CLAIMS

[Claim 1]

A patterning process for forming a pattern in a substrate to be processed, the method comprising, in the following order, steps of:

(i-1) forming an organic underlayer film on a substrate to be processed, forming a tin-containing middle layer film on the organic underlayer film, and further forming an upper layer resist film on the tin-containing middle layer film;

(i-2) performing pattern exposure and subsequent development in the upper layer resist film to form an upper layer resist pattern;

(i-3) dry-etching the tin-containing middle layer film while using the upper layer resist pattern as a mask to transfer the upper layer resist pattern to the tin-containing middle layer film, and further dry-etching the organic underlayer film while using the tin-containing middle layer film having the transferred upper layer resist pattern as a mask to form an organic underlayer film pattern on an upper portion of which a portion of the tin-containing middle layer film is left;

(i-4) removing the portion of the tin-containing middle layer film left on the upper portion of the organic underlayer film pattern by dry-etching;

(i-5) forming an inorganic silicon-containing film comprising polysilicon, amorphous silicon, silicon oxide, silicon nitride, silicon oxynitride, silicon carbide, or a composite material thereof, by a CVD method or an ALD method, so as to cover the organic underlayer film pattern;

(i-6) removing a portion of the inorganic silicon-

containing film by dry-etching to expose the upper portion of the organic underlayer film pattern;

(i-7) removing the organic underlayer film pattern to form an inorganic silicon-containing film pattern with a pattern pitch that is 1/2 of a pattern pitch of the upper layer resist pattern; and

(i-8) processing the substrate to be processed while using the inorganic silicon-containing film pattern as a mask to form a pattern in the substrate to be processed,

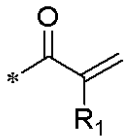
wherein the tin-containing middle layer film is formed from a composition for forming a tin-containing middle layer film, the composition comprising a compound having a crosslinkable organic structure, and

wherein a compound having one or more selected from the group consisting of:

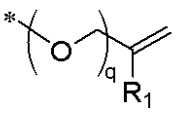
a hydroxyl group;

an organic group having a protective group which is to be eliminated by an action of acid or heat or both to generate one or more hydroxyl groups or carboxyl groups; and

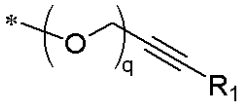
an organic group represented by any one of the following general formulae (a-1) to (a-3) and (b-1) to (b-4)
is used as the crosslinkable organic structure:



(a-1)

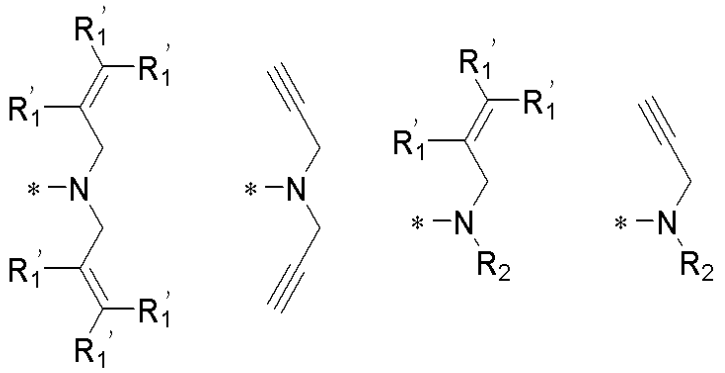


(a-2)



(a-3)

, wherein in the general formulae (a-1) to (a-3), R_1 represents a hydrogen atom or a monovalent organic group having 1 to 10 carbon atoms, q represents 0 or 1, and * represents a bonding point,



(b-1) (b-2) (b-3) (b-4)

, wherein in the general formulae (b-1) and (b-3), R_1' represents a hydrogen atom or a methyl group, and in the same formula, they may be the same or different; in (b-3) to (b-4), R_2 represents a hydrogen atom, a substituted or unsubstituted saturated or unsaturated monovalent organic group having 1 to 20 carbon atoms, a substituted or unsubstituted aryl group having 6 to 30 carbon atoms, or a substituted or unsubstituted arylalkyl group having 7 to 31 carbon atoms; * represents a bonding point.

[Claim 2]

A patterning process for forming a pattern in a substrate to be processed, the method comprising, in the following order, steps of:

(ii-1) forming an organic underlayer film on a substrate to be processed, forming a tin-containing middle layer film on the organic underlayer film, and further forming an upper layer resist film on the tin-containing middle layer film;

(ii-2) performing pattern exposure and subsequent development in the upper layer resist film to form an upper layer resist pattern;

(ii-3) dry-etching the tin-containing middle layer film while using the upper layer resist pattern as a mask to transfer the upper layer resist pattern to the tin-containing middle layer film, and further dry-etching the organic underlayer film while using the tin-containing middle layer film having the transferred upper layer resist pattern as a mask to form an organic underlayer film pattern on an upper portion of which a portion of the tin-containing middle layer film is left;

(ii-4) forming an inorganic silicon-containing film comprising polysilicon, amorphous silicon, silicon oxide, silicon nitride, silicon oxynitride, silicon carbide, or a composite material thereof, by a CVD method or an ALD method, so as to cover the portion of the tin-containing middle layer film and the organic underlayer film pattern;

(ii-5) removing a portion of the inorganic silicon-containing film by dry-etching to expose an upper portion of the portion of the tin-containing middle layer film;

(ii-6) removing the portion of the tin-containing middle layer film left on the upper portion of the organic underlayer film pattern by dry-etching;

(ii-7) removing the organic underlayer film pattern by dry-etching to form an inorganic silicon-containing film pattern with a pattern pitch that is 1/2 of a pattern pitch of the upper layer resist pattern; and

(ii-8) processing the substrate to be processed while using the inorganic silicon-containing film pattern as a mask to form a pattern in the substrate to be processed,

wherein the tin-containing middle layer film is

formed from a composition for forming a tin-containing middle layer film, the composition comprising a compound having a crosslinkable organic structure, and

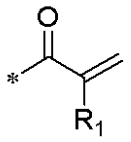
wherein a compound having one or more selected from the group consisting of:

a hydroxyl group;

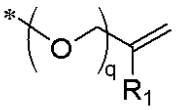
an organic group having a protective group which is to be eliminated by an action of acid or heat or both to generate one or more hydroxyl groups or carboxyl groups; and

an organic group represented by any one of the following general formulae (a-1) to (a-3) and (b-1) to (b-4)

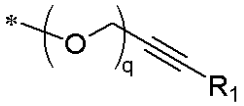
is used as the crosslinkable organic structure:



(a-1)

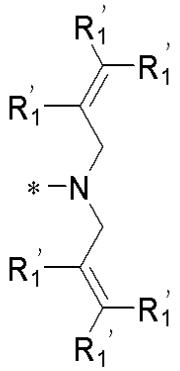


(a-2)

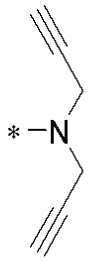


(a-3)

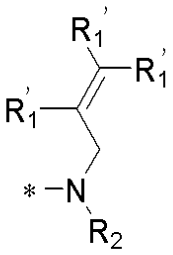
, wherein in the general formulae (a-1) to (a-3), R_1 represents a hydrogen atom or a monovalent organic group having 1 to 10 carbon atoms, q represents 0 or 1, and * represents a bonding point,



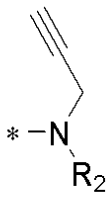
(b-1)



(b-2)



(b-3)



(b-4)

, wherein in the general formulae (b-1) and (b-3), R_1' represents a hydrogen atom or a methyl group, and in

the same formula, they may be the same or different; in (b-3) to (b-4), R_2 represents a hydrogen atom, a substituted or unsubstituted saturated or unsaturated monovalent organic group having 1 to 20 carbon atoms, a substituted or unsubstituted aryl group having 6 to 30 carbon atoms, or a substituted or unsubstituted arylalkyl group having 7 to 31 carbon atoms; * represents a bonding point.

[Claim 3]

The patterning process according to claim 1 or 2, wherein in the step (i-4) or (ii-6), the tin-containing middle layer film is etched by plasma formed in a H_2-containing gas.

[Claim 4]

The patterning process according to any one of claims 1 to 3, wherein the tin-containing middle layer film is formed by spin coating using a composition for forming a tin-containing middle layer film.

[Claim 5]

The patterning process according to any one of claims 1 to 4, wherein in the step (i-1) or (ii-1), a water-repellent coating film is further formed on the upper layer resist film.

[Claim 6]

The patterning process according to any one of claims 1 to 5, wherein in the step (i-1) or (ii-1), an organic adhesive film is formed in middle between the tin-containing middle layer film and the upper layer resist film.