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VENT GROOVE MODIFIED SPUTTER TARGET ASSEMBLYField of the Invention

[0001] This invention relates to a sputter target having certain vent groove configuration and an apparatus containing same. In particular, the groove configuration of the present invention reduces defect rate through a reduction in arcing and subsequent particle deposition onto the substrate.

Background of the Invention

[0002] In the manufacture of sputtering targets used for applications, such as in the semi-conductor industry, it is desirable to produce a target with a sputter surface that will provide film uniformity during sputtering onto a wafer. Physical vapor deposition is a widely used process by which a target is utilized for the deposition of thin layers of material onto desired substrates.

[0003] This process requires a gas ion bombardment of a target having a face formed of a desired material that is to be deposited as a thin film or layer on a substrate. Ion bombardment of the target not only causes atoms or molecules of the target materials to be sputtered, but imparts considerable thermal energy to the target. This heat is dissipated beneath or around a backing plate that is positioned in a heat exchange relationship with the target. The target forms a part of a cathode assembly that, together with an anode, is placed in an evacuated chamber filled with an inert gas, preferably argon. A high voltage electrical field

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is applied across the cathode and the anode. The inert gas is ionized by collision with electrons ejected from the cathode. Positively charged gas ions are attracted to the cathode and, upon impingement with the target surface, these ions dislodge the target material. The dislodged target material traverses the evacuated enclosure and deposits as a thin film on the desired substrate, which is normally located close to the anode.

[0004] Ideally the film deposited is highly uniform and defect free. However, a substantial number of unwanted blobs or splats of target material is formed on the substrate within conventional sputtering chambers. These defects are believed to result from a phenomenon known as arcing (in the event that arcing occurs, undesirable effects can occur to the target, such as pitting, flaking, cracking, and localized heating of the target material).

[0005] Conventional sputter deposition chamber typically employ sealing surfaces having grooves with sealing members such as o-rings disposed between the target assembly and the chamber wall so as to form a vacuum seal. Specifically, the sealing member is generally disposed between the sputter target assembly (i.e., the so-called race or race track) and the sidewalls of the vacuum chamber where the target assembly serves as the top or lid portion of the chamber. The gas may be trapped within the space created by the o-ring seal between the mating surfaces of the groove of such a sealing surface. Consequently, during the sputtering process, the trapped gas flows

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from the sealing surface grooves into the vacuum chamber, which leads to target arcing.

[0006] Various attempts have been made to reduce, eliminate or control the arcing phenomenon resulting from the trapped gas. Mostovoy et al in U.S. Patent No. 6,416,634 discloses a plurality of vent grooves configured to restrict the flow of gas from the o-ring race through certain restrictive openings. Other redesigns of the vent groove in an attempt to reduce the arcing have been proposed. As illustrated in Figs. 1A-1C the geometry of the vent groove has been modified by increasing the distance of the groove from the side wall, and increasing the width of the groove and a combination thereof. Unfortunately, none of these modifications have been found to be adequate to minimize the arcing and thereby the defects in the film deposited on the substrate.

[0007] To overcome the disadvantages associated with the related art, it is an object of the present invention to provide a new grooved vent configuration which is conducive to the removal of gases from the vacuum chamber during pump-down.

[0008] It is another object of the invention to provide vent grooves designed in a semi-circular cross-section with no sharp corners so as to minimize turbulence and not restrict gas flow.

[0009] Other objects and aspects of the present invention will become apparent to one of ordinary skill in the art upon review of the specification, drawings and claims appended hereto.

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SUMMARY OF THE INVENTION

[0010] A sputter target assembly including vent grooves having a certain configuration so as to reduce target arcing during the physical vapor deposition of a film.

Brief Description of the Drawings

[0011] The objects and advantages of the invention will be better understood from the following detailed description of the preferred embodiments thereof in connection with the accompanying figures wherein like numbers denote same features throughout and wherein:

[0012] Figs. 1A-C is a graphical representation of a sputter target assembly wherein the dimensions of the grooved vent have been varied;

[0013] Fig. 2 is a schematic diagram of a conventional magnetron sputtering system;

[0014] Fig. 3 illustrates a perspective view of target backing plate having a race-track which accommodates a sealing member and a vent groove disposed therein;

[0015] Figs. 4A depicts a schematic diagram of the vent groove in accordance with the present invention;

[0016] Fig. 4B illustrates a perspective view of a sputter target assembly having eight semi-circular conical grooves located in contact with the race track;

[0017] Fig. 4C is an actual representation of the sputter target manufactured in accordance with the invention; and

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[0018] Fig. 5 illustrates the performance results of the target assemblies with grooved semi-circular conical grooves as compared to the conventional grooves.

Detailed Description of the Invention

[0019] In the manufacture of thin films on substrates via a physical vapor deposition process, it is necessary to understand and minimize the arc-induced defects that occur during the process.

[0020] Illustrated in Fig. 2 is a conventional sputtering system 100 employing a sputter target assembly 105 is explained. The sputter target assembly includes a target 110 and a target backing plate 115 which extends beyond the perimeter of target 110, and includes a peripheral lip which interfaces with sidewall 120 to form sealed processing chamber 125. With reference to Fig. 3, the peripheral lip, or in certain cases the sputter target assembly 110 itself, includes a so-called "race", "race track" or groove 300, which is adapted to receive a sealing member such as an o-ring. It will be understood that the sealing member need not have an o-ring configuration, and may be made of any suitable material that would serve the sealing function.

[0021] The race track includes a number of vent grooves 310 which can be equally spaced on the inner side of the processing chamber 125. The vent grooves allow gas which would otherwise be trapped between the o-ring and the inner wall race track to be pumped therefrom as the processing region is pumped to a

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vacuum pressure, as discussed below. This trapped gas may result from many sources including outgassing of the o-ring, permeation of air from the ambient environment surrounding the sputtering system 100 through the o-ring toward the vacuum environment within the sputtering system 100, air trapped by the o-ring during venting of the sputtering system 100 to atmospheric pressure, etc. Without the aid of the grooved vents, the trapped gas would interfere with the seating of the o-ring within the race track; and proper seating of the o-ring within the groove 300 is essential for adequate sealing between the target backing plate 115 and the sidewall 120 during vacuum processing.

[0022] Referring back to Fig. 2, sputter system 100 includes a magnet 130 disposed above the target backing plate 115, and a switch 135 for connecting target backing plate 115 to a D.C. voltage source 140. A substrate support 145 is positioned below sputter target assembly 105 within the sealed processing chamber 125. The substrate support is adapted to support a semiconductor substrate 150 during processing within the sputter system 100.

[0023] During operation, a first lift mechanism 155 raise substrate 150 and the sealed process chamber 150 is evacuated to a pressure of about 2 to 5 milliTorrs (i.e., vacuum) via a vacuum pump (not shown). Switch 135 is closed and a large negative voltage (e.g., about 500 volts) is placed on the target assembly 105 relative the substrate support 145. A corresponding electric field is produced between the target assembly

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105 and the substrate support 145. An inert gas such as argon (Ar) is then introduced into the chamber. Positively charged argon ions (Ar⁺) such as argon ion 160 thereby are formed between the target assembly 105 and the semiconductor substrate 150. These positively charged argon ions accelerate toward and collide with the surface of the negatively charged target 110. As a result of these collisions, electrons are emitted from the target 110.

[0024] Each electron accelerates toward the substrate support 145 due to the electric field generated between the target assembly 105 and the substrate support 145, and due to magnetic fields generated by the magnet 130, travels in a spiral trajectory. The spiraling electrons eventually strike argon atoms above the substrate so as to generate additional positively charged argon ions that accelerate toward and strike the target 110. Additional electrons thereby are admitted from the target 110, which generate additional positively charged argon ions, which generate additional electrons, etc. This feedback process continues until a steady-state plasma is produced above the substrate support 145.

[0025] As the plasma reaches steady state, an area essentially free of charged particles, forms between the surface of target 110 and a top boundary of the plasma and individual electrons emitted from target 110 are believed to tunnel (e.g., in a wave form rather than in a particle form) so as to maintain this large voltage differential. As described further below,

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occasionally the plasma is breached and a large flux of charged particles (similar to a flow of current) travels through the plasma (i.e., an arc is produced).

[0026] In addition to electrons, due to momentum transfer between the argon ions and the target 110, target atoms are ejected or "sputtered" from target 110. The sputtered target atoms travel to and condense on the semiconductor substrate 200 forming a thin film of target material thereon. Ideally, this thin film is highly uniform and defect free. However, a substantial number of blobs or splats of target material (i.e., splat defects or splats) may appear within thin films formed by sputter deposition within a sputtering system that employs a conventional target backing plate having grooved vents therein.

[0027] Although not wanting to be limited to any particular theory, it is believed that these splat defects are formed as a result from arc-induced localized heating of target 110 that melts and liberates a portion of the target material. The liberated target material travels to the substrate 150, splatters thereon, cools and reforms, due to surface tension, as a splat defect in the deposited thin film. Splats are very large (e.g., 500 μm) in relation to typical metal line widths (e.g., less than 1 μm) and affect device yield by shorting metal lines. It is believed that up to 50% of the in-film defects produced in current interconnect metallization schemes are induced, splat-type defects.

[0028] It has been discovered that conventional vent grooves contribute to splat formation by initiating

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target arcing. In particular, it has been found that the use of a number of grooves having specific configuration leads to a concentrated flow of trapped gas from the o-ring to the processing region. The concentrated trapped gas flow produces a high trapped gas partial pressure toward the formed plasma. Because of the high voltage present across space between the target and the substrate during processing, the high trapped gas partial pressure within each vent groove increases the possibility for arcing to occur between the target surface and the top boundary of the plasma when the trapped gas exits the grooved vents and enters the processing region. For example, the trapped gas may leave the grooved vent with sufficient pressure to enter plasma with a density that leads to electrical breakdown of the trapped gas atoms. The likelihood of splat formation thereby is increased.

[0029] Fig. 4A is a schematic diagram of a vent groove configuration in accordance with the present invention. As discussed with respect to conventional sputter target assemblies include a backing plate having a lipped perimeter. However, the invention is equally applicable to non-lipped target assemblies, as described above. With reference to Figs. 4A and 4B, the target assembly includes a race-track 400 to accommodate a sealing member such as an o-ring therein. Unlike the conventional target backing plate 115 of Fig. 2, the groove of the inventive target backing plate has an inner wall 410 having a plurality of vent grooves 420 disposed therein, having a particular configuration. Although any number of equally spaced

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vent grooves may be utilized, preferably vent grooves 420 are an even number, so as to balance the removal of gas therefrom during the application of a vacuum (i.e., also referred to as "pump-down") to the process chamber. Most preferably, eight restrictive vent grooves are employed. The preferred configurations and dimensions of the vent grooves are discussed below with reference to Fig. 4C.

[0030] The invention may comprise any number of vent grooves, the configurations of which is designed to facilitate a quick and complete pump down operation, thereby reducing the arcing. More specifically, the geometry change of the vent grooves ensure that the vacuum side of the o-ring allows unobstructed flow of trapped air or gas during pump-down. As a result, the vent groove of the present invention, substantially decrease the concentration of trapped air that is vented by each grooved vent, decrease the partial pressure of the trapped gas vented to the processing region, and therefore reduce the possibility of arcing.

[0031] With reference to Fig. 4C, the vent grooves are disposed around the o-ring race in a geometry that maintains the integrity of the o-ring seal under high vacuum condition, but allows gas on the vacuum side of the o-ring to vent to the chamber. The vent grooves, preferably have a semi-spherical or semi-circular configuration with a variable cross-section in both the vertical and horizontal plane. The lack of sharp corners facilitates the unrestricted gas flow, and turbulence is minimized.

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[0032] As illustrated in Fig. 4C, the vent grooves are disposed on the perimeter of the target assembly. The vent grooves are placed on the race-track with the opening facing the processing region. The size of the vent grooves, can be adapted for the different size target assemblies and the respective chambers in which they are utilized. In a preferred embodiment, 8 semi-circular conical grooves are spaced at approximately equal distance around the perimeter of the race-track. Dimensions of the vent grooves can be adapted to the various size groove tracks, and in the preferred embodiment are machined to a dimension of 0.200 inches in diameter and a depth of about 0.080 inches. Naturally, the depth of the vent groove is such as not to meet the bottom level of the race track. The vent grooves are disposed at 45° between the o-ring groove inner diameter and the target sidewall.

Example

[0033] As illustrated in Fig. 5, the vent grooves configured in accordance with the present invention demonstrate reduced arcing as shown by the analyzed substrates. Lots of twenty five wafers were processed, where a layer of Al alloy material was deposited thereon. One lot was processed utilizing a target of the present invention having semi-spherical or semi-circular configuration vent groove, and three lots were prepared with target having a standard rectangular configuration vent groove. All the wafers were processed at a power of 13kW, with a pressure of 2.1 Torr in the chamber for a lifetime of 950 kWh (i.e.,

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until the target has been utilized to its maximum potential). As shown in the table, below, the Al alloy was deposited to a thickness of 4,000 Å and the defects were measured.

TABLE

Type of vent groove on the target	Tools	Processed Lot	Lot Defect	Ratio of Defects
Invention (semi-spherical configuration)	TSP 143	48	2	4%
Conventional (rectangular configuration)	TBM 150	54	7	13%
	TBM 144	92	17	18%
	TSP 145	63	9	14%
Normal Avg.		209	33	15%
Difference				11%

[0034] Thus, as illustrated in the table above the target of the present invention having semi-spherical grooves attains an 11% improvement in the elimination of defects which result from arcing. Similarly, these result are shown graphically in Fig. 5.

[0035] While the invention has been described in detail with reference to specific embodiments thereof, it will become apparent to one skilled in the art that various changes and modifications can be made, and equivalents employed, without departing from the scope of the appended claims.

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What is claimed is:

1. A sealing configuration of a physical vapor deposition system, comprising:

a track adapted to receive a sealing member, the track having a plurality of vent grooves configured in a semi-spherical or semi-circular fashion to allow the removal of substantially all trapped gases in the track during the pump-down of the physical vapor deposition system in order to achieve a vacuum therein, and reduce or eliminate arcing of the target during subsequent plasma processing.

2. The sealing configuration of claim 1, wherein the vent grooves have a variable configuration in both the vertical and horizontal plane.

3. The sealing configuration of claim 1, further comprising: at least four vent grooves disposed at approximately equal distance from one another on the periphery of the track.

4. The sealing configuration of claim 1, wherein the sealing member is an o-ring.

5. The sealing configuration of claim 1, wherein the sealing member provides an adequate seal between the target backing plate and the sidewall of a process chamber in said physical vapor deposition system.

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6. The sealing configuration of claim 1, wherein the vent grooves are machined to a dimension of 0.200 inches in diameter and a depth of about 0.080 inches.

7. The sealing configuration of claim 1, wherein the vent grooves are disposed at a 45° angle between the track's inner diameter and the target side wall.

8. A sputter target assembly of a physical vapor deposition system, the sputter target assembly comprising:

a target backing plate that includes a sealing surface, the sealing surface including a track adapted to receive a sealing member, the track including a number of openings configured in a semi-spherical or semi-circular fashion to allow the removal of substantially all trapped gases in the groove during the pump-down of the physical vapor deposition system in order to achieve a vacuum therein, and reduce or eliminate arcing of the target during subsequent plasma processing; and

a sputter target connected to the backing plate.

9. The sputter target assembly of claim 8, wherein the openings have a variable configuration in both the vertical and horizontal plane.

10. The sputter target assembly of claim 8, further comprising: at least four openings are disposed

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at approximately equal distance from one another on the periphery of the track.

11. The sputter target assembly of claim 8, wherein the sealing member is an o-ring.

12. The sputter target assembly of claim 8, wherein the sealing member provides an adequate seal between the target backing plate and the sidewall of a process chamber in said physical vapor deposition system.

13. The sputter target assembly of claim 8, wherein the openings are machined to a dimension of 0.200 inches in diameter and a depth of about 0.080 inches.

14. The sputter target assembly of claim 8, wherein the openings are disposed at a 45° angle between the track's inner diameter and the target side wall.