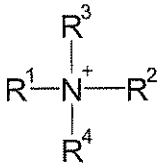
Claims

1. An aqueous composition for developing photoresists applied to semiconductor substrates, said composition comprising a quaternary ammonium compound of formula I

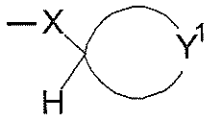


z Z (I)

wherein

(a) R^1 is selected from a C_4 to C_{30} organic radical of formula –X-$CR^{10}R^{11}R^{12}$, wherein R^{10}, R^{11} and R^{12} are independently selected from a C_1 to C_{20} alkyl and two or three of R^{10}, R^{11} and R^{12} may together form a ring system, and
R^2, R^3 and R^4 are selected from R^1 or a C_1 to C_{10} alkyl, C_1 to C_{10} hydroxyalkyl C_1 to C_{30} aminoalkyl or C_1 to C_{20} alkoxyalkyl, and X is a chemical bond or a C_1 to C_4 divalent organic radical, or

(b) R^1 and R^2 are independently selected from an organic radical of formula IIa or IIb



(IIa)

or

-X-Y^2 (IIb)

wherein Y^1 is C_4 to C_{20} alkanediyl, Y^2 is a one-, two- or tricyclic C_5 to C_{20} carbocyclic or heterocyclic aromatic system, and R^3 and R^4 are selected from R^1 or a C_1 to C_{10} alkyl, C_1 to C_{10} hydroxyalkyl, C_1 to C_{30} aminoalkyl, or C_1 to C_{20} alkoxyalkyl, and X is a chemical bond or a C_1 to C_4 divalent organic radical, and X is a chemical bond or a C_1 to C_4 divalent organic radical, or

(c) at least two of R^1, R^2, R^3, and R^4 together form a saturated mono, bi or tricyclic C_5 to C_{30} organic ring system and the remaining R^3 and R^4, if any, together form a monocyclic C_5 to C_{30} organic ring system or are selected from a C_1 to C_{10} alkyl, C_1 to C_{10} hydroxyalkyl, C_1 to C_{30} aminoalkyl, or C_1 to C_{20} alkoxyalkyl, and X is a chemical bond or a C_1 to C_4 divalent organic radical, or

(d) a combination thereof, and

wherein Z is a counter-ion and z is an integer, which is chosen so that the overall bulky quaternary ammonium compound is electrically uncharged.

7. The aqueous composition according to anyone of the preceding claims, wherein R^1 is selected from bicyclo[2.2.1]heptane, Tricyclo[3.3.1.$1^{3,7}$]decane and R^2, R^3 and R^4 are independently selected from linear C_1 to C_4 alkyl.

8. The aqueous composition according to anyone of the preceding claims, wherein R^1 and R^2 are selected from C_5 to C_{10} cycloalkyl and R^3 and R^4 are independently selected from linear C_1 to C_4 alkyl.

9. The aqueous composition according to anyone of the preceding claims, further comprising a surfactant.

10. The aqueous composition according to anyone of the preceding claims, wherein Z is OH^-.

11. The aqueous composition according to anyone of the preceding claims, the composition having a pH of 8 or more, preferably a pH of from 9 to 14.

12. The aqueous composition according to any one of the preceding claims, wherein the solvent consists essentially of water.

~~12~~13. Use of a composition according to anyone of the preceding claim for developing photoresist layers applied to semiconductor substrates to obtain a patterned photoresist layer having line-space dimensions of 50 nm or less and an aspect ratio of 2 or more.

~~13~~14. A method for manufacturing integrated circuit devices, optical devices, micromachines and mechanical precision devices comprising the steps of

(i) providing a substrate

(ii) providing the substrate with a photoresist layer;

(iii) exposing the photoresist layer to actinic radiation through a mask with or without an immersion liquid;

(iii) contacting the substrate at least once with an aqueous composition according to anyone of claims the preceding claims to obtain a patterned photoresist layer; and

(iv) removing the composition from the contact with the substrate.

~~14~~15. The method according to claim ~~13~~14, wherein the substrate is a semiconductor substrate.

~~15~~16. The method according to anyone of claims ~~13~~-14 or ~~14~~15, wherein the patterned material layers are having a feature dimensions of 50 nm or less and aspect ratios of more than 2.

~~16~~17. The method according to anyone of claims ~~13~~-14 to ~~15~~16, wherein the photoresist is an immersion photoresist, an EUV photoresist or eBeam photoresist.

~~17~~18. The method according to anyone of the claims ~~13~~-14 to ~~16~~17, the integrated circuit devices comprise integrated circuits having a large-scale integration (LSI), very-large-scale integration (VLSI) or the ultra-large-scale integration (ULSI).