ELECTROSTATIC CHUCK WITH PHOTO-PATTERNABLE SOFT PROTRUSION CONTACT SURFACE

RELATED APPLICATIONS

This application is a continuation of U.S. Application No. 13/667,516, filed November 2, 2012, which is a continuation-in-part of U.S. Application No. 13/266,657, filed October 27, 2011, which is the U.S. National Stage of International Application No. PCT/US2010/034667, filed on May 13, 2010, published in English, which claims the benefit of U.S. Provisional Application No. 61/216,305, filed on May 15, 2009. The entire teachings of the above applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

An electrostatic chuck holds and supports a substrate during a manufacturing process and also removes heat from the substrate without mechanically clamping the substrate. During use of an electrostatic chuck, the back side of a substrate, such as a semiconductor wafer, is held to the face of the electrostatic chuck by an electrostatic force. The substrate is separated from one or more electrodes in the face of the electrostatic chuck by a surface layer of material that covers the electrode. In a Coulombic chuck, the surface layer is electrically insulating, while in a Johnsen-Rahbek electrostatic chuck, the surface layer is weakly conducting. The surface layer of the electrostatic chuck may be flat or may have one or more protrusions, projections or other surface features that further separate the back side of the substrate from the covered electrode. Heat delivered to the substrate during processing can be transferred away from the substrate and to the electrostatic chuck by contact heat conduction with the protrusions and/or by gas heat conduction with a cooling gas. Contact heat conduction is generally more efficient than gas heat conduction in removing heat from the substrate. However, controlling the amount of contact between the substrate and the protrusions can be difficult.

as an alumina insulator, by a ceramic to ceramic bond 210. The ceramic to ceramic bond 210 may be formed of a polymer, such as polytetrafluoroethylene (PTFE) or modified PTFE (which includes PFA and/or FEP in addition to PTFE). Further, the ceramic to ceramic bond 210 may be formed of polymers such as perfluoroalkoxy (PFA), fluorinated ethylene-propylene (FEP) and polyether ether ketone (PEEK). Underneath the insulator 209 there is a thermally conductive bond 211 (which may be formed, for example, using TRA-CON thermally conductive epoxy, sold by Henkel AG & Co. KGaA of Düsseldorf, Germany) and a water cooled base 212. The adhesion coating 204 may extend down an edge of the electrostatic chuck (including down the edges of the gas seal rings) to form a metals reduction layer 213, which prevents beam strikes on the edges of the electrostatic chuck from causing aluminum particles to strike the substrate.

In accordance with an embodiment of the invention, the polyetherimide (PEI) used for the protrusions 201, charge control layer 202 or other components of the electrostatic chuck may be formed of unfilled amorphous polyether imide (PEI), in a thickness of between about 12 microns and about 25 microns. For example, PEI sold under the tradename ULTEM 1000 may be used, sold by Sabic Innovative Plastics Holdings BV. Where the protrusions 201 and/or charge control layer 202 or other components are formed of polyether ether ketone (PEEK), they may be made from unfilled PEEK, in a thickness of between about 12 microns and about 25 microns. For example, PEEK sold under the trade name Victrex® APTIV PEEK™ FILM, 2000-006 (unfilled amorphous grade) may be used, sold by Victrex U.S.A., Inc. of West Conshohocken, PA, U.S.A.

An electrostatic chuck featuring polymer protrusions and a polymer charge control layer in accordance with an embodiment of the invention may include features of the electrostatic chuck of U.S. Patent App. No. 12/454,336, filed on May 15, 2009, published as U.S. Patent Application Publication No. 2009/0284894, the teachings of which are hereby incorporated by reference in their entirety. In particular, features relating to equally spaced protrusions, trigonal pattern protrusions and low particle production may be included, and other features may also be included.

example as shown in the embodiments of FIGS. 8 and 9. For example, a grounding technique may include a conductive path covering at least a portion of a workpiece-contacting surface of a gas seal ring of the electrostatic chuck, the conductive path comprising at least a portion of an electrical path to ground. The conductive path may, for example, comprise diamond-like carbon or silicon carbide, and may have a surface resistivity of between about 10^5 ohms per square and about 10^7 ohms per square. Other conductive paths may be used that are taught in International Application No. PCT/US2011/050841, published as WO2012/033922, entitled "High Conductivity Electrostatic Chuck," the entire teachings of which are hereby incorporated herein by reference. For example, teachings related to conductive paths covering over the outside edges of electrostatic chucks may be used.

Although photo-patternable polymers are discussed herein, similar spray-coating methods may be used with other soft materials, in accordance with an embodiment of the invention. For example, conductive polymers, high chemical-resistance polymers, high temperature resistant polymers, and other materials may be spray coated with a shadow mask to make soft protrusions for electrostatic chucks. In one example, conductive polymers may be spray coated to form conductive soft embossments for a grounded electrostatic chuck. For example, the conductive polymers may comprise a blend of a carbon nanotube and a polymer (such as Entegris TEGO™ polymer, sold by Entegris, Inc. of Billerica, MA, U.S.A.); a carbon nanotube filled polycarbonate; and/or a conductive nanoparticle doped polymer. Such conductive polymer protrusions may be used with a wrap-around DLC coating for grounding of the electrostatic chuck, such as one of the conductive paths that are taught in International Application No. PCT/US2011/050841, published as WO2012/033922, entitled "High Conductivity Electrostatic Chuck," the entire teachings of which are hereby incorporated herein by reference. Various features of embodiments described herein may be combined; for example, heights and surface roughnesses of protrusions discussed herein may be obtained with a variety of different protrusions, including photo-patternable protrusions taught herein.

In addition, in accordance with an embodiment of the invention, polymers taught herein, including photo-patternable polymers, conductive polymers, high

chemical-resistance polymers and high temperature resistant polymers, may be used for protrusions on vacuum chucks and mechanical chucks.

In accordance with an embodiment of the invention, an electrostatic chuck is a Coulombic chuck. The dielectric can include aluminum, for example alumina or aluminum nitride. In a further embodiment according to the invention, an electrostatic chuck is a Johnsen-Rahbek electrostatic chuck. Alternatively, the electrostatic chuck may not be a Johnsen-Rahbek electrostatic chuck, and the dielectric may be chosen so that a Johnsen-Rahbek (JR) force or partial hybrid Johnsen-Rahbek force does not act on the wafer or substrate.

The teachings of all patents, published applications and references cited herein are incorporated by reference in their entirety.

While this invention has been particularly shown and described with references to example embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the scope of the invention encompassed by the appended claims.

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