METHOD OF MANUFACTURING SPRAY COATING LAYER AND SPRAY COATING LAYER MANUFACTURED BY THE SAME METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

Example embodiments of the present invention relate to a powder for a spray-coating process and a method of forming the same, and a spray-coating layer using the powder and a method of forming the same. More particularly, example embodiments of the present invention relate to a powder for a spray-coating process having a reduced number of voids therein and a method of forming the same, and a spray-coating layer using the powder having an improved layer density and a method of forming the same.

2. Description of the Related Art

In a general plasma processing system, source gases are changed into plasma and a substrate such as a semiconductor wafer is processed by the source plasma. The source plasma causes damage to an inner surface of a process chamber of the plasma processing system in addition to processing the substrate. For that reason, a protective layer for preventing damage to the process chamber is coated on the inner surface of the process chamber. A spray-coating layer is most widely used as the protective layer in the plasma processing chamber so as to prevent etching of the inner surface of the process chamber due to the source plasma. The spray-coating layer is formed by a spray-coating process using a powder comprising yttrium oxide (Y_2O_3), aluminum oxide (Al_2O_3), silicon oxide (SiO_2) boron carbide (B_4C), etc.

FIG. 1A is a picture showing a cross-sectional area of a conventional spray-

coating layer, and FIG. 1B is an enlarged picture showing a portion of the picture shown in FIG. 1A.

Referring to FIGS. 1A and 1B, the conventional spray-coating layer has a crystalline structure and has a lot of voids or spaces therein. The source plasma in the processing chamber penetrates into the spaces in the crystalline structure of the spray-coating layer, and thus the spray-coating layer is etched off by the source plasma. Accordingly, the spray-coating layer is peeled off from the inner surface of the processing chamber of the plasma process system, and thus the source plasma directly causes damage to the inner surface of the process chamber.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides a powder for a spray-coating process having an amorphous structure and a less space therein.

Another example embodiment of the present invention provides a method of forming the above powder for a spray-coating process.

Another example embodiment of the present invention provides a spray-coating layer using the above powder having an improved layer density.

Another example embodiment of the present invention provides a method of forming the above spray-coating layer.

According to an aspect of the present invention, there is provided a spray powder for a spray-coating process. The spray powder comprises coarse-grained particles including yttrium oxide and aluminum oxide and having an average diameter of about 20 μm to about 60 μm.

In an example embodiment, a weight ratio of the yttrium oxide with respect to the aluminum oxide is in a range of about 1:0.4 to 1.

According to an aspect of the present invention, there is provided a spray

powder for a spray-coating process. The spray powder includes particles having an average diameter of about 20 μm to about 60 μm and generated from a slurry mixture including a first slurry and a second slurry. The first slurry includes yttrium oxide particles having diameters of about 0.01 μm to about 2 μm, a first dispersing agent for uniformly dispersing the yttrium oxide particles, a first bonding agent for bonding the yttrium oxide particles, and a first solvent into which the yttrium oxide particles, the first dispersing agent and the first bonding agent are dissolved. The second slurry includes aluminum oxide particles having diameters of about 0.5 μm to about 2 μm, a second dispersing agent for uniformly dispersing the aluminum oxide particles, a second bonding agent for bonding the aluminum oxide particles, and a second solvent into which the aluminum oxide particles, the second dispersing agent and the second bonding agent are dissolved.

In an example embodiment, the first dispersing agent includes a basic material and the second dispersing agent includes an acidic material. A ratio of the first dispersing agent with respect to the first slurry is in a range of about 0.3% to about 0.5%, and a ratio of the second dispersing agent with respect to the second slurry is in a range of about 0.3% to about 2%.

In an example embodiment, a ratio of the first bonding agent with respect to the first slurry is in a range of about 2% to about 3%, and a ratio of the second bonding agent with respect to the second slurry is in a range of about 2% to about 3%.

In an example embodiment, a ratio of solid materials with respect to the first and the second slurries is in a range of about 20% to about 30%, respectively.

In an example embodiment, a weight ratio of yttrium oxide with respect to aluminum oxide is in a range of about 1:0.4 to 1 in the slurry mixture.

According to an aspect of the present invention, there is provided a method

of forming a spray powder for a spray-coating process. A first slurry is formed to have yttrium oxide particles, a first dispersing agent for dispersing the yttrium oxide particles, and a first solvent, and a second slurry is formed to have aluminum oxide particles, a second dispersing agent for dispersing the aluminum oxide particles, and a second solvent. A slurry mixture is formed by mixing the first and the second slurries with each other, and a spray-drying process and a heat treating process are performed on the slurry mixture, to thereby form coarse-grained particles including yttrium oxide and aluminum oxide.

In an example embodiment, the yttrium oxide particles have an average diameter of about 0.01 μm to about 2 μm and the aluminum oxide particles have an average diameter of about 0.5 μm to about 2 μm.

In an example embodiment, the first dispersing agent includes a basic material. The first dispersing agent includes at least one material selected from the group consisting of a carboxyl-based material, an ester-based material, an amide-based material and in combinations thereof, and a ratio of the first dispersing agent with respect to the first slurry is in a range of about 0.3% to about 0.5%.

In an example embodiment, the second dispersing agent includes an acidic material. The second dispersing agent includes at least one material selected from the group consisting of a carboxyl-based material, an ester-based material, an amide-based material and in combinations thereof, and a ratio of the second dispersing agent with respect to the second slurry is in a range of about 0.3% to about 2%.

In an example embodiment, the first slurry has basic properties and the second slurry has acidic properties. The yttrium oxide particles in the first slurry have a negative surface charge and the aluminum oxide particles in the second slurry have a positive surface charge, and the yttrium oxide particles and the aluminum oxide

particles are bonded to each other by electrostatic attraction.

In an example embodiment, a ratio of solid materials with respect to the first and the second slurries is in a range of about 20% to about 30%, respectively.

In an example embodiment, the first and the second solvents include one of an organic material and an aqueous solution.

In an example embodiment, the first slurry further include a first bonding agent for bonding the yttrium oxide particles to each other and the second slurry further include a second bonding agent for bonding the aluminum oxide particles to each other.

In an example embodiment, the first bonding agent comprises one of polyvinyl-based material and acrylic-based material and a ratio of the first bonding agent with respect to the first slurry is in a range of about 2% to about 3%, and the second bonding agent comprises one of polyvinyl-based material and acrylic-based material and a ratio of the second bonding agent with respect to the second slurry is in a range of about 2% to about 3%.

In an example embodiment, a weight ratio of yttrium oxide in the first slurry with respect to aluminum oxide in the second slurry is in a range of about 1:0.4 to 1 in the slurry mixture.

In an example embodiment, the heat treating process to the slurry mixture is performed at a temperature of about 800°C to about 1,500°C.

In an example embodiment, the formation process including the steps of forming the first slurry including yttrium oxide particles, forming the second slurry including aluminum oxide particles, forming the slurry mixture and performing the spray-drying process and the heat treating process may be performed in an atmosphere of one of air, hydrogen, oxygen and nitrogen and a mixture thereof.

According to an aspect of the present invention, there is provided a method

of forming a spray powder for a spray-coating process. A spray powder having coarse-grained particles comprising yttrium oxide and aluminum oxide is prepared and the spray powder is sprayed to an object in a dissolved state. The average diameter of the particles is in a range of about 20 μm to about 60 μm.

In an example embodiment, the spray powder is sprayed by one of an atmospheric plasma spray (APS) process, a high-velocity oxygen-fuel (HVOF) spray process, a vacuum plasma spray (VPS) process and a kinetic spray process.

According to an aspect of the present invention, there is provided a method of forming a spray powder for a spray-coating process. A spray powder is prepared using a slurry mixture including a first slurry and a second slurry. The spray powder includes particles having an average diameter of about 20 μm to about 60 μm, the first slurry including yttrium oxide particles having diameters of about 0.01 μm to about 2 μm, a first dispersing agent for uniformly dispersing the yttrium oxide particles, a first bonding agent for bonding the yttrium oxide particles, and a first solvent into which the yttrium oxide particles, the first dispersing agent and the first bonding agent are dissolved. The second slurry includes aluminum oxide particles having diameters of about 0.5 μm to about 2 μm, a second dispersing agent for uniformly dispersing the aluminum oxide particles, a second bonding agent for bonding the aluminum oxide particles, and a second solvent into which the aluminum oxide particles, the second dispersing agent and the second bonding agent are dissolved. Then, the spray powder is sprayed to an object in a dissolved state.

In an example embodiment, the first dispersing agent includes a basic material and the second dispersing agent includes an acidic material. A ratio of the first dispersing agent with respect to the first slurry is in a range of about 0.3% to about 0.5%, and a ratio of the second dispersing agent with respect to the second slurry is in a range of about 0.3% to about 2%.

In an example embodiment, a ratio of the first bonding agent with respect to the first slurry is in a range of about 2% to about 3%, and a ratio of the second bonding agent with respect to the second slurry is in a range of about 2% to about 3%.

In an example embodiment, a ratio of solid materials with respect to the first and the second slurries is in a range of about 20% to about 30%, respectively.

In an example embodiment, a weight ratio of yttrium oxide in the first slurry and aluminum oxide in the second slurry is in a range of about 1:0.4 to 1 in the slurry mixture.

In an example embodiment, the spray powder is sprayed by one of an APS process, an HVOF spray process, a VPS process and a kinetic spray process.

According to an aspect of the present invention, there is provided a spray-coating layer comprising yttrium oxide and aluminum oxide and having an amorphous structure that is formed by a spray-coating process.

In an example embodiment, the porosity thereof is in a range of about 0.5% to about 2%.

In an example embodiment, an adhesive strength thereof is at least about 13 MPa.

In an example embodiment, the hardness thereof is at least about 650 HV.

In an example embodiment, a weight ratio of yttrium oxide in the first slurry and aluminum oxide in the second slurry is in a range of about 1:0.4 to 1 in the slurry mixture, and a spray powder having an average diameter of about 20 μm to about 60 μm is used in the spray-coating process.

In an example embodiment, the spray-coating layer is positioned on a surface of an inner member of a process chamber in which a plasma process is performed on a substrate.

According to example embodiments of the present invention, a spray powder is formed into coarse-grained particles including yttrium oxide and aluminum oxide and having an average diameter of about 20 μm to about 60 μm. A spray-coating layer is formed by a spray-coating process using the spray powder, and thus has an amorphous structure and a low porosity. Therefore, when the spray-coating layer is formed on the inside of a plasma processing system, a source plasma may be sufficiently prevented from penetrating the spray-coating layer. As a result, the spray-coating layer may prevent the source plasma from making direct contact with the plasma processing system. In addition, the spray-coating layer is sufficiently adhered to the plasma processing system for preventing the separation of the spray-coating layer from the plasma processing system, to thereby minimize contamination caused by the spray-coating layer. Particularly, the spray-coating layer may sufficiently prevent etching of the plasma processing system caused by the source plasma, to thereby remarkably improve the lifespan of the plasma processing system.

The spray-coating layer is formed by a spray-coating process using the spray powder including coarse-grained particles of which the average diameter is about 20 μm to about 60 μm. Therefore, when the spray-coating layer is formed on the inside of the plasma processing system, the source plasma may be sufficiently prevented from penetrating the spray-coating layer.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other features and advantages of the present invention will become readily apparent by reference to the following detailed description when considering in conjunction with the accompanying drawings, in which:

FIG. 1A is a picture showing a cross-sectional area of a conventional spray-coating layer, and FIG. 1B is an enlarged picture showing a portion of the picture shown in FIG. 1A;

FIG. 2 is a picture showing a powder for a spray-coating process in accordance with an example embodiment of the present invention;

FIG. 3 is a flowchart illustrating processing steps for a method of forming the spray powder in accordance with an example embodiment of the present invention;

FIG. 4 is a flowchart illustrating processing steps for a method of forming the first slurry shown in FIG. 3;

FIG. 5 is a flowchart illustrating processing steps for a method of forming the second slurry shown in FIG. 3;

FIG. 6 is a view illustrating a bonding mechanism of yttrium oxide and aluminum oxide in the slurry mixture shown in FIG. 3;

FIG. 7 is a flowchart illustrating a method of forming a spray-coating layer in accordance with an example embodiment of the present invention;

FIG. 8A is a picture showing a cross-sectional surface of the spray-coating layer in accordance with an example embodiment of the present invention, and FIG. 8B is an enlarged picture showing a portion of the spray-coating layer shown in FIG. 8A;

FIG. 9 is a view illustrating an inner structure of the plasma processing system in accordance with an example embodiment of the present invention; and

FIG. 10 is a view illustrating an X-ray diffraction pattern of the spray-coating layer in accordance with an example embodiment of the present invention.

DESCRIPTION OF THE EMBODIMENTS

The invention is described more fully hereinafter with reference to the

accompanying drawings, in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein. Rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. In the drawings, the size and relative sizes of layers and regions may be exaggerated for clarity.

It will be understood that when an element or layer is referred to as being "on," "connected to" or "coupled to" another element or layer, it can be directly on, connected or coupled to the other element or layer or intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on," "directly connected to" or "directly coupled to" another element or layer, there are no intervening elements or layers present. Like numbers refer to like elements throughout. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

It will be understood that, although the terms first, second, third etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms are only used to distinguish one element, component, region, layer or section from another region, layer or section. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the present invention.

Spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. It will be understood that the spatially relative terms are intended to encompass

different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the exemplary term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein, the singular forms "a," "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

Embodiments of the invention are described herein with reference to cross-section illustrations that are schematic illustrations of idealized embodiments (and intermediate structures) of the invention. As such, variations from the shapes of the illustrations as a result, for example, of manufacturing techniques and/or tolerances, are to be expected. Thus, embodiments of the invention should not be construed as limited to the particular shapes of regions illustrated herein but are to include deviations in shapes that result, for example, from manufacturing. For example, an implanted region illustrated as a rectangle will, typically, have rounded or curved features and/or a gradient of implant concentration at its edges rather than a binary change from implanted to non-implanted region. Likewise, a buried region formed by implantation may result in some implantation in the region between the buried region

and the surface through which the implantation takes place. Thus, the regions illustrated in the figures are schematic in nature and their shapes are not intended to illustrate the actual shape of a region of a device and are not intended to limit the scope of the invention.

Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. It will be further understood that terms, such as those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

FIG. 2 is a picture showing a powder for a spray-coating process in accordance with an example embodiment of the present invention.

Referring to FIG. 2, a powder for a spray-coating process (hereinafter referred to as spray powder) may be provided from a slurry mixture including a first slurry and a second slurry.

In an example embodiment, the first slurry may include yttrium oxide particles, a first dispersing agent, a first bonding agent and a first solvent.

For example, the yttrium oxide particles may have diameters of about 0.01 μm to about 2 μm. When the diameter of the yttrium oxide particles is smaller than about 0.01 μm, the average diameter of the spray powder may be decreased because the spray powder has a coarse-grained structure of the yttrium oxide particles, so that the yttrium oxide particles may be difficult to accurately control, and thus the spray powder may be difficult to form into a spherical grained structure of the yttrium oxide. In contrast, when the diameter of the yttrium oxide particles is greater

than about 2 μm, the yttrium oxide particles may combine together with one other to the grain-structured crystal having a large void ratio.

The first dispersing agent may uniformly disperse the yttrium oxide particles in the first slurry. In an example embodiment, the first dispersing agent may have basic properties. For example, the first dispersing agent may comprise a basic material. Otherwise, the first dispersing agent may be formed into a basic mixture in such a manner that a solid or a liquid dispersing agent is dissolved into a basic solvent. Examples of the first dispersing agent may include a material having a carboxyl group, a material having an ester group and a material having an amide group. These may be alone or in combinations thereof. The pH of the first dispersing agent may be in a range of about 10 to about 12. In the present embodiment, the pH of the first dispersing agent is about 10. The yttrium oxide particles have a negative (-) surface charge in the basic first dispersing agent.

When a ratio of the first dispersing agent is more than about 0.5% in the first slurry, the yttrium oxide particles are difficult to form into a spherical shape in the spray powder having the coarse-grained crystalline structure in a spray-drying process. For example, when the spray-drying process is performed at an excessively high temperature, the spherical spray powder has different hardness between an inner portion and an outer surface of the spherical spray powder, and thus the solvent in the spray powder penetrates the outer surface thereof and pours outward out of the spherical particles of the spray powder, to thereby form craters on the outer surfaces of the spray powder particles. In contrast, when the ratio of the dispersing agent is excessively high in some portions of the spray powder, and thus the evaporation rate of the solvent may be locally different in the spray powder and the solvent may locally pour out of the spherical spray powder. Accordingly, the spray powder may be formed into a non-spherical shape.

When the non-spherical spray powder is sprayed onto the inner surface of the process chamber in a plasma treating process, the fluidity of the spray powder may be deteriorated and the spray powder may not be uniformly supplied into a plasma gun. Therefore, a thin layer coated on the inner surface of the process chamber by the spray-coating process (spray-coating layer) has non-uniform material properties and there is a danger that a supply pipe to the plasma gun may become clogged with the spray powder. In addition, when the spray powder has a lot of voids and spaces within crystalline structures, the spray-coating layer may also have a lot of voids and spaces, to thereby increase an void ratio in the spray-coating layer.

When a ratio of the first dispersing agent is less than about 0.3% in the first slurry, the viscosity of the first slurry may be significantly increased due to an excessively small amount of the first dispersing agent. Therefore, the yttrium oxide particles may cohere with each other and the first bonding agent may not be sufficiently reacted with the yttrium oxide particles, so that the coarse-grained structure of yttrium oxide may be easily broken in the spray powder due to a weak bond strength in the coarse-grained structure. Further, the fluidity of a slurry mixture of the first and second slurries may also be deteriorated, and thus there may be a problem in that a spray dryer may become clogged with the slurry mixture in the spray-drying process when a ratio of the first dispersing agent is less than about 0.3% in the first slurry.

For that reason, the ratio of the first dispersing agent in the first slurry may be in a range of about 0.3% to about 0.5%.

In an example embodiment, the first bonding agent may improve the bond strength between the yttrium oxide particles in the first slurry. When a ratio of the first bonding agent is less than about 2% in the first slurry, the yttrium oxide particles are not sufficiently bonded to each other, so that the spray powder having the coarse-

grained structure of the yttrium oxide particles may not be formed into a spherical shape. In contrast, when a ratio of the first bonding agent is more than about 3% in the first slurry, the viscosity of the first slurry rapidly increases although the spray powder may be sufficiently formed into a spherical shape. Therefore, the fluidity of the slurry mixture of the first and second slurries may be deteriorated, and thus the spray dryer may become clogged with the slurry mixture in the spray-drying process. Accordingly, the ratio of the first bonding agent may be in a range of about 2% to about 3% in the first slurry. The first bonding agent may comprise a vinyl-based material and an acrylic-based material. When the first bonding agent includes the vinyl-based material, the first solvent may include an organic material such as an ethanol, and when the first bonding agent includes the acrylic-based material, the first solvent may include an aqueous solution. Examples of the vinyl-based material may include ethylene vinyl acetate (EVA) resin, polyvinyl chloride (PVC) resin, polyvinyl pyrolidine, polyvinyl alcohol resin, polyvinyl butyral, polyvinyl acetate, polyvinyl ether, etc. These may be use alone or in combinations thereof. Examples of the acrylic-based material may include poly(methacrylic acid), poly(methyl methacrylate), polyacrylonitrile, poly(n-butyl acrylate), poly(styrene-co-methyl methacrylate), etc. These may also be used alone or in combinations thereof.

In an example embodiment, the first slurry may include the first solvent. The first solvent may include the organic solvent or an aqueous solution.

The first slurry may be formed by a ball mill. A ratio of solid materials in the first slurry (hereinafter referred to as solid ratio) is proportional to the ratio of the first dispersing agent. When the solid ratio is less than about 20% in the first slurry, the yttrium oxide particles are hardly dissolved into the first solvent, to thereby reduce a grain size of the coarse-grained structure. In contrast, when the solid ratio is more than about 30% in the first slurry, the viscosity of the first slurry may be so high that

the process for forming the spray powder may be too rapid to accurately control. In addition, the ratio of the first dispersing agent in the first slurry may be so high that the spray powder may be formed into a non-spherical shape. For those reasons, the solid ratio in the first slurry may be in a range of about 20% to about 30%.

In an example embodiment, the second slurry may include aluminum oxide particles, a second dispersing agent, a second bonding agent and a second solvent.

For example, the aluminum oxide particles may have diameters of about 0.5 μm to about 2 μm. When the diameter of the aluminum oxide particles is smaller than about 0.5 μm, the average diameter of the spray powder may be decreased because the spray powder has a coarse-grained structure of the aluminum oxide particles, so that the aluminum oxide particles may be difficult to accurately control, and thus the spray powder may be difficult to form into a spherical grained structure. In contrast, when the diameter of the aluminum oxide particles is greater than about 2 μm, the aluminum oxide particles may combine together with each other to the grain-structured crystal having a large void ratio.

The second dispersing agent may uniformly disperse the aluminum oxide particles in the second slurry. In an example embodiment, the second dispersing agent may have acid properties. For example, the second dispersing agent may comprise an acidic material. Otherwise, the second dispersing agent may be formed into an acid mixture in such a manner that a solid or a liquid dispersing agent is dissolved into an acid solvent. Examples of the second dispersing agent may include a material having a carboxyl group, a material having an ester group and a material having an amide group. These may be alone or in combinations thereof. The pH of the second dispersing agent may be in a range of about 2 to about 4. In the present embodiment, the pH of the second dispersing agent is about 2. The aluminum oxide particles have a positive (+) surface charge in the acid second dispersing agent.

When a ratio of the second dispersing agent is more than about 2% in the second slurry, the aluminum oxide particles are hardly formed into the spherical grained structure in the spray powder by the same reason as in the case that the ratio of the first dispersing agent is more than about 0.5% in the first slurry.

When the ratio of the second dispersing agent is less than about 0.3% in the second slurry, the coarse-grained structure of aluminum oxide is easily broken in the spray powder by the same reason as in the case that the ratio of the second dispersing agent is less than about 0.3% in the second slurry. Further, the fluidity of the slurry mixture of the first and second slurries is also deteriorated, and thus there is a problem in that a spray dryer is clogged with the slurry mixture in the spray-drying process when the ratio of the second dispersing agent is less than about 0.3% in the second slurry.

For that reason, the ratio of the second dispersing agent in the second slurry may be in a range of about 0.3% to about 2%.

In an example embodiment, the second bonding agent may improve the bond strength between the aluminum oxide particles in the second slurry. When a ratio of the second bonding agent is less than about 2% in the second slurry, the aluminum oxide particles are not sufficiently bonded to each other, so that the spray powder having the coarse-grained structure of the second oxide particles may not be formed into a spherical shape. In contrast, when a ratio of the second bonding agent is more than about 3% in the second slurry, the viscosity of the second slurry rapidly increases although the spray powder may be sufficiently formed into a spherical shape. Therefore, the fluidity of the slurry mixture of the first and second slurries is deteriorated, and thus the spray dryer is clogged with the slurry mixture in the spray-drying process. Accordingly, the ratio of the second bonding agent may be in a range of about 2% to about 3% in the second slurry. The second bonding agent has

substantially the same structure and function as the first bonding agent, and thus any detailed descriptions on the second bonding agent is to be omitted hereafter.

In an example embodiment, the second slurry may include the second solvent. The second solvent may include an organic solvent or an aqueous solution.

The second slurry may be formed by a ball mill. A solid ratio of the second slurry is proportional to the ratio of the second dispersing agent. When the solid ratio is less than about 20% in the second slurry, the aluminum oxide particles are hardly dissolved into the second solvent, to thereby reduce a grain size of the coarse-grained structure. In contrast, when the solid ratio is more than about 30% in the second slurry, the viscosity of the second slurry may be so high that the process for forming the spray powder may be too rapid to accurately control. In addition, the ratio of the second dispersing agent in the second slurry may be so high that the spray powder may be formed into a non-spherical shape. For those reasons, the solid ratio in the second slurry may be in a range of about 20% to about 30%.

When a weight ratio of yttrium oxide to aluminum oxide is in a range of about 1:9 to about 4:6 in a first slurry mixture, the spray-coating layer including the spray powder of the first slurry mixture is characterized by aluminum oxide to such properties of high mechanical strength and weak adhesive strength. In contrast, when a weight ratio of yttrium oxide to aluminum oxide is in a range of about 8:2 to about 9:1 in a second slurry mixture, the spray-coating layer including the spray powder of the second slurry mixture is characterized by yttrium oxide to such properties of weak mechanical strength and adhesive strength. Accordingly, the weight ratio of yttrium oxide to aluminum oxide is in a range of about 5:5 to about 7:3 in the slurry mixture. In the present embodiment, the weight ratio of yttrium oxide to aluminum oxide is about 5:5 in the slurry mixture. In such a case, the spray-coating layer formed from the spray powder including the slurry mixture is characterized by

both of aluminum oxide and yttrium oxide to such properties of high mechanical strength and adhesive strength.

The spray powder is formed through some processing steps using the slurry mixture. The slurry mixture may include the first slurry which is a mixture of the yttrium oxide particles, the first dispersing agent, the first bonding agent and the first solvent and the second mixture which is a mixture of the aluminum oxide particles, the second dispersing agent, the second bonding agent and the second solvent.

In an example embodiment, the coarse-grained spray powder particles may include yttrium oxide and aluminum oxide. When the average diameter of the coarse-grained spray powder particles is less than about 20 μm, the size of the spray powder particles is so small that the spray powder may not be sufficiently sprayed onto a surface of an object. In contrast, when the average diameter of the coarse-grained spray powder particles is more than about 60 μm, the size of the spray powder particles is so large that the spray powder may be agglomerated on the surface of an object, to thereby deteriorate the uniformity of the spray-coating layer on the object.

Accordingly, the coarse-grained particles of the spray powder may have an average diameter in a range of about 20 μm to about 60 μm. In the present embodiment, the particles of the spray powder may have an average diameter in a range of about 30 μm to about 40 μm.

The spray powder is formed into the spray-coating layer on the object through a spray-coating process, to thereby improve mechanical strength and adhesive strength and to reduce the voids or spaces within the grained crystalline structures in the spray-coating layer.

FIG. 3 is a flowchart illustrating processing steps for a method of forming the spray powder in accordance with an example embodiment of the present invention.

Referring to FIG. 3, the first slurry is formed into a mixture of yttrium oxide, the first dispersing agent and the first bonding agent in the first solvent (step S110).

In an example embodiment, the first slurry may include yttrium oxide particles having diameters of about 0.01 μm to about 2 μm, the first dispersing agent for uniformly dispersing the yttrium oxide particles, the first bonding agent for bonding the yttrium oxide particles and the first solvent into which the yttrium oxide particles, the first dispersing agent and the first bonding agent are dissolved. In case that the bond strength between the yttrium oxide particles is sufficiently strong to combine the yttrium oxide particles together with each other, the first slurry may not include the first bonding agent.

The yttrium oxide particles, the first dispersing agent, the first bonding agent and the first solvent in the first slurry are substantially the same as those of the spray powder that is described in detail with reference to FIG. 2, and thus any further detailed descriptions on the yttrium oxide particles, the first dispersing agent, the first bonding agent and the first solvent is to be omitted.

Hereinafter, the processing steps for a method of forming the first slurry are described in detail with reference to FIG. 4.

FIG. 4 is a flowchart illustrating processing steps for a method of forming the first slurry shown in FIG. 3.

Referring to FIG. 3, the first solvent is prepared at first for formation of the first slurry (step S111). For example, the first solvent may include an organic solvent such as ethanol. Yttrium oxide particles are provided into the first solvent (step S112). Then, the first dispersing agent is provided into a mixture of the first solvent and the yttrium oxide particles (step S113). In an example embodiment, the first dispersing agent may comprise basic carboxyl materials. The yttrium oxide particles have a negative (-) surface charge due to the first dispersing agent. For example, a ratio of

the first dispersing agent to the mixture of the first slurry may be in a range of about 0.3% to about 0.5%. Then, the first bonding agent is provided into a mixture of the first solvent, the yttrium oxide particles and the first dispersing agent (step S114). For example, the first bonding agent may comprise polyvinyl butyral at a ratio of about 2% to about 3% with respect to the mixture of the first slurry.

While the above example embodiment discloses that the yttrium oxide particles, the first dispersing agent and the first bonding agent are sequentially provided into the first solvent, the actual sequence may be varied in accordance with processing conditions, as would be known to one of ordinary skill in the art.

Then, the yttrium oxide particles, the first dispersing agent and the first bonding agent are mixed with one another in the first solvent by a ball mill, to thereby form a mixture of the first slurry.

Referring again to FIG. 3, the second slurry is formed into a mixture of aluminum oxide, the second dispersing agent and the second bonding agent in the second solvent (step S120).

In an example embodiment, the second slurry may include aluminum oxide particles having diameters of about 0.5 μm to about 2 μm, the second dispersing agent for uniformly dispersing the aluminum oxide particles, the second bonding agent for bonding the aluminum oxide particles and the second solvent into which the aluminum oxide particles, the second dispersing agent and the second bonding agent are dissolved. In case that the bond strength between the aluminum oxide particles is sufficiently strong to combine the aluminum oxide particles together with each other, the second slurry may not include the second bonding agent.

The aluminum oxide particles, the second dispersing agent, the second bonding agent and the second solvent in the second slurry are substantially the same as those of the spray powder that is described in detail with reference to FIG. 2, and

thus any further detailed descriptions on the aluminum oxide particles, the second dispersing agent, the second bonding agent and the second solvent is to be omitted.

Hereinafter, the processing steps for a method of forming the second slurry are described in detail with reference to FIG. 5.

FIG. 5 is a flowchart illustrating processing steps for a method of forming the second slurry shown in FIG. 3.

Referring to FIG. 5, the second solvent is prepared at first for formation of the second slurry (step S121). For example, the second solvent may include an organic solvent such as ethanol. Aluminum oxide particles are provided into the second solvent (step S122). Then, the second dispersing agent is provided into a mixture of the second solvent and the aluminum oxide particles (step S123). In an example embodiment, the second dispersing agent may comprise acidic carboxyl materials. The aluminum oxide particles have a positive (+) surface charge due to the second dispersing agent. For example, a ratio of the second dispersing agent to the mixture of the second slurry may be in a range of about 0.3% to about 2%. Then, the second bonding agent is provided into a mixture of the second solvent, the aluminum oxide particles and the second dispersing agent (step S124). For example, the second bonding agent may comprise polyvinyl butyral at a ratio of about 2% to about 3% with respect to the mixture of the second slurry.

While the above example embodiment discloses that the aluminum oxide particles, the second dispersing agent and the second bonding agent are sequentially provided into the second solvent, the actual sequence may be varied in accordance with processing conditions, as would be known to one of ordinary skill in the art.

Then, the aluminum oxide particles, the second dispersing agent and the second bonding agent are mixed with one another in the second solvent by a ball mill, to thereby form a mixture of the second slurry.

Referring again to FIG. 3, the first slurry and the second slurry are mixed with each other, to thereby form the slurry mixture (step S130). In an example embodiment, the first slurry and the second slurry are mixed in such a manner that the weight ratio of yttrium oxide to aluminum oxide is in a range of about 5:5 to about 7:3, that is, in a range of about 1:0.4 to 1.

FIG. 6 is a view illustrating a bonding mechanism of yttrium oxide and aluminum oxide in the slurry mixture shown in FIG. 3.

Referring to FIG. 6, yttrium oxide has a negative (-) surface charge and aluminum oxide has a positive (+) surface charge, so that yttrium oxide is strongly bonded with aluminum oxide by electrostatic attraction.

Referring again to FIG. 3, a spray-drying process and a heat treating process are performed on the slurry mixture, to thereby form particles having a coarse-grained structure including yttrium oxide and aluminum oxide (step S140). That is, the particles are formed through sequential processing steps of the spray-drying process on the slurry mixture and the heat treating process on the dried slurry mixture.

The spray-drying process is performed at a temperature of about 60°C to about 110°C in a dry chamber while the slurry mixture is injected into the dry chamber. When the spray-drying process may be performed at a temperature less than about 60°C, organic solvents in the slurry mixture may not be sufficiently volatilized, to thereby increase a process time of the spray-drying process. Particularly, when neutral solvents such as pure water and alcoholic solvents such as methanol and ethanol are used as the organic solvents for the slurry mixture, the organic solvents are significantly difficult to be volatilized at a temperature of less than about 60°C, to thereby remarkably reduce the efficiency of the spray-drying process. In addition, when the spray-drying process may be performed at a temperature of more than

about 110°C, the organic solvents in the slurry mixture may be rapidly volatilized and thus a plurality of voids is generated in the spray powder. Accordingly, the spray-drying process is performed at a temperature of about 60°C to about 110°C, and the slurry mixture is changed into the spray powder.

Then, the dried slurry mixture or the spray powder is heated at a high temperature in the dry chamber, to thereby improve hardness of the spray powder. When the heat treating process is performed at a temperature lower than about 800° C, the spray powder is difficult to have a sufficient hardness so that spherical particles of the spray powder are broken and flattened. As a result, the pipe through which the spray powder is provided to the plasma gun may become clogged with the spray powder. In contrast, when the heat treating process is performed at a temperature higher than about 1,500°C, yttrium oxide and aluminum oxide in the spray powder are chemically reacted with each other, and thus the spray powder is grown into a lump of powder. Accordingly, the heat treating process is performed at a temperature of about 800°C to about 1,500°C, and the spray powder may have a sufficient hardness. After completion of the spray-drying process and the heat treating process, the above slurry mixture is changed into the spray powder having the coarse-grained particles of yttrium oxide and aluminum oxide of which the average diameter is ranged from about 20 μm to about 60 μm.

As a result, the slurry mixture of the first slurry including yttrium oxide and the second slurry including aluminum oxide may be formed into the spray powder having the coarse-grained structure of which the average diameter is in a range of about 20 μm to about 60 μm.

The formation process of the spray powder may be performed in an atmosphere of one of air, hydrogen, oxygen and nitrogen and a mixture thereof. That is, step S110 for forming the first slurry, step S120 for forming the second slurry, step

S130 for forming the slurry mixture and step S140 for performing the spray-drying process and the heat treating process to the slurry mixture may be performed in an atmosphere of one of air, hydrogen, oxygen and nitrogen and a mixture thereof. In the present example embodiment, the spray-drying process may be performed in an atmosphere of air and the heat-treating process may be performed in an atmosphere of one of air, hydrogen, oxygen and nitrogen.

The spray powder for the spray-coating layer may include the coarse-grained particles including yttrium oxide and aluminum oxide, so that the spray-coating layer has an amorphous crystalline structure and a reduced number of voids or spaces therein. Therefore, when the spray-coating layer is formed on the inner surface of the plasma process chamber, the source plasma may be sufficiently prevented from penetrating the spray-coating layer. Accordingly, the spray-coating layer may be sufficiently adhered to the inner surface of the process chamber and the separation of the spray-coating layer from the inner surface of the process chamber may be sufficiently prevented in the plasma processing system. As a result, etching of the plasma processing system caused by the source plasma may be sufficiently prevented by the spray-coating layer.

Hereinafter, a method of forming the spray-coating layer using the spray powder and the spray-coating layer including the spray powder are described in detail.

FIG. 7 is a flowchart illustrating a method of forming a spray-coating layer in accordance with an example embodiment of the present invention.

Referring to FIG. 7, a spray powder is prepared at first (step S210). The spray powder includes a plurality of coarse-grained particles of yttrium oxide and aluminum oxide and the coarse-grained particles have diameters of about 20 μm to

about 60 μm. In an example embodiment, the spray powder may be formed through a spray-drying process using a slurry mixture including first and second slurries. The first slurry may include yttrium oxide particles having diameters of about 0.01 μm to about 2 μm, a first dispersing agent for uniformly dispersing the yttrium oxide particles, a first bonding agent for bonding the yttrium oxide particles, and a first solvent into which the yttrium oxide particles, the first dispersing agent and the first bonding agent are dissolved. The second slurry may include aluminum oxide particles having diameters of about 0.5 μm to about 2 μm, a second dispersing agent for uniformly dispersing the aluminum oxide particles, a second bonding agent for bonding the yttrium oxide particles, and a second solvent into which the aluminum oxide particles, the second dispersing agent and the second bonding agent are dissolved. In an example embodiment, the weight ratio of yttrium oxide to aluminum oxide is in a range of about 5:5 to about 7:3 in the slurry mixture, that is, in a range of about 1:0.4 to 1.

Then, the spray powder is dissolved and sprayed onto the object (step S220). In an example embodiment, the melting and spray of the spray powder may be performed by an atmospheric plasma spray (APS) process, a high-velocity oxygen-fuel (HVOF) spray process, a vacuum plasma spray (VPS) process or a kinetic spray process. Accordingly, the spray-coating layer is formed on a surface of the object.

FIG. 8A is a picture showing a cross-sectional surface of the spray-coating layer in accordance with an example embodiment of the present invention, and FIG. 8B is an enlarged picture showing a portion of the spray-coating layer shown in FIG. 8A.

Referring to FIGS. 8A and 8B, the spray powder of which the particles has the coarse-grained structure including yttrium oxide and aluminum oxide is formed into the spray-coating layer on the object, so that the spray-coating layer has an

amorphous crystalline structure. As a result, the voids and spaces within crystalline structures are minimized in the spray-coating layer, to thereby reduce porosity of the spray-coating layer. For example, the spray-coating layer may have the porosity of about 0.5% to about 2%, and more particularly, of about 0.5% to about 1%. In addition, the spray-coating layer may have an adhesive strength greater than about 13 MPa and hardness greater than about 650 HV, more particularly, greater than about 700 HV.

FIG. 9 is a view illustrating an inner structure of the plasma processing system in accordance with an example embodiment of the present invention.

Referring to FIG. 9, the inner structure 100 of the plasma processing system may include an inner member 110 installed in the plasma processing system and a spray-coating layer 120 on the inner member 110.

In an example embodiment, the inner member 110 may be positioned in the process chamber (not shown) of the plasma processing system. A substrate is loaded into the process chamber and the process chamber includes an inner space for performing the plasma process to the substrate. A source gas is supplied into the process chamber and is transformed into a source plasma, and the substrate is processed in the space of the process chamber using the source plasma during the plasma process. For example, the source gas may include a deposition gas for coating a thin layer on the substrate or an etching gas for etching the thin layer from the substrate. The substrate may include a semiconductor substrate for manufacturing a semiconductor device or a glass substrate for manufacturing a flat display device.

In an example embodiment, the inner member 110 may include a chamber liner, a baffle, and a shield ring in the process chamber. The chamber liner is positioned along the inner surface of the process chamber and may prevent damage

to the inner surface of the chamber caused by the source gas. The shield ring is positioned along a peripheral portion of a chuck for supporting the substrate in the process chamber and may prevent damage to the chuck caused by the source gas. The inner member 110 may include the inner surface of the process chamber itself, as would be known to one of ordinary skill in the art.

The spray-coating layer 120 is positioned on the inner member 110. That is, the spray-coating layer 120 may be positioned on the inner surfaces of each of the chamber liner, the baffle, the shield ring and the process chamber.

The spray-coating layer 120 has substantially the same structure and function as the spray-coating layer described with reference to FIGS. 7, 8A and 8B, and thus any detailed descriptions on the spray-coating layer 120 is omitted.

The spray-coating layer 120 may prevent the source plasma from making direct contact with the inner member 110. In addition, the spray-coating layer 120 may be sufficiently adhered to the inner member 110 for preventing the separation of the spray-coating layer 120 from the inner member 110, to thereby minimize contamination caused by the spray-coating layer 120.

Experiments on particle sizes of yttrium oxide and aluminum oxide

Table 1

	Y_2O_3 (μm)	Al_2O_3 (μm)	Particle Size (μm)	Spray Atmosphere	Adhesive Strength (MPa)	Hardness (HV)	Porosity (%)
Experiment 1	5	-	35	Atmospheric	7-10	400-450	4-6
Experiment	-	4	25	Atmospheric	7-10	700-800	4-6

2							
Experiment 3	5	4	40	Atmospheric	10	550	6
Experiment 4	5	2	38	Atmospheric	11	530	4
Experiment 5	5	0.5	35	Atmospheric	9	550	3
Experiment 6	2	4	30	Atmospheric	10	550	4
Experiment 7	2	2	35	Atmospheric	13	650	2
Experiment 8	2	0.5	35	Atmospheric	13.5	680	2
Experiment 9	0.01	4	30	Atmospheric	10	550	3
Experiment 10	0.01	2	35	Atmospheric	13	650	1.2
Experiment 11	0.01	0.5	30	Atmospheric	14	700	0.8

The spray powder was formed by the same spray-drying process as described in an example embodiment of the present invention at various particle sizes of aluminum oxide and yttrium oxide, as shown in Table 1, and the spray-coating layer was formed by the same spray-coating process as described in an example embodiment of the present invention using the spray powder. The spray

powder and the spray-coating layer were formed by the above process in each experiment, and the particle size of each spray powder and the adhesive strength, the mechanical strength and the porosity of each spray-coating layer were measured in each of the experiments. Table 1 shows the measured results of the particle size of the spray powder and the adhesive strength, the mechanical strength and the porosity of the spray-coating layer.

Table 1 indicates that the adhesive strength, the mechanical strength and the porosity in Experiments 7, 8, 10 and 11 (referred to as Experimental Group 1) were much better than those in Experiments 1-6 and 9 (referred to as Experimental Group 2). The particle size of yttrium oxide was in a range of about 0.01 μm to about 2 μm and the particle size of aluminum oxide was in a range of about 0.5 μm to about 2 μm in Experimental Group 1, while the particle size of yttrium oxide and aluminum oxide was greater than about 2 μm in Experimental Group 2.

The above experimental results on Table 1 show that the adhesive strength, the mechanical strength and the porosity of the spray-coating layer may be optimized when the spray powder for forming the spray-coating layer includes the yttrium oxide particles of which the sizes are in a range of about 0.01 μm to about 2 μm and the aluminum oxide particles of which the sizes are in a range of about 0.5 μm to about 2 μm.

Experiments on the weight ratio of yttrium oxide to aluminum oxide

Table 2

	Y_2O_3 (wt%)	Al_2O_3 (wt%)	Particle Size (μm)	Spray Atmosphere	Adhesive Strength (MPa)	Hardness (HV)

Experiment 1	10	90	30	Atmospheric	10	750
Experiment 2	20	80	35	Atmospheric	10	750
Experiment 3	30	70	33	Atmospheric	11	720
Experiment 4	40	60	40	Atmospheric	11	720
Experiment 5	50	50	35	Atmospheric	13	700
Experiment 6	60	40	35	Atmospheric	13	650
Experiment 7	70	30	30	Atmospheric	13	600
Experiment 8	80	20	28	Atmospheric	10	520
Experiment 9	90	10	33	Atmospheric	10	430

The spray powder was formed by the same spray-drying process as described in an example embodiment of the present invention at various weight ratios of aluminum oxide and yttrium oxide in the slurry mixture, and the spray-coating layer was formed by the same spray-coating process as described in an example embodiment of the present invention using the spray powder. The spray powder and the spray-coating layer were formed by the above process in each experiment, and the particle size of each spray powder and the adhesive strength and the mechanical strength of each spray-coating layer were measured in each of the experiments. Table 2 shows the measured results of the particle size of the spray powder and the adhesive strength and the mechanical strength of the spray-coating layer.

Table 2 indicates that the adhesive strengths in Experiments 5-7 (referred to as Experimental Group 3) were much better than that in Experiments 1-4 (referred to as Experimental Group 4). The weight ratio of yttrium oxide to aluminum oxide was in a range of about 5:5 to about 7:3 in Experimental Group 3, while the weight ratio of

yttrium oxide to aluminum oxide was in a range of about 1:9 to about 4:6 in Experimental Group 4. In addition, the adhesive strength and the mechanical strength in Experimental Group 3 were much better than those in Experiments 8-9 (referred to as Experimental Group 5). The weight ratio of yttrium oxide yttrium oxide to aluminum oxide was in a range of about 8:2 to about 9:1 in Experimental Group 5.

The above experimental results on Table 2 show that the adhesive strength and the mechanical strength of the spray-coating layer may be optimized when the spray powder for forming the spray-coating layer includes yttrium oxide and aluminum oxide in such a composition that the weight ratio of yttrium oxide to aluminum oxide is in a range of about 5:5 to about 7:3, that is in a range of about 1:0.4 to 1.

Experiments on the ratio of the dispersing agents and solid materials in the slurry

Table 3

	First Dispersing Agent (%)	Second Dispersing Agent (%)	Solid Materials (%)	Spherical/Non-Spherical Particle
Experiment 1	2	2	40	X
Experiment 2	1	1	30	X
Experiment 3	2	1	35	X
Experiment 4	1	2	35	X
Experiment 5	0.5	1	30	O
Experiment 6	0.3	2	30	O

Experiment 7	0.5	2	30	O
Experiment 8	0.3	1	25	O
Experiment 9	3	2	45	X
Experiment 10	3	1	40	X
Experiment 11	3	0.5	35	X
Experiment 12	0.5	0.5	25	O
Experiment 13	0.5	0.3	25	O
Experiment 14	0.5	3	35	X

The spray powder was formed by the same spray-drying process as described in an example embodiment of the present invention at various ratios of the first dispersing agent in the first slurry, at various ratios of the second dispersing agent in the second slurry and at various ratios of the solid materials of the first and second slurries in the slurry mixture. The spray powder was formed by the above process in each experiment, and whether the spray powder was formed into spherical particles or non-spherical particles was detected in each of the experiments. Table 3 shows the detected results of the particle shape of the spray powder.

Table 3 indicates that the spray powder was detected to be spherical in Experiments 5-9, 12 and 13 (referred to as Experimental Group 6), and to be non-spherical in Experiments 1-4, 9-11 and 14 (referred to as Experimental Group 7). In Experimental Group 6, the ratio of the first dispersing agent in the first slurry was in a range of about 0.3% to about 0.5%, the ratio of the second dispersing agent in the second slurry was in a range of about 0.3% to about 2%, and the ratio of the solid material in the first and second slurries was in a range of about 20% to about 30%. In contrast, in Experimental Group 7, the ratio of the first dispersing agent in the first slurry was greater than about 0.5%, the ratio of the second dispersing agent in the

second slurry was greater than about 2%, and the ratio of the solid material in the first and second slurries was greater than about 30%.

The above experimental results on Table 3 show that most of the spray powder is formed to be a spherical shape under the conditions in which the ratio of the first dispersing agent in the first slurry was in a range of about 0.3% to about 0.5%, the ratio of the second dispersing agent in the second slurry was in a range of about 0.3% to about 2%, and the ratio of the solid material in the first and second slurries was in a range of about 20% to about 30%.

Experiments on the ratio of the bonding agent and heating temperature variation

Table 4

	Bonding Agent (%)	Heating Temperature (°C)	Spherical/Non-Spherical Particle
Experiment 1	0.2	700	X
Experiment 2	0.2	800	X
Experiment 3	0.2	1,400	X
Experiment 4	0.2	1,500	X
Experiment 5	0.5	700	X
Experiment 6	0.5	800	X
Experiment 7	0.5	1,400	X
Experiment 8	0.5	1,500	X
Experiment 9	1	700	X
Experiment 10	1	800	X
Experiment 11	1	1,400	X

Experiment 12	1	1,500	X
Experiment 13	2	700	X
Experiment 14	2	800	O
Experiment 15	2	1,400	O
Experiment 16	2	1,500	O
Experiment 17	3	700	X
Experiment 18	3	800	O
Experiment 19	3	1,400	O
Experiment 20	3	1,500	O
Experiment 21	4	1,500	O

The spray powder was formed by the same spray-drying process as described in an example embodiment of the present invention at various ratios of the first bonding agent in the first slurry, at various ratios of the second bonding agent in the second slurry and at various heating temperature of the heat treating process to the slurry mixture including the first and second slurries. The spray powder was formed by the above process in each experiment, and whether the spray powder was formed into spherical particles or non-spherical particles was detected in each of the experiments. Table 4 shows the detected results of the particle shape of the spray powder.

Table 4 indicates that the spray powder was detected to be spherical in Experiments 14-16 and 18-21 (referred to as Experimental Group 8), and to be non-spherical in Experiments 1-13 and 17 (referred to as Experimental Group 9). In Experimental Group 8, the ratio of the first bonding agent in the first slurry was greater than about 2%, the ratio of the second bonding agent in the second slurry

was also greater than about 2%, and the heat treating process was performed at a temperature of about 800°C to about 1,500°C. In contrast, in Experimental Group 9, the ratio of the first bonding agent in the first slurry was less than about 2%, the ratio of the second bonding agent in the second slurry was also less than about 2%, and the heat treating process was performed at a temperature lower than about 800°C or more than about 1,500°C. When the first bonding agent and the second bonding agent are more than about 3% in the first slurry and the second slurry, respectively, and the heat treating process was performed at a temperature of about 800°C to about 1,500°C, the fluidity of the slurry mixture including the first and second slurries was deteriorated despite the spherical particles of the spray powder, so that there was a problem in that the spray dryer for the spray-drying process was frequently clogged with the slurry mixture.

The above experimental results on Table 4 show that most of the spray powder is formed to be a spherical shape under the conditions in which the first bonding agent and the second bonding agent are in a range of about 2% to about 3% in the first slurry and the second slurry, respectively, and the heat treating process was performed at a temperature of about 800°C to about 1,500°C.

FIG. 10 is a view illustrating an X-ray diffraction pattern of the spray-coating layer in accordance with an example embodiment of the present invention. In FIG. 10, a horizontal line indicates a diffraction angle (2θ) of the X-ray diffraction and a vertical line indicates an intensity of the X-ray.

FIG. 10 does not show a particular diffraction angle (2θ) corresponding to a high intensity of the X-ray which indicates a crystalline structure of the spray-coating layer. That is, FIG. 10 indicates that the spray-coating layer is formed to have an amorphous structure.

According to the example embodiments of the present invention, a spray

powder is formed into coarse-grained particles including yttrium oxide and aluminum oxide and having an average diameter of about 20 μm to about 60 μm. A spray-coating layer is formed by a spray-coating process using the spray powder, and thus has an amorphous structure and a low porosity. Therefore, when the spray-coating layer is formed on the inside of a plasma processing system, a source plasma may be sufficiently prevented from penetrating the spray-coating layer. As a result, the spray-coating layer may prevent the source plasma from making direct contact with the plasma processing system. In addition, the spray-coating layer may be sufficiently adhered to the plasma processing system for preventing the separation of the spray-coating layer from the plasma processing system, to thereby minimize contamination caused by the spray-coating layer. Particularly, the spray-coating layer may sufficiently prevent etching of the plasma processing system caused by the source plasma, to thereby remarkably improve the lifespan of the plasma processing system.

Although the example embodiments of the present invention have been described, it is understood that the present invention should not be limited to these example embodiments but various changes and modifications can be made by one skilled in the art within the spirit and scope of the present invention as hereinafter claimed.

WHAT IS CLAIMED IS:

1. A method of forming a spray-coating layer, comprising:

preparing a spray powder using a slurry mixture including a first slurry and a second slurry, the spray powder including particles having an average diameter of about 20 μm to about 60 μm, the first slurry including yttrium oxide particles having diameters of about 0.01 μm to about 2 μm, a first dispersing agent for uniformly dispersing the yttrium oxide particles, a first bonding agent for bonding the yttrium oxide particles, and a first solvent into which the yttrium oxide particles, the first dispersing agent and the first bonding agent are dissolved, and the second slurry including aluminum oxide particles having diameters of about 0.5 μm to about 2 μm, a second dispersing agent for uniformly dispersing the aluminum oxide particles, a second bonding agent for bonding the aluminum oxide particles, and a second solvent into which the aluminum oxide particles, the second dispersing agent and the second bonding agent are dissolved; and

spraying the spray powder to an object in a dissolved state,

wherein a weight ratio of the yttrium oxide and the aluminum oxide is in a range of about 1:0.4 to 1 in the slurry mixture.

2. The method of claim 1, wherein the first dispersing agent includes a basic material and the second dispersing agent includes an acidic material.

3. The method of claim 2, wherein a ratio of the first dispersing agent with respect to the first slurry is in a range of about 0.3% to about 0.5%, and a ratio of the second dispersing agent with respect to the second slurry is in a range of about 0.3% to about 2%.

4. The method of claim 1, wherein a ratio of the first bonding agent with respect to the first slurry is in a range of about 2% to about 3%, and a ratio of the second bonding agent with respect to the second slurry is in a range of about 2% to about 3%.

5. The method of claim 1, wherein a ratio of solid materials with respect

to the first and the second slurries is in a range of about 20% to about 30%, respectively.

6. The method of claim 1, wherein spraying the spray powder is performed by one of an APS process, an HVOF spray process, a VPS process and a kinetic spray process.

7. A spray-coating layer comprising yttrium oxide and aluminum oxide and having an amorphous structure that is formed by a spray-coating process, wherein a weight ratio of the yttrium oxide and the aluminum oxide is in a range of about 1:0.4 to 1 in the slurry mixture.

8. The spray-coating layer of claim 7, wherein porosity thereof is in a range of about 0.5% to about 2%.

9. The spray-coating layer of claim 7, wherein an adhesive strength thereof is at least about 13 MPa.

10. The spray-coating layer of claim 7, wherein a hardness thereof is at least about 650 HV.

11. The spray-coating layer of claim 7, wherein a spray powder having an average diameter of about 20 μm to about 60 μm is used in the spray-coating process.

12. The spray-coating layer of claim 7, wherein the spray-coating layer is positioned on a surface of an inner member of a process chamber in which a plasma process is performed on a substrate.