dry-etching by use of the patterned silicon nitride and silicon dioxide films as a mask, to form trench isolation grooves.

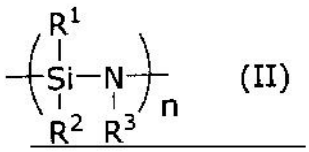
[0020] The widths of the formed trench isolation grooves depend on the pattern used in the exposure of the photoresist coating. In general, the widths of trench isolation grooves in semiconductor elements are properly selected according to the aimed elements. However, the present invention is characterized in enabling to fill even the grooves of high aspect ratios homogeneously and densely with silicon dioxide. Accordingly, in the present invention, the groove width is preferably 5 to 50 nm, more preferably 5 to 40 nm. The aspect ratio, which is a ratio of the groove depth to the width, is preferably 3 to 100, more preferably 10 to 50.

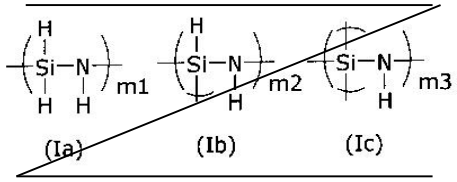
[0021] In the next procedure, the silicon substrate thus prepared is coated with silicon dioxide fine particles, which are applied in the form of a dispersion containing silicon dioxide fine particles, a polymer, a surfactant and a dispersion medium.

[0022] There are various kinds of silicon dioxide fine particles. Examples of them include colloidal silica, fumed silica, and silica in other forms different from each other in production processes and properties. Although any of them can be used, colloidal silica is generally selected in view of availability. The size of the fine particles can be freely selected according to, for example, the method of applying the dispersion, and the relief structure formed on the substrate to be coated. However, they normally have a mean particle size of 4 to 50 ~~nm~~ μm, preferably 4 to 20 ~~nm~~ μm. In the case where an insulating film is intended to be formed on a substrate having grooves and/or holes, it is preferred to use silicon dioxide fine particles smaller than the groove widths and/or hole diameters so that the film can be evenly formed in the grooves and/or holes. Since silicon

by dissolving any known polysilazane compound in a solvent.

[0035] The polysilazane compound used in the present invention is not particularly restricted, and hence can be freely selected unless it impairs the effect of the invention. It may be either an inorganic or organic compound. Preferred examples of the polysilazane compound include a polysilazane comprising the following units (Ia) to (Ic) in combination:

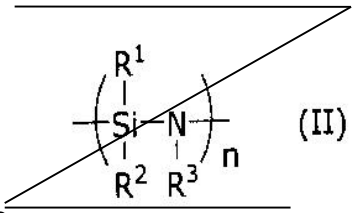

(II)

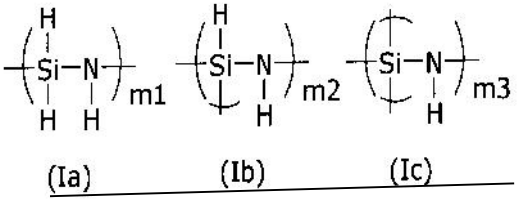

(Ia) (Ib) (Ic)

(wherein each of m1 to m3 is a number indicating the polymerization degree).

It is particularly preferred for the above polysilazane to have a polystyrene-reduced weight average molecular weight of 700 to 30000.

[0036] Examples of the polysilazane compound also include: a polysilazane which has a skeleton mainly represented by the following formula (II):


(II)


(Ia) (Ib) (Ic)

(wherein each of R^1, R^2 and R^3 is independently a hydrogen atom, an alkyl group, an alkenyl group, a cycloalkyl group, an aryl group, an alkylsilyl group, an alkylamino group, an alkoxy group, or another group, such as a fluoroalkyl group, which contains a carbon atom directly connecting to the silicon atom, provided that at least one of R^1, R^2 and R^3 is a hydrogen atom; and n is a number indicating the polymerization degree) and which has a number average molecular weight of about 100 to 50000; and modified compounds thereof.

CLAIMS

[1] A method for forming an insulating film, comprising

(1) a step of coating with silicon dioxide fine particles, in which a substrate is coated with a silicon dioxide dispersion containing silicon dioxide fine particles, a polymer, a surfactant and a dispersion medium;

(2) a step of coating with polysilazane, in which the substrate surface coated with the silicon dioxide dispersion is further coated with a polysilazane composition; and

(3) a step of heating, in which the substrate coated with the polysilazane composition is heated, so as to covert the polysilazane into silicon dioxide and thereby to form an insulating film made of the silicon dioxide fine particles and the silicon dioxide derived from the polysilazane.

[2] The method according to claim 1 for forming an insulating film, wherein the step of heating is carried out at a temperature of 200 to 1500°C.

[3] The method according to claim 1 ~~or 2~~ for forming an insulating film, wherein the step of heating is carried out in an atmosphere containing water vapor.

[4] The method according to ~~any of~~ claim~~s~~ 1 ~~to 3~~ for forming an insulating film, wherein the weight ratio between the silicon contained in the coated silicon dioxide dispersion and that in the coated polysilazane composition is in the range of 1:15 to 6:1 per unit area of the substrate.

[5] The method according to ~~any of~~ claim~~s~~ 1 ~~to 4~~ for forming an insulating film, further comprising

a step of additional heating, in which the substrate is further heated in an inert gas atmosphere after the step of heating.

[6] The method according to ~~any of~~ claim~~s~~ 1 ~~to 5~~ for forming an insulating film, furthermore comprising

a step of preliminary heating, in which the substrate is heated to evaporate at least a part of the dispersion medium after the step of coating with silicon dioxide fine particles and before the step of coating with polysilazane.

[7] The method according to ~~any of~~ claim~~s~~ 1 ~~to 6~~ for forming an insulating film, wherein the substrate has a trench structure for insulating electronic parts and the formed insulating film constitutes a trench isolation structure.

[8] The method according to ~~any of~~ claim~~s~~ 1 ~~to 6~~ for forming an insulating film, wherein the insulating film serves as an inter-metal dielectric film or a pre-metal dielectric film.

[9] A silicon dioxide fine particle dispersion used in the method according to ~~any of~~ claim~~s~~ 1 ~~to 8~~ for forming an insulating film, containing

silicon dioxide fine particles, a polymer, a surfactant and a dispersion medium.

[10] The silicon dioxide fine particle dispersion according to claim ~~8~~ 9, wherein the content of the silicon dioxide fine particles is in the range of 2 to 30 wt% based on the total weight of the dispersion.

[11] The silicon dioxide fine particle dispersion according to claim 9 ~~or 10~~, wherein the polymer is selected from the group consisting of acrylic acid polymer, methacrylic acid polymer, polyvinylpyrrolidone, and derivatives thereof.

[12] The silicon dioxide fine particle dispersion according to ~~any of~~ claim 1 ~~9 to 11~~, wherein the content of the polymer is in the range of 1 to 10 wt% based on the total weight of the dispersion.

[13] The silicon dioxide fine particle dispersion according to ~~any of~~ claim 9 ~~to 12~~, wherein the surfactant is selected from the group consisting of alkylsulfonic acids and ethylene oxide type surfactants.

[14] The silicon dioxide fine particle dispersion according to ~~any of~~ claim 9 ~~to 13~~, wherein the content of the surfactant is in the range of 0.01 to 5 wt% based on the total weight of the dispersion.