# SILICON NITRIDE LAYER FOR PANEL LEVEL PACKAGING REDISTRIBUTION LAYER

## BACKGROUND

### Field

**[0001]** Embodiments of the present disclosure generally relate to panel level packaging. More specifically, embodiments herein relate to a redistribution layer stack having a silicon and nitrogen containing barrier film and a method of forming the silicon and nitrogen containing barrier film.

### Description of the Related Art

**[0002]** Panel level packaging (PLP) is a more efficient and cost-effective method of semiconductor packaging as compared to traditional wafer-level packaging. PLP allows multiple chips to be processed simultaneously on a larger substrate than a traditional wafer. During the PLP process, layers of electrical interconnects, known as redistribution layers (RDLs), are used to redistribute electric signals from individual chips to the larger surface of the substrate, often through the use of copper interconnects. As RDLs are stacked on top of each other, smaller line and/or space design (high wiring density) is desirable to improve signal and power integrity. Over the copper interconnects and a base layer of an RDL stack, an insulation layer is disposed to isolate the copper interconnects. However, the insulation layer may not adhere to the copper interconnects and the base layer. Accordingly, what is needed in the art is an RDL stack having a silicon and nitrogen containing barrier film and a method of forming the silicon and nitrogen containing barrier film.

## SUMMARY

**[0003]** In one or more embodiments, a device is provided. The device includes a carrier layer. A base layer is disposed over the carrier layer. The base layer has a first surface contacting the carrier layer, and a second surface opposite the first surface. The second surface has a plurality of pillars disposed thereon. A via having an interconnect therein is disposed through the base layer. A silicon and nitrogen containing barrier film is disposed between the insulation layer and each of the base layer, the interconnect, and the plurality of pillars. The silicon and nitrogen containing barrier film has a thickness of about 500 angstroms to about 4000 angstroms. The

silicon and nitrogen containing barrier film has a density of about 2 grams per cubic centimeter to about 2.5 grams per cubic centimeter.

**[0004]** In one or more embodiments, a method is provided. The method includes positioning a redistribution layer (RDL) in a processing chamber. The RDL has at least one of a copper interconnect and a copper pillar. The method further includes conducting a plasma treatment operation on the RDL. The plasma treatment operation includes flowing a first gas mixture including an ammonia ($NH_3$) precursor, a nitrogen ($N_2$) precursor, and a hydrogen ($H_2$) precursor, and applying a radio frequency (RF) power to the first gas mixture at a first power level. The processing chamber has an internal pressure and a process temperature of about 100° Celsius to about 300° Celsius. The method further includes depositing a silicon and nitrogen containing barrier film on the RDL. The silicon and nitrogen containing barrier film is deposited by maintaining the process temperature, the internal pressure, and the flow of the first gas mixture. A second gas mixture including a silane ($SiH_4$) precursor and the first gas mixture is flowed at a second flow rate. The RF power is increased to a second power level.

**[0005]** In one or more embodiments, a method is provided. The method includes positioning a redistribution layer (RDL) in a processing chamber. The RDL has at least one of a copper interconnect and a copper pillar. The method further includes conducting a plasma treatment operation on the RDL. The plasma treatment operation includes flowing a first gas mixture. The first gas mixture includes an ammonia ($NH_3$) precursor at a first flow rate, a nitrogen ($N_2$) precursor at a second flow rate, and a hydrogen ($H_2$) precursor at a third flow rate. The plasma treatment operation further includes applying a radio frequency (RF) power to the first gas mixture at a first power level. The processing chamber has an internal pressure and a process temperature of about 100° Celsius to about 300° Celsius. The method further includes depositing a silicon and nitrogen containing barrier film on the RDL. The silicon and nitrogen containing barrier film is deposited by maintaining the process temperature, the internal pressure, the first flow rate, the second flow rate, and the third flow rate. A second gas mixture is flowed. The second gas mixture includes a silane ($SiH_4$) precursor and the first gas mixture. The $SiH_4$ precursor is flowed at a fourth flow rate. The RF power is increased to a second power level.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0006]** 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 exemplary embodiments and are therefore not to be considered limiting of its scope, and may admit to other equally effective embodiments.

**[0007]** FIG. 1 is a schematic, cross-sectional view of a device, according to one or more embodiments.

**[0008]** FIG. 2 is a schematic, cross-sectional view of a processing chamber, according to one or more embodiments.

**[0009]** FIG. 3 is a flow diagram illustrating operations of a method for fabricating a device according to one or more embodiments.

**[0010]** FIG. 4A is a schematic, cross-sectional view of an RDL stack, according to one or more embodiments.

**[0011]** FIG. 4B is a schematic, cross-sectional view of an RDL stack with a silicon and nitrogen containing barrier film disposed thereon, according to one or more embodiments.

**[0012]** To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

## DETAILED DESCRIPTION

**[0013]** Embodiments of the present disclosure generally relate to panel level packages having a silicon and nitrogen containing barrier film disposed therethrough. A panel level package includes an RDL stack. An RDL stack has a carrier layer, and a base layer disposed on the carrier layer. The base layer has at least one copper interconnect disposed therethrough, and a plurality of copper pillars disposed thereon. A silicon and nitrogen containing barrier film is disposed over the base layer, copper

interconnects, and copper pillars. The silicon and nitrogen containing barrier film is a silicon nitride film having the chemical formula $SiN_x$, where x is in a range from about 1 to about 1.7. An insulation layer is disposed over the silicon and nitrogen containing barrier film. The silicon and nitrogen containing barrier film aids in adhesion of the insulation layer to the base layer, the interconnect, and the plurality of pillars. The silicon and nitrogen containing barrier film protects the base layer, interconnect, and the plurality of pillars by preventing the inter-diffusion of copper and oxygen atoms from the base layer, the interconnect, and the plurality of pillars to the insulation layer.

**[0014]** FIG. 1 is a schematic, cross-sectional view of a device 100, according to one or more embodiments. The device 100 is a panel level package. The device includes an RDL stack 101. The RDL stack 101 includes a carrier layer 102, base layer 104, at least one interconnect 106, and a plurality of pillars 107 disposed on the base layer 104.

**[0015]** The base layer 104 is disposed over the carrier layer 102. The carrier layer 102 may be a substrate. The carrier layer 102 may be made of glass or the like. The base layer 104 includes an organic material. The organic material includes, but is not limited to, a build-up film, a polymide, a photo imageable dielectric (PID), or combinations thereof.

**[0016]** The base layer 104 has a first surface 104a and a second surface 104b. The first surface 104a contacts the carrier layer 102. The first surface 104a is opposite the second surface 104b. The base layer 104 has at least one via 105 disposed therein. The at least one via 105 may extend from the first surface 104a to the second surface 104b of the base layer 104. An interconnect 106 is disposed in the at least one via 105 and on the second surface 104b. The interconnect 106 may extend through the via 105 above of the second surface 104b of the base layer 104. The interconnect 106 includes copper. Although one via 105 and one interconnect 106 are shown in FIG. 1, it should be understood that the device 100 may include any number of vias or interconnects. A plurality of pillars 107 are disposed on the second surface 104b. The plurality of pillars 107 may be disposed laterally to the interconnect 106. Each pillar of the plurality of pillars 107 may be a conductive material, such as copper or the like. Each pillar of the plurality of pillars 107 has a substantially smooth surface.

Although one plurality of pillars 107 is shown in FIG. 1, it should be understood that the device 100 may include any number of pluralities of pillars.

**[0017]** The device 100 may have a seed layer 108. The seed layer 108 may be formed on desired surfaces of the RDL stack 101. The seed layer 108 is disposed between the base layer 104 and the interconnect 106, throughout the interconnect 106, or between the second surface 104b and each pillar of the plurality of pillars 107. In some embodiments, seed layer 108 is disposed between the base layer 104 and the interconnect 106, throughout the interconnect 106, and between the second surface 104b and each pillar of the plurality of pillars 107. The seed layer 108 may be formed of a conductive material such as copper, tungsten, aluminum, silver, gold, or any other suitable materials or combinations thereof.

**[0018]** The insulation layer 110 may be disposed on the RDL stack 101. The insulation layer 110 is disposed over the base layer 104, the interconnect 106, and the plurality of pillars 107. The insulation layer 110 includes an organic material. The organic material includes, but is not limited to, a build-up film, a polymide, a photo imageable dielectric (PID), or combinations thereof. The insulation layer 110 and the base layer 104 may include a same material or a different material. The insulation layer 110 acts as a passivating layer on the RDL stack 101 and provides for electrical isolation between interconnects 106. The insulation layer 110 needs to adhere to the base layer 104, the interconnect 106, and the plurality of pillars 107 as it is disposed thereon. However, the interconnect 106 and the plurality of pillars 107 have a smooth surface that is difficult for the insulation layer 110 to bond to. The insulation layer 110 is formed by a process that creates only a physical bond between the insulation layer 110 and each of the base layer 104, the interconnect 106 and the plurality of pillars 107. For example, the insulation layer 110 may be formed by a lamination process. A physical bond does not provide adequate bond strength on the smooth surface of the interconnect 106 and plurality of pillars 107 for the insulation layer 110 to effectively bond to. A silicon and nitrogen containing barrier film 109 serves as an adhesive, aiding in the bonding of the insulation layer 110 to the interconnect 106 and the plurality of pillars 107. The silicon and nitrogen containing barrier film 109 provides a chemical bond between the insulation layer 110 and the interconnect 106 and plurality

of pillars 107. This chemical bond provides a stronger bond than a physical bond on smooth surface materials.

**[0019]** A silicon and nitrogen containing barrier film 109 is disposed between the base layer 104 and the insulation layer 110, between the interconnect 106 and the insulation layer 110, and between each pillar of the plurality of pillars 107 and the insulation layer 110. The silicon and nitrogen containing barrier film 109 aids in adhesion of the insulation layer 110 to the base layer 104, interconnect 106 and the plurality of pillars 107. The silicon and nitrogen containing barrier film 109 further protects the base layer 104, the interconnect 106, and the plurality of pillars 107 by preventing the inter-diffusion of copper and oxygen atoms from the base layer 104, the interconnect 106, and the plurality of pillars 107 to the insulation layer 110.

**[0020]** The silicon and nitrogen containing barrier film 109 is a silicon nitride film having the chemical formula $SiN_x$, where x is in a range from about 1 to about 1.7. For example, the silicon and nitrogen containing barrier film 109 may be a silicon mononitride (SiN) film or a silicon nitride ($Si_3N_4$) film. In some embodiments, the silicon and nitrogen containing barrier film 109 may be deposited to a thickness of about 500 angstroms to about 4,000 angstroms. For example, the silicon and nitrogen containing barrier film 109 may be deposited to a thickness from about 500 angstroms to about 1,000 angstroms, about 1,000 angstroms to about 2,000 angstroms, about 2,000 angstroms to about 3,000 angstroms, or about 3,000 angstroms to about 4,000 angstroms. In some embodiments, the silicon and nitrogen containing barrier film 109 may have a density from about 2 grams per cubic centimeter to about 2.5 grams per cubic centimeter. The density of the silicon and nitrogen containing barrier film 109 directly corresponds to less voids in the film. Having less voids provides for greater inter-diffusion prevention of copper and oxygen atoms from the base layer 104, the interconnect 106, and the plurality of pillars 107 to the insulation layer 110. A wet etch rate of the silicon and nitrogen containing barrier film 109 inversely corresponds to the density of the silicon and nitrogen containing barrier film 109. For example, a low wet etch rate corresponds to a high density. The silicon and nitrogen containing barrier film 109 may have a wet etch rate of 3000 angstroms per minute or less under a buffered oxide etching solution. A compressive stress of the silicon and nitrogen containing barrier film 109 directly corresponds to the density of the silicon and nitrogen

containing barrier film 109. For example, a high compressive stress value corresponds to a high density. The silicon and nitrogen containing barrier film 109 has a compressive stress of about 500 megapascal.

**[0021]** The silicon and nitrogen containing barrier film 109 is deposited via a method 300. The method 300 includes a plasma treatment operation and a plasma enhanced chemical vapor deposition (PECVD) operation. The plasma treatment operation includes positioning an RDL stack in a process chamber having an internal pressure and process temperature therein. A first gas mixture is supplied to the processing region. The first gas mixture includes an ammonia ($NH_3$) precursor, a nitrogen ($N_2$) precursor, and a hydrogen ($H_2$) precursor. The $NH_3$ precursor is flowed at a first flow rate into the input manifold. The $N_2$ precursor is flowed at a second flow rate into the input manifold. The $H_2$ precursor is flowed at a third flow rate into the input manifold. The first gas mixture ($NH_3$, $N_2$, H2) is formed in the input manifold. The first gas mixture is flowed from the input manifold into the processing region. A radio frequency (RF) power is applied to the first gas mixture to energize the gases into a plasma. The plasma treatment improves surface adhesion performance of the RDL stack for the silicon and nitrogen containing barrier film to be disposed thereon. The plasma treatment operation improves surface adhesion by cleaning the base layer, the interconnect, and the plurality of pillars and removing any native oxides disposed thereon. After the plasma treatment operation, a deposition operation is conducted. The deposition operation is a PECVD operation. During the deposition operation, the pressure within the process chamber, the processing temperature, the first flow rate, the second flow rate, and the third flow rate are maintained at the same level corresponding to the plasma treatment operation. A silane ($SiH_4$) precursor is flowed at a fourth flow rate into the input manifold. The $SiH_4$ precursor is added to the first gas mixture to form a second gas mixture. The second gas mixture is supplied to the processing region. The RF power is increased from the first power level to a second power level. The deposition operation disposes the silicon and nitrogen containing barrier film over the RDL stack.

**[0022]** FIG. 2 is a schematic, cross-sectional view of a processing chamber 200, such as a PECVD chamber, according to one or more embodiments. The process chamber 200 includes a chamber body 202. The chamber body 202 defines a

processing region 203 therein. The processing region 203 includes a pedestal 205 disposed therein. The pedestal 205 may support a RDL stack 101 thereon. The pedestal 205 has heater elements 206 disposed therein. A showerhead assembly 207 is coupled to the chamber body 202 and disposed within the processing region 203. The showerhead assembly 207 is disposed opposite the pedestal 205. An input manifold 208 is coupled to the chamber body 202, and is fluidly coupled to the showerhead assembly 207. A vacuum pump 209 is coupled to the chamber body 202.

**[0023]** A plurality of gas sources 210 are fluidly coupled to the input manifold 208. The plurality of gas sources 210 includes a first gas source 212, a second gas source 214, a third gas source 216, and a fourth gas source 218. Each gas source of the plurality of gas sources 210 is configured to provide a process gas to the input manifold 208 and through the showerhead assembly 207. According to one or more embodiments, which can be combined with other embodiments described herein, the process gas includes at least one or more of ammonia ($NH_3$) precursors, nitrogen ($N_2$) precursors, hydrogen ($H_2$) precursors, and silane ($SiH_4$) precursors.

**[0024]** The plurality of gas sources 210 have a respective plurality of flow controllers 220. A first flow controller 222 is disposed between the first gas source 212 and the input manifold 208. The first flow controller 222 may control the flow of an $NH_3$ precursor, for example, at a flow rate of about 1,000 standard cubic centimeters per minute (sccm) to about 3,000 sccm. This example flow rate is for a substrate with dimensions of 730 mm × 920 mm. Thus, the $NH_3$ precursor has a flow rate per unit area ratio of about 1:6.7 sccm per squared centimeters (sccm/$cm^2$) to about 3:6.7 sccm/$cm^2$. A second flow controller 224 is disposed between the second gas source 214 and the input manifold 208. The second flow controller 224 may control the flow of a $N_2$ precursor, for example, at a flow rate of about 3,000 sccm to about 12,000 sccm. This example flow rate is for a substrate with dimensions of 730 mm × 920 mm. Thus, the $N_2$ precursor has a flow rate per unit area ratio of about 3:6.7 sccm/$cm^2$ to about 12:6.7 sccm/$cm^2$. A third flow controller 226 is disposed between the third gas source 216 and the input manifold 208. The third flow controller 226 may control the flow of a $H_2$ precursor, for example, at a flow rate of about 10,000 sccm to about 20,000 sccm. This example flow rate is for a substrate with dimensions of 730 mm × 920 mm. Thus, the $H_2$ precursor has a flow rate per unit area ratio of

about 10:6.7 sccm/cm$^2$ to about 20:6.7 sccm/cm$^2$. A fourth flow controller 228 is disposed between the fourth gas source 218 and the input manifold 208. The fourth flow controller 228 may control the flow of a $SiH_4$ precursor, for example, at a flow rate of about 200 sccm to about 1,200 sccm. This example flow rate is for a substrate with dimensions of 730 mm × 920 mm. Thus, the $SiH_4$ precursor has a flow rate per unit area ratio of about 2:67.16 sccm/cm$^2$ to about 12:67.16 sccm/cm$^2$. Each flow controller of the plurality of flow controllers 220 may be operated independently from each other. Each flow controller of the plurality of flow controllers 220 may be operated simultaneously.

**[0025]** A radio frequency (RF) power source 230 is coupled to the showerhead assembly 207. The RF power source 230 may facilitate generation of plasma between the showerhead assembly 207 and the pedestal 205 to form a plasma in the processing region 203. The RF power source 230 may form a plasma from any process gas from the plurality of gas sources 210. The RF power may range from about 0.05 watts per square centimeter (watts/cm$^2$) to about 0.45 watts/cm$^2$. Thus, in some embodiments including a substrate with dimensions of 730 mm × 920 mm, the RF power may range from about 500 to about 3,000 watts.

**[0026]** FIG. 3 is a flow diagram illustrating operations of a method 300 for fabricating a device 100 according to one or more embodiments. The device 100 has an insulation layer 110 disposed on the base layer 104, the interconnect 106, and the plurality of pillars 107. However, the insulation layer 110 is formed by a process that only creates a physical bond between the insulation layer 110 and each of the base layer 104, the interconnect 106 and the plurality of pillars 107. For example, the insulation layer 110 may be formed by a lamination process. A physical bond does not provide adequate bond strength on the smooth surface of the interconnect 106 and the smooth surface of the plurality of pillars 107 for the insulation layer 110 to effectively bond to. Therefore, the RDL stack 101 is treated with a plasma treatment operation, and a silicon and nitrogen containing barrier film 109 is disposed over the RDL stack 101 on the surface of the interconnect 106, the plurality of pillars 107, and the base layer 104, before disposing the insulation layer 110 thereon. The silicon and nitrogen containing barrier film 109 provides a chemical bond between the insulation layer 110 and the interconnect 106 and the plurality of pillars 107. The silicon and

nitrogen containing barrier film 109 is formed through a PECVD operation at a temperature that prevents damage to the base layer 104, and the interconnect 106 and plurality of pillars 107 thereon. The silicon and nitrogen containing barrier film 109 is a low-thickness, high-density film that exhibits both diffusion barrier and adhesive properties.

**[0027]** At procedure 301, as shown in FIG. 4A, a plasma treatment operation is conducted. The plasma treatment operation includes positioning an RDL stack 101 in the process chamber 200. A first gas mixture is flowed into the processing region 203 of the process chamber 200, the process chamber 200 having an internal pressure and process temperature therein, and an RF power is applied to the energize the first gas mixture into a plasma.

**[0028]** In general, the following exemplary plasma treatment operation parameters may be used to treat the RDL stack 101. The pressure within the process chamber 200 may range from about 0.5 Torr to about 2 Torr. For example, the pressure within the process chamber may be from about 0.5 Torr to about 1 Torr, about 1 Torr to about 1.5 Torr, or about 1.5 Torr to about 2 Torr. The process parameters may range from a processing temperature of about 100° Celsius to about 300° Celsius. For example, the processing temperature may be from about 100° Celsius to about 150° Celsius, about 150° Celsius to about 200° Celsius, about 200° Celsius to about 250° Celsius, or about 250° Celsius to about 300° Celsius.

**[0029]** During the plasma treatment operation, the RDL stack temperature is maintained at a low processing temperature, such as about 100° Celsius to about 300°. The plasma treatment operation improves the adhesion of the surface of the RDL stack for a silicon and nitrogen containing barrier film to be disposed thereon. Utilizing a low processing temperature range prevents damage to the base layer or the copper structures thereon. As higher processing temperatures can damage the material reliability of the RDL stack, conducting the plasma treatment operation at a lower temperature maintains the RDL stack integrity.

**[0030]** During the plasma treatment operation, a first gas mixture is supplied to the processing region 203. The first gas mixture includes an ammonia ($NH_3$) precursor, a nitrogen ($N_2$) precursor, and a hydrogen ($H_2$) precursor. The $NH_3$ precursor is flowed

into the input manifold 208 at a first flow rate. For example, the first flow rate is about 1,000 sccm to about 3,000 sccm. This example flow rate is for a substrate with dimensions of 730 mm × 920 mm. Thus, the $NH_3$ precursor has a flow rate per unit area ratio of about 1:6.7 sccm per squared centimeters (sccm/$cm^2$) to about 3:6.7 sccm/$cm^2$. The $N_2$ precursor is flowed into the input manifold 208 at a second flow rate. For example, the second flow rate is about 3,000 sccm to about 12,000 sccm. This example flow rate is for a substrate with dimensions of 730 mm × 920 mm. Thus, the $N_2$ precursor has a flow rate per unit area ratio of about 3:6.7 sccm/$cm^2$ to about 12:6.7 sccm/$cm^2$. The $H_2$ precursor is flowed into the input manifold 208 at a third flow rate. For example, the third flow rate is about 10,000 sccm to about 20,000 sccm. This example flow rate is for a substrate with dimensions of 730 mm × 920 mm. Thus, the $H_2$ precursor has a flow rate per unit area ratio of about 10:6.7 sccm/$cm^2$ to about 20:6.7 sccm/$cm^2$. The first gas mixture, including the $NH_3$ precursor, the $N_2$ precursor, and the $H_2$ precursor, is formed in the input manifold 208. The first gas mixture is then flowed from the input manifold 208 into the processing region 203.

**[0031]** An RF power is applied at an first power level to the first gas mixture within the processing region 203. In some embodiments, the plasma treatment operation is a continuous plasma process, which includes maintaining the RF power on while continuing to expose the RDL stack 101 to the first gas mixture. In some embodiments, the first power level may range from about 0.05 watts/$cm^2$ to about 0.2 watts/$cm^2$. For example, the first power level may range from about 0.07 watts/$cm^2$ to about 0.14 watts/$cm^2$. In some embodiments including a substrate with dimensions of 730 mm × 920 mm, the total first power level is about 500 watts to about 1,000 watts. The plasma treatment operation may range from about 30 seconds to 120 seconds, for example, from about 30 seconds to about 60 seconds, about 60 seconds to about 90 seconds, or about 90 seconds to about 120 seconds. The plasma treatment operation cleans the base layer 104, the interconnect 106, and the plurality of pillars 107 and removes any native oxides disposed thereon. In a subsequent procedure 302, a silicon and nitrogen containing barrier film 109 is disposed over the base layer 104, the interconnect 106, and the plurality of pillars 107. Cleaning and removing native oxides on the base layer 104, the interconnect 106, and the plurality of pillars 107 before disposing the silicon and nitrogen containing barrier film 109 thereon provides for better resulting adhesion. Through cleaning and removing native oxides,

the plasma treatment operation provides for strong copper-silicon chemical bonding between the silicon and nitrogen containing barrier film 109, and each of the interconnect 106 and the plurality of pillars 107.

**[0032]** At procedure 302, as shown in FIG. 4B, a deposition operation is conducted. The deposition operation deposits a silicon and nitrogen containing barrier film 109 over the base layer 104, interconnect 106, and plurality of pillars 107. The deposition operation is a PECVD operation.

**[0033]** When depositing the silicon and nitrogen containing barrier film 109, some processing conditions from the plasma treatment operation of procedure 301 are maintained at a same level for the deposition operation. That is, some processing conditions are unchanged from the plasma treatment operation to the deposition operation. The pressure within the process chamber, the processing temperature, the first flow rate, the second flow rate, and the third flow rate are maintained at the same level from the plasma treatment operation to the deposition operation. A silane ($SiH_4$) precursor is flowed at a fourth flow rate into the input manifold. The $SiH_4$ precursor is added to the first gas mixture in the input manifold to form the second gas mixture. The second gas mixture is flowed into the processing region from the input manifold. The RF power is increased to a second power level.

**[0034]** During the deposition operation, a second gas mixture is supplied to the processing region 203. The second gas mixture includes a $SiH_4$ precursor. The $SiH_4$ precursor is flowed into the input manifold 208 at a fourth flow rate. For example, the fourth flow rate is about 200 sccm to about 1,200 sccm. This example flow rate is for a substrate with dimensions of 730 mm × 920 mm. Thus, the $SiH_4$ precursor has a flow rate per unit area ratio of about 2:67.16 sccm/cm$^2$ to about 12:67.16 sccm/cm$^2$. In the input manifold 208, the $SiH_4$ precursor is added to the first gas mixture ($NH_3$, $N_2$, $H_2$) to form the second gas mixture. The second gas mixture is then flowed from the input manifold 208 into the processing region 203. The RF power is increased from the first power level to a second power level. The second power level may range from a power level of about 0.14 watts/cm$^2$ to about 0.45 watts/cm$^2$. Thus, in some embodiments including a substrate with dimensions of 730 mm × 920 mm, the total second power may range from a power level of about 1,000 watts to about 3,000 watts.

**[0035]** In one embodiment including a substrate with dimensions of 730 mm × 920 mm, the following deposition operation parameters may be used to dispose the silicon and nitrogen containing barrier film 109 over the RDL stack 101. The processing temperature is about 200° Celsius. The pressure within the processing region 203 is about 1 Torr. The gas flow rate of a $NH_3$ precursor is about 2,000 sccm. The gas flow rate of a $N_2$ precursor is about 7,000 sccm. The gas flow rate of a $H_2$ precursor is about 10,000 sccm. The gas flow rate of a $SiH_4$ precursor is about 1,200 sccm. $H_2$ accounts for about 50% of the total amount of gas flowed into the processing region 203. A total RF power of about 3,000 watts is used.

**[0036]** The resulting silicon and nitrogen containing barrier film 109 provides adhesion between the insulation layer 110 and the base layer 104, interconnect 106 and the plurality of pillars 107. The silicon and nitrogen containing barrier film 109 further protects the base layer 104, interconnect 106, and the plurality of pillars 107 by preventing the inter-diffusion of copper and oxygen atoms from the base layer 104, interconnect 106, and the plurality of pillars 107, to the insulation layer 110. In some embodiments, the silicon and nitrogen containing barrier film 109 may be deposited to a thickness of about 500 angstroms to about 4,000 angstroms. For example, the silicon and nitrogen containing barrier film 109 may have a thickness from about 500 angstroms to about 1,000 angstroms, about 1,000 angstroms to about 2,000 angstroms, about 2,000 angstroms to about 3,000 angstroms, or about 3,000 angstroms to about 4,000 angstroms. In some embodiments, the silicon and nitrogen containing barrier film 109 may have a density from about 2 grams per cubic centimeter to about 2.5 grams per cubic centimeter. In some embodiments, the silicon and nitrogen containing barrier film 109 may have a wet etch rate of 3000 angstroms per minute or less under a buffered oxide etching solution. The silicon and nitrogen containing barrier film 109 may have a compressive stress of about 500 megapascal. The low-thickness, but high-density properties of the silicon and nitrogen containing barrier film 109 provide protective properties to prevent the inter-diffusion of copper and oxygen atoms from the base layer 104, interconnect 106, and the plurality of pillars 107 to the insulation layer 110.

**[0037]** At procedure 303, as shown in FIG. 1, the insulation layer 110 is disposed on the RDL stack 101. The insulation layer 110 is disposed over the base layer 104,

the interconnect 106, and the plurality of pillars 107. The insulation layer 110 is deposited onto the silicon and nitrogen containing barrier film 109. The insulation layer 110 may be deposited by any suitable process, such as lamination, wet electroless plating processes, or the like. The insulation layer 110 includes an organic material. The organic material includes, but is not limited to, a build-up film, a polymide, a photo imageable dielectric (PID), or combinations thereof. The insulation layer 110 and the base layer 104 may include a same material or a different material. The insulation layer 110 acts as a passivating layer on the RDL stack 101 and provides for electrical isolation between interconnects 106.

**[0038]** Benefits of the present disclosure include a silicon and nitrogen containing barrier film that provides both protective diffusion barrier and adhesive qualities to an RDL stack and the structures disposed thereon. The silicon and nitrogen containing barrier film may be deposited through a low temperature plasma treatment and PECVD operation that prevents damage to the underlying base layer that the film is to be disposed on. The silicon and nitrogen containing barrier film exhibits low-thickness but high-density properties which improves spatial efficiency of the RDL stack while also protecting the RDL stack from electrical failure from copper and oxygen inter-diffusion between the base layer and the insulation layer. The silicon and nitrogen containing barrier film has adhesive properties, aiding in the bonding of the insulation layer to the interconnect and the plurality of pillars.

**[0039]** While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure 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 device, comprising:

a carrier layer;

a base layer disposed over the carrier layer, the base layer having:

a first surface contacting the carrier layer; and

a second surface opposite the first surface, the second surface having a plurality of pillars disposed thereon;

a via therethrough, the via having an interconnect disposed therein;

an insulation layer disposed over the base layer; and

a silicon and nitrogen containing barrier film disposed between the insulation layer and each of the base layer, interconnect, and plurality of pillars, the silicon and nitrogen containing barrier film having a thickness of about 500 angstroms to about 4000 angstroms and a density of about 2 grams per cubic centimeter to about 2.5 grams per cubic centimeter.

2. The device of claim 1, wherein the silicon and nitrogen containing barrier film has a wet etch rate of about 3000 angstroms per minute or less under a buffered oxide etching solution.

3. The device of claim 1, wherein a seed layer is disposed through the interconnect and beneath the plurality of pillars.

4. The device of claim 1, wherein the silicon and nitrogen containing barrier film has a compressive stress of about 100 megapascals to about 1000 megapascals.

5. The device of claim 1, wherein the base layer and the insulation layer are organic materials, and wherein the plurality of pillars and the interconnect are copper.

6. The device of claim 1, wherein the silicon and nitrogen containing barrier film comprises a silicon nitride having a chemical formula $SiN_X$, wherein x is in a range from about 1 to about 1.7.

7. A method comprising:

positioning a redistribution layer (RDL) stack in a processing chamber, the RDL stack having a base layer and at least one of a copper interconnect and a copper pillar; and

conducting a plasma treatment operation, the plasma treatment operation comprising:

flowing a first gas mixture, the first gas mixture including an ammonia ($NH_3$) precursor, a nitrogen ($N_2$) precursor, and a hydrogen ($H_2$) precursor;

applying a radio frequency (RF) power to the first gas mixture at a first power level, wherein the RDL stack is at a process temperature of about 100° Celsius to about 300° Celsius, and the processing chamber has an internal pressure; and

depositing a silicon and nitrogen containing barrier film by:

maintaining the process temperature, the internal pressure, and flow of the first gas mixture;

flowing a second gas mixture at a second flow rate, the second gas mixture including a silane ($SiH_4$) precursor and the first gas mixture; and

increasing the RF power to a second power level.

8. The method of claim 7, wherein the first power level of the RF power is about 0.07 watts per square centimeter to about 0.14 watts per square centimeter.

9. The method of claim 7, wherein the second power level of the RF power is about 0.14 watts per square centimeter to about 0.45 watts per square centimeter.

10. The method of claim 7, wherein the $H_2$ precursor is about 30% or more of a total amount of gas flowed into the processing chamber.

11. The method of claim 7, wherein the $H_2$ precursor has a flow rate per unit area ratio of about 10:6.7 sccm per squared centimeters (sccm/$cm^2$) to about 20:6.7 sccm/$cm^2$.

12. The method of claim 7, wherein the $SiH_4$ precursor has a flow rate per unit area ratio of about 2:67.16 sccm per squared centimeters (sccm/$cm^2$) to about 12:67.16 sccm/$cm^2$.

13. The method of claim 7, wherein the $NH_3$ precursor has a flow rate per unit area ratio of about 1:6.7 sccm per squared centimeters (sccm/$cm^2$) to about 3:6.7 sccm/$cm^2$.

14. The method of claim 7, wherein the $N_2$ precursor has a flow rate per unit area ratio of about 3:6.7 sccm per squared centimeters (sccm/$cm^2$) to about 12:6.7 sccm/$cm^2$.

15. The method of claim 7, wherein the silicon and nitrogen containing barrier film has a wet etch rate of about 3000 angstroms per minute or less under a buffered oxide etching solution.

16. The method of claim 7, wherein the silicon and nitrogen containing barrier film has a thickness of about 500 angstroms to about 4000 angstroms.

17. The method of claim 7, wherein the silicon and nitrogen containing barrier film has a compressive stress of about 100 megapascals to about 1000 megapascals.

18. A method comprising:

positioning a redistribution layer (RDL) stack in a processing chamber, the RDL stack having a base layer and at least one of a copper interconnect and a copper pillar; and

conducting a plasma treatment operation, the plasma treatment operation comprising:

flowing a first gas mixture into the processing chamber, the first gas mixture including:

an ammonia ($NH_3$) precursor at a first flow rate;

a nitrogen ($N_2$) precursor at a second flow rate; and

a hydrogen ($H_2$) precursor at a third flow rate; and

applying a radio frequency (RF) power to the first gas mixture at a first power level, wherein the RDL stack is at a process temperature of about 100° Celsius to about 300° Celsius, and the processing chamber has an internal pressure; and

depositing a silicon and nitrogen containing barrier film by:

maintaining the process temperature, the internal pressure, the first flow rate, the second flow rate, and the third flow rate;

flowing a second gas mixture into the processing chamber, the second gas mixture including a silane ($SiH_4$) precursor and the first gas mixture, the $SiH_4$ precursor having a fourth flow rate; and

increasing the radio frequency to a second power level .

19. The method of claim 18, wherein the silicon and nitrogen containing barrier film has a wet etch rate of about 3000 angstroms per minute or less under a buffered oxide etching solution.

20. The method of claim 18, wherein the silicon and nitrogen containing barrier film has a compressive stress of about 100 megapascals to about 1000 megapascals.