface of the stage **204**, the voltages of the electrodes **230**, **232** need to be set. The first electrodes **230** may have substantially the same voltage, which may be a positive voltage. The second electrodes **232** may also have substantially the same voltage, which may be a negative voltage.

The configuration shown in FIG. **2**B, in which two vertically aligned "positive" electrodes and two vertically aligned "negative" electrodes are present above and below the stage **204**, forms an electric field with desirable characteristics, in which the electric field is parallel to the surface of the stage **204**. The substrate **208** is positioned on the stage **204** such that the latent image lines are parallel to the electric field lines generated by the electrode assembly **201**. The charged species are affected by the electric field because the charged species are charged. The electric field drives the charged species generated by the photoacid generators in the photoresist layer in the direction of the electric field. The line edge roughness may be reduced by driving the charged species in a direction parallel with the latent image lines. In contrast, when a voltage is not applied to the first terminal **256** or the second terminal **258**, an electric field is not created to drive the charged species in any particular direction. As a result, the charged species may move randomly, resulting in increased line edge roughness.

In another embodiment, the electrodes **230**, **232** may be configured to form an electric field predominantly in a direction perpendicular to the plane defined by the surface of the stage **204**. To create an electric field predominantly in the direction perpendicular to the plane defined by the surface of the stage **204**, the voltages of the electrodes **230**, **232** may be set differently than in the prior embodiment. For example, the first electrodes **230** may have opposite voltages. For example, one first electrode **230** may have a positive voltage and the other first electrode **230** may have a negative voltage. The second electrodes **232** may also have opposite voltages. For example, one second electrode **232** may have a positive voltage and the other second electrode **232** may have a negative voltage. The configuration shown in FIG. **2**B, in which two horizontally aligned "positive" electrodes and two horizontally aligned "negative" electrodes are present above and below the stage **204**, forms an electric field with desirable characteristics, in which the electric field is perpendicular to the surface of the stage **204**.

In yet another embodiment, the electrodes **230**, **232** may be configured to form an electric field predominantly in a direction not perpendicular and not parallel to the plane defined by the surface of the stage **204**. Rather, the electrodes **230**, **232** are configured to form an electric field in a direction between 0 degrees and 90 degrees with respect to the plane defined by the surface of the stage **204**.

FIG. **3** depicts a flow diagram of a method **300** for controlling photoacid distribution/diffusion in a photoresist layer during a post-baking process. The method **300** begins at block **302** by positioning a substrate, such as substrate **208** described above, into a processing chamber, such as the processing chamber **200** in FIG. **2**A. At block **304**, a predetermined speed for translating a line of radiation is optionally determined. The predetermined speed is based on a number of factors, such as thermal recipe for processing the substrate, the properties of the substrate, a power of the continuous wave electromagnetic radiation, a width of the line of radiation, a power density at the line of radiation or the like.

At block **306**, after the substrate **208** is positioned on the stage **204**, an electric field is applied to the processing chamber to control the photoacid movement that occurs in a photoresist layer disposed on the substrate when the photoresist layer is heated by the continuous wave electromagnetic radiation source **210**. The photoacid that is generated may move primarily in a single plane, to reduce the likelihood of the photoacid diffusing into a region in which photoacid is not intended to be included. By utilizing directional control of photoacid distribution, a photoresist layer with a well-defined edge profile having substantially no blurring, having high resolution, and having reduced line edge roughness may be obtained.

At block **308** a continuous wave electromagnetic radiation is emitted from a continuous wave electromagnetic radiation source **210** as described above. The continuous wave electromagnetic radiation is used to selectively irradiate the photoresist layer formed on the substrate **208**. The continuous wave electromagnetic radiation is preferably collimated by the collimator **214**. The continuous wave electromagnetic radiation is subsequently focused into a line of radiation **222** extending across the upper surface **224** of the substrate **208**. In one embodiment, the width **238** of the line of radiation **222** is approximately 12 mm. The line of radiation is then translated at block **310** relative to the upper surface **224** at the constant predetermined speed, as optionally determined in block **302**. The translation is undertaken by the translation mechanism **206** under the control of the controller **228**.

At block **312**, the irradiated portions on the surface of the substrate alter the acid diffusion and distribution in the photoresist layer such that latent image lines are formed in the photoresist layer. The electric field generated in block **306** aids in controlling the direction of the latent image lines such that the latent image lines have a well-defined edge profile. The result of method **300** can be seen in FIG. **7** below.

FIG. **4** illustrates another embodiment of a processing chamber **400** where a post exposure bake procedure may be formed. The processing chamber **400** is similar to the processing chamber **200** shown in FIGS. **2**A and **2**B. Like-named components are similar except for any differences described below.

The processing chamber **400** differs from the processing chamber **200** in its arrangement of the electrode assembly **401**. The electrode assembly **401** includes a first electrode **430** and a second electrode **432**. The electrode assembly **401** may be disposed in the processing chamber **400** such that the antennas (not shown) are perpendicular to the range of motion. Such positioning of the electrode assembly **401** may change the orientation of the electrode field over the upper surface **224** of the substrate **208**.

FIG. **5** illustrates another embodiment of a processing chamber **500** where a post exposure bake procedure may be formed. The processing chamber **500** is similar to the processing chamber **200** shown in FIGS. **2**A and **2**B. Like-named components are similar except for any differences described below.

The processing chamber **500** differs from the processing chamber **200** in its arrangement and location of the electrode assembly **501**. The electrode assembly **501** may be disposed exterior to the processing chamber **500**. Such positioning of the electrode assembly **501** allows for direct contact with the electrode assembly **501**. The electrode assembly **501** includes a first electrode **530** and a second electrode **532**.

FIG. **6** is a more detailed side view of the focusing optic **212** and the detection module **602**. The purpose of the focusing optic **212** is to focus continuous wave electromagnetic radiation emitted from the continuous wave electromagnetic radiation source **210** into a line of continuous wave radiation on the surface of the substrate **208**. In one embodiment, the focusing optics **212** includes a series of seven lenses, labeled as A-G. All of the lenses A-G are preferably cylindrical lenses having spherical, or Plano, figure. Such cylindrical lenses having spherical or Plano figure are selected for their relative ease, and low cost, of manufacture, as compared to cylindrical lenses having spherical or Plano

figure shown. In addition, besides focusing the line of continuous wave electromagnetic radiation, the totality of the cylindrical lenses significantly reduces any optical aberrations.

Also, in one embodiment, lens A is an expander lens that has a substantially optically flat entry side and a cylindrical exit side. The expander lens is used to expand the continuous wave electromagnetic radiation condensed by an interleave combiner for subsequent focusing by the remainder of the focusing lenses B-G. For example, in a preferred embodiment, the beam of continuous wave electromagnetic radiation is expanded to 10 nm wide and the fast axis divergence is reduced to less than 0.1 degree. The reduced divergence makes it possible to achieve a narrower line width. Once focused by the remainder of the lenses B-G, the resulting beam is approximately 10 nm [check this] wide at the surface of the substrate **208**.

The final lens G preferably has opposing substantially optically flat entry and exit sides, and acts as a quartz window to isolate the wafer environment from the lens environment. The final lens G also shifts the focus somewhat away from the radiation source.

The lenses A-G may be held in place within the focusing optics **212** by a frame **612**. In one embodiment, the frame **612** is made from machined stainless steel. The frame **612** also preferably includes some tolerances to ensure a robust system should the lenses not align in use, where any misalignment merely shifts the line of focus towards or away from the substrate surface (or it moves laterally). The shift in focus may then be adjusted by an automated focusing system (not shown). In addition, during one embodiment, purge gas may be pumped into the frame **612** and through a gas injector **614** into spaces **616** between the lenses A-G to keep the lenses A-G cool. The purge gas may be, for example, nitrogen.

The detection module **602** may include at least one reflected power detector **618** and at least one emitted power detector **620**. The at least one emitted power detector **620** is configured to detect a portion of the emitted continuous wave electromagnetic radiation emitted from the continuous wave electromagnetic radiation source, while the at least one reflected power detector **618** is configured to detect a portion of reflected continuous wave electromagnetic radiation reflected from the surface of the substrate **208**. The emitted power detector **620** monitors the output of the continuous wave electromagnetic radiation source **210**, while the reflected power detector **618** is used to detect reflectivity, emissivity, energy absorbed by the substrate, and/or the temperature of the substrate.

The beam splitter **622** is configured to sample a portion of the emitted continuous wave electromagnetic radiation by reflecting a portion of the emitted continuous wave electromagnetic radiation incident on a first substantially planar surface thereof towards the emitted power detector **620**. In one embodiment, a second planar surface (not shown) of the beam splitter **622**, opposite the first planar surface, is used to reflect continuous wave electromagnetic radiation reflected from the surface **224** of the substrate **208** towards the reflected power detector **618**. The beam splitter is preferably disposed between the continuous wave electromagnetic radiation sources **210** and stage **204**. The beam splitter **622** is also preferably coated with an anti-reflective coating, such as MgF. In use, the beam splitter **622** reflects or samples less than 1% of the continuous wave electromagnetic radiation emitted by the continuous wave electromagnetic radiation source **210**.

In use, the ratio of the detected emitted power to the detected reflected power provides a measurement of the absorption at the substrate. Absorption is the process by which radiant energy is absorbed, converted into other forms of energy, such as heat, and then reradiated at a longer wave length, according to Planck's law for thermal radiation.

In one embodiment, the emitted power detector **620** and the reflected power detector **618** detect continuous wave electromagnetic radiation. In one embodiment, at least one reflected power detector **618** is configured as a temperature detector to detect the temperature on the surface **224** of the substrate **208** at the line of continuous wave electromagnetic radiation **222**. To detect temperature, the temperature detector detects continuous wave electromagnetic wavelengths. Detecting the electromagnetic wavelengths is achieved by positioning a filter **624** between the reflected continuous wave electromagnetic radiation and the reflected power detector **618**.

The reflected power detector **618** and emitted power detector **620** also preferably include pinhole apertures (not shown) to maximize the single detected while minimizing the collection of any stray radiation that may be scattered within the optics due to the non-zero reflectivity of the lenses in the apparatus.

In one embodiment, which may include 15 and 16 opposing laser diode modules, 15 pairs of reflected power detectors **618** and emitted power detectors **620** are preferably provided. Every other reflected power detector **618** is preferably configured as a temperature detector, as described above.

In another embodiment, reflectors **626** are positioned between the focusing optics **212** and the substrate **208**. The reflectors **626** are configured to reflect radiation reflected from the surface of the substrate back to the line of continuous wave electromagnetic radiation. In a preferred embodiment, the reflectors **626** are cylindrical mirrors with center of curvature at the focus of the lens.

FIG. **7** depicts a photoresist layer **700** on a material layer **702** formed on a substrate **704** during a photolithography exposure process. As discussed above, an electric field from the electrode assembly **201** is applied during a post exposure baking process. In one embodiment, the electric field may be parallel to the surface of the substrate **704**. In another embodiment, the electric field may be perpendicular to the surface of the substrate **704**. In yet another embodiment, the electric field may be between 0 degrees and 90 degrees with respect to the surface of the substrate **704**. During the lithographic exposure process, radiation **705** is directed to an irradiated region **706** of the photoresist layer **700**. Photoacid **708** is generated in the irradiated region **706** in the photoresist layer **700** when photoacid generator is exposed to the radiation **705**, such that latent image lines **701** are formed in the photoresist layer **700**.

In a conventional process, photoacid is primarily generated in the irradiated region **706** of the photoresist layer **700** during the light exposure processing. During the post-exposure bake process, movement of the photoacid is generally random and the interface between areas within the photoresist layer **700** that include the generated photoacid and areas that do not include the generated photoacid comprise an unclear boundary. For example the random movement may result in at least a portion of the photoacid diffusing into a second region **710** that may not be irradiated. Such photoacid drift may result in line edge roughness, resolution loss, photoresist footing, and profile deformation, which may cause inaccurate transfer of features to the

underlying material layer **702**. The inaccurate transfer of features could lead to device failure.

By applying the electric field described above to the photoresist layer **700** during the post-exposure bake process, distribution of photoacid in the irradiated region may be efficiently controlled and confined. The electric field as applied to the photoresist layer **700** may move photoacid in vertical directions with minimal lateral motion. Thus, the photoacid generally does not diffuse into the adjacent second regions **710** that are not irradiated. Generally, photoacid has a certain polarity that may be affected by an electric field applied thereto. Such an applied electric field will orient photoacid molecules in directions that are in accordance with the electric field. When such electric field is applied the photoacid moves in a desired direction such that the photoacid generally does not cross into the second regions **710**.

FIG. **8** illustrates one embodiment of a track lithography tool **800**. The track lithography tool **800** is a cluster tool that may be used to deposit and develop a photoresist material. In one embodiment, the track lithography tool **800** includes a front end module **802**, a central module **804**, and a rear module **806**. The front end module **802** may be used to accept one or more cassettes (not shown) of substrates (not shown) that are to be processed in the track lithography tool. The front end module **802** also includes multiple processing chambers that are adapted to perform processing steps found in the substrate processing sequence. For example, the front end module **802** may include chambers such as a bake chamber, a chill chamber, or the like.

The central module **804** includes a plurality of processing chambers that are adapted to perform various processing steps in the substrate processing sequence. For example, the central module **804** may include a coater/developer chamber, a bake chamber, a chill chamber, or the like.

The rear module **806** includes a plurality of processing chambers that are adapted to perform various processing steps found in the substrate processing sequence. For example, the rear module **806** may include a coater developer chamber, a bake chamber, a chill chamber, or the like. In one embodiment, a robot (not shown) is adapted to transfer substrate between the rear module **806** and a stepper/scanner **808**. The stepper/scanner **808**, which may be purchased from Canon USA, Inc. of San Jose, Calif., Nikon Precision Inc. of Belmont, Calif., or ASML US, Inc. of Tempe, Ariz., is a lithographic projection apparatus used, for example, in the manufacture of integrated circuits (ICs). The stepper/scanner **808** exposes a photosensitive material (photoresist), deposited on the substrate in the track lithography tool **800**, to some form of electromagnetic radiation to generate a circuit pattern correspondent to an individual layer of the IC device to be formed on the substrate surface.

In one embodiment, the processing chamber **200**, **400**, or **500** may be placed in one of the modules **802**, **804**, **806** so that photoacid distribution/diffusion may be controlled in a photoresist layer during a post-baking process.

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

What is claimed is:

1. A processing chamber for processing a substrate, the processing chamber comprising:
- a stage with a substrate support surface;
- a continuous wave electromagnetic module configured to heat a surface of the substrate, the continuous wave electromagnetic module comprising:
  - a continuous wave electromagnetic radiation source, wherein the continuous wave electromagnetic radiation source is a continuous wave electromagnetic laser;
- a translation mechanism configured to translate the stage or the continuous wave electromagnetic radiation source; and
- a plurality of electrode assemblies surrounding the stage to create an electric field about the surface of the substrate support surface, wherein each electrode assembly includes a first electrode interleaved with a second electrode such that an opening is formed therebetween.

2. The processing chamber of claim **1**, wherein the continuous wave electromagnetic module further comprises:
- a focusing optic, wherein the focusing optic is disposed between the continuous electromagnetic wave source and the stage.

3. The processing chamber of claim **2**, wherein the focusing optic includes a collimator.

4. The processing chamber of claim **1**, wherein the plurality of electrode assemblies are positioned outside the processing chamber.

5. The processing chamber of claim **1**, wherein the plurality of electrode assemblies generate an electric field substantially parallel to the substrate support surface.

6. The processing chamber of claim **1**, wherein the plurality of electrode assemblies generate an electric field substantially perpendicular to the substrate support surface.

7. The processing chamber of claim **1**, wherein the plurality of electrode assemblies generate an electric field between 0 and 90 degrees with respect to the substrate support surface.

8. The processing chamber of claim **1**, wherein the plurality of electrode assemblies are positioned outside the processing chamber.

9. The processing chamber of claim **1**, wherein the plurality of electrode assemblies generate an electric field substantially parallel to the substrate support surface.

10. The processing chamber of claim **1**, wherein the plurality of electrode assemblies generate an electric field substantially perpendicular to the substrate support surface.

11. A method of processing a substrate, the method comprising:
- applying a photoresist layer to a substrate positioned in a processing chamber;
- providing an electric field to the photoresist layer disposed on the substrate with a plurality of electrode assemblies surrounding the substrate to create an electric field about a surface of the substrate, wherein each electrode assembly includes a first electrode interleaved with a second electrode such that an opening is formed therebetween;
- scanning a surface of the substrate with a continuous wave electromagnetic radiation source, wherein the continuous wave electromagnetic radiation source is a high power continuous wave electromagnetic laser; and
- selectively irradiating the surface of the substrate with the continuous wave electromagnetic radiation source.

12. The method of claim **11**, wherein providing an electric field to the photoresist layer disposed on the substrate comprises:
- generating an electric field substantially parallel to a surface of the substrate.

13. The method of claim **11**, wherein providing an electric field to the photoresist layer disposed on the substrate comprises:

generating an electric field substantially perpendicular to a surface of the substrate.

14. The method of claim **11**, wherein providing an electric field to the photoresist layer disposed on the substrate comprises:

generating an electric field between 0 degrees and 90 degrees with respect to a surface of the substrate.

15. The method of claim **11**, further comprising:

translating a line of radiation relative to the upper surface of the substrate.

16. The method of claim **11**, further comprising:

altering an acid diffusion in the photoresist layer.

17. The method of claim **11**, further comprising:

determining a speed of translation for the line of radiation.

18. A processing chamber for processing a substrate, the processing chamber comprising:

a stage with a substrate support surface;

a continuous wave electromagnetic module configured to heat a surface of the substrate, the continuous wave electromagnetic module comprising:

a continuous wave electromagnetic radiation source, wherein the continuous wave electromagnetic radiation source is a continuous wave electromagnetic laser; and

a focusing optic, wherein the focusing optic is disposed between the continuous wave electromagnetic radiation source and the stage;

a translation mechanism configured to translate the stage or the continuous wave electromagnetic radiation source; and

a plurality of electrode assemblies surrounding the stage to create an electric field about the surface of the substrate support surface, wherein each electrode assembly includes a first electrode interleaved with a second electrode such that an opening is formed therebetween.

19. The processing chamber of claim **18**, wherein the focusing optic includes a collimator.

20. The processing chamber of claim **18**, wherein the processing chamber is positioned in a track lithography tool.

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