CLAIMS

1. A positive tone photoresist formulation comprising:

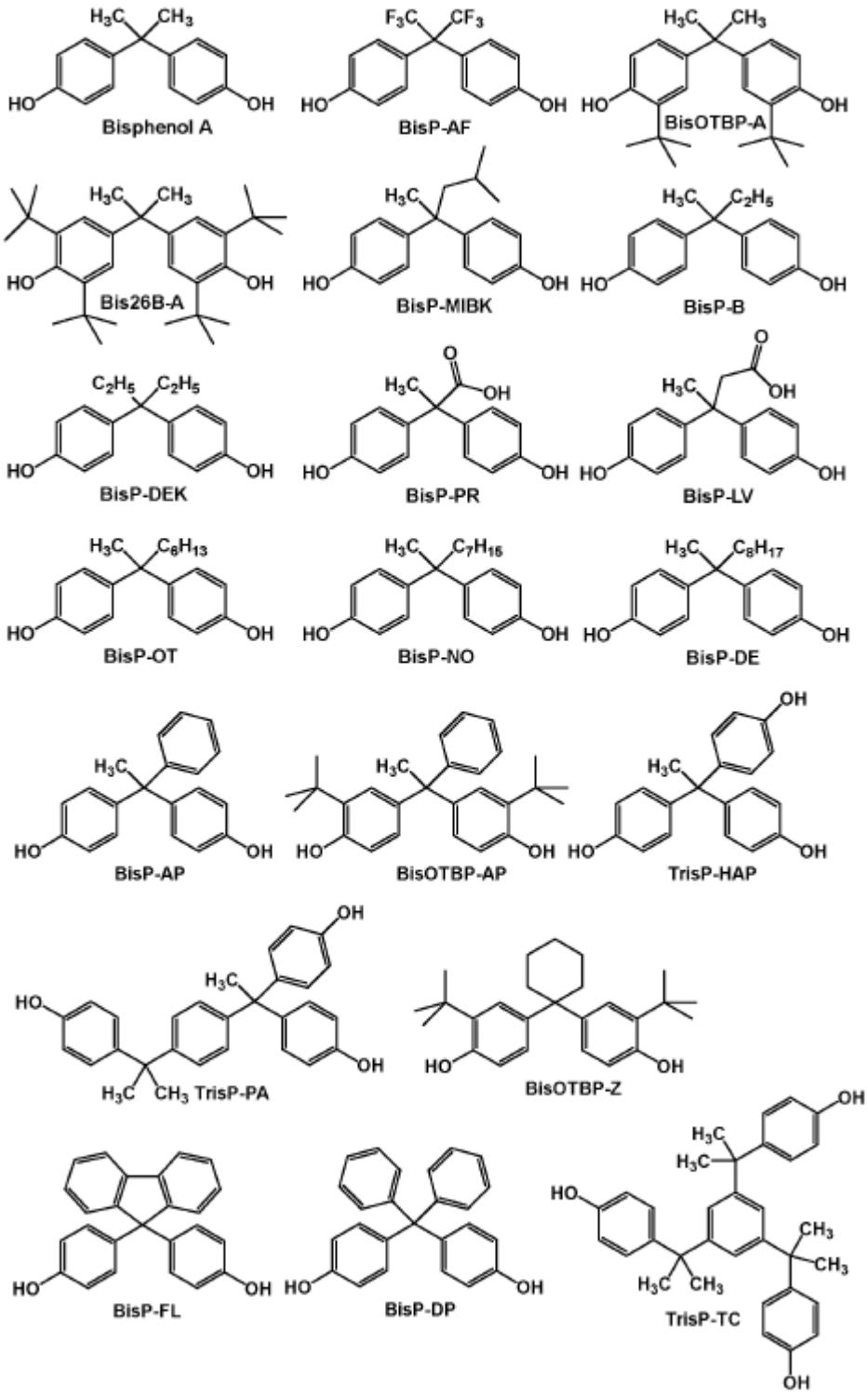
(a) a siloxane polymer comprising a first repeating unit and a second repeating unit; and

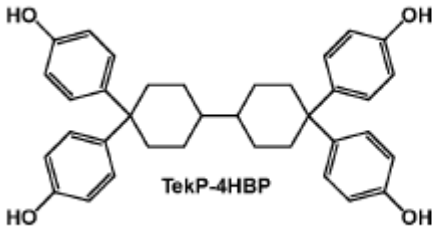
(b) a photoactive dissolution modulator;

wherein the first repeating unit contains at least one maleimide group; and the second repeating unit does not contain a maleimide group;

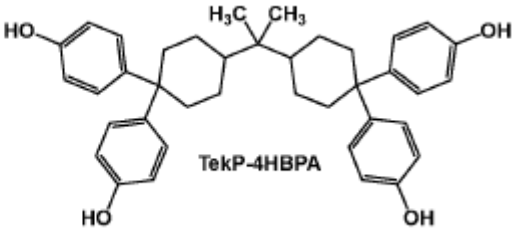
wherein the photoactive dissolution modulator is selected from diazonaphthoquinone (DNQ) or derivatives thereof;

wherein the diazonaphthoquinone derivative is an ester compound of naphthoquinone diazide sulfonic acid with a compound selected from the group consisting of the following;


Bisphenol A
BisP-AF
BisOTBP-A
Bis26B-A
BisP-MIBK
BisP-B
BisP-DEK
BisP-PR
BisP-LV
BisP-OT
BisP-NO
BisP-DE
BisP-AP
BisOTBP-AP
TrisP-HAP
TrisP-PA
BisOTBP-Z
BisP-FL
BisP-DP
TrisP-TC



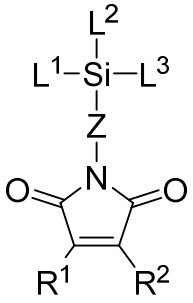
TekP-4HBP



TekP-4HBPA

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2. The positive tone photoresist formulation according to claim 1, wherein the first repeating unit is derived from a first siloxane monomer represented by the following Formula (1):



Formula (1),

wherein:

L1, **L2** and **L3** are the same or different from each other and each independently is selected from **R**, O**R**, and halogen, wherein at least one of **L1**, **L2** and **L3** is O**R** or halogen;

R is selected from the group consisting of H, straight-chain alkyl having 1 to 30 carbon atoms, branched-chain alkyl having 3 to 30 carbon atoms, cyclic alkyl having 3 to 30 carbon atoms, and aryl having 6 to 20 carbon atoms, wherein one or more non-adjacent and non-terminal CH_2 groups are optionally replaced by -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, $-NR^0-$, $-SiR^0R^{00}-$, $-CF_2-$, $-CR^0=CR^{00}-$, $-CY^1=CY^2-$ or -C≡C-, and wherein one or more H atoms are optionally replaced by F;

R1 and **R2** are the same or different from each other and each independently is selected

from H, alkyl having 1 to 20 carbon atoms, cycloalkyl having 3 to 20 carbon atoms and aryl having 6 to 20 carbon atoms, wherein one or more H atoms are optionally replaced by F, or **R¹** and **R²** together form a mono- or polycyclic organic ring system, wherein one or more H atoms are optionally replaced by F;

Z denotes a straight-chain alkylene group having 1 to 20 carbon atoms, a branched-chain alkylene group having 3 to 20 carbon atoms or a cyclic alkylene group having 3 to 20 carbon atoms, in which one or more non-adjacent and non-terminal CH_2 groups are optionally replaced by -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, -NR^0-, -SiR^0R^{00}-, -CF_2-, -CR^0=CR^{00}-, -CY^1=CY^2- or -C≡C-, and in which one or more H atoms are optionally replaced by F;

Y¹ and **Y²** are the same or different from each other and each independently is selected from H, F, Cl and CN;

R⁰ and **R⁰⁰** are the same or different from each other and each independently is selected from H, straight-chain alkyl having 1 to 20 carbon atoms and branched-chain alkyl having 3 to 20 carbon atoms which are optionally fluorinated;and

wherein the second siloxane monomer is different from the first siloxane monomer.

3. The positive tone photoresist formulation according to claim 2,

wherein one of the conditions (1) or (2) applies:

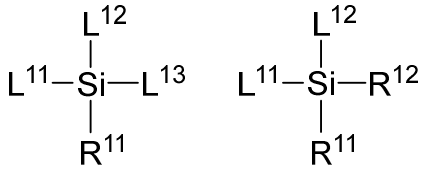
(1) **L¹** = **L²** = **L³** = O**R**; or

(2) **L¹** = **L²** = **R**, and **L³** = Cl.

4. The positive tone photoresist formulation according to claim 2,

wherein **R¹** and **R²** are the same or different from each other and each independently is selected from H, alkyl having 1 to 12 carbon atoms, cycloalkyl having 3 to 12 carbon atoms and aryl having 6 to 14 carbon atoms, wherein one or more H atoms are optionally replaced by F, or **R¹** and **R²** together form a mono- or polycyclic aliphatic ring system, a mono- or polycyclic aromatic ring system or a polycyclic aliphatic and aromatic ring system, wherein one or more H atoms are optionally replaced by F.

5. The positive tone photoresist formulation according to claim 1, wherein the second repeating unit is derived from a second siloxane monomer represented by one of the following Structures S1 or S2:



S1 or S2 ;

wherein:

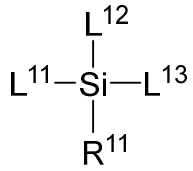
L^{11}, **L^{12}**, and **L^{13}** are the same or different from each other and each independently is selected from O**R'** and halogen;

R' is selected from the group consisting of straight-chain alkyl having 1 to 30 carbon atoms, branched-chain alkyl having 3 to 30 carbon atoms, cyclic alkyl having 3 to 30 carbon atoms, and aryl having 6 to 20 carbon atoms, wherein one or more non-adjacent and non-terminal CH_2 groups are optionally replaced by -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, $-NR^0-$, $-SiR^0R^{00}-$, $-CF_2-$, $-CR^0=CR^{00}-$, $-CY^1=CY^2-$ or -C≡C-, and wherein one or more H atoms are optionally replaced by F;

R^{11}, and **R^{12}** are the same or different from each other and each independently is selected from the group consisting of H, straight-chain alkyl having 1 to 30 carbon atoms, branched-chain alkyl having 3 to 30 carbon atoms, cyclic alkyl having 3 to 30 carbon atoms, and aryl having 6 to 20 carbon atoms, which optionally contain one or more functional groups selected from -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, $-NR^0-$, $-SiR^0R^{00}-$, $-CF_2-$, $-CR^0=CR^{00}-$, $-CR^0=CR^{00}{}_2-$, $-CY^1=CY^2-$, and -C≡C-, and wherein one or more H atoms are optionally replaced by F; and

R^0, **R^{00}**, **Y^1**, and **Y^2** are defined as in claim 2.

6. The positive tone photoresist formulation according to claim 5, wherein the second siloxane monomer is represented by the following Structure S1:



S1 ;

wherein:

L^{11}, **L^{12}**, and **L^{13}** are the same or different from each other and each independently is selected from O**R'**;

R' is selected from the group consisting of

straight chain alkyl having 1 to 20, preferably 1 to 12, carbon atoms, branched-chain alkyl having 3 to 20, preferably 3 to 12, carbon atoms, cyclic alkyl having 3 to 20, preferably 3 to 12, carbon atoms, and aryl having 6 to 14 carbon atoms, wherein one or more non-adjacent and non-terminal CH_2 groups are optionally replaced by -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, -NR^0-, -SiR^0R^{00}-, -CF_2-, -CR^0=CR^{00}-, -CY^1=CY^2- or -C≡C-, and wherein one or more H atoms are optionally replaced by F.

R^{11} is selected from the group consisting of H, straight-chain alkyl having 1 to 20, preferably 1 to 12, carbon atoms, branched-chain alkyl having 3 to 20, preferably 3 to 12, carbon atoms, cyclic alkyl having 3 to 20, preferably 3 to 12, carbon atoms, and aryl having 6 to 14 carbon atoms, which optionally contain one or more functional groups selected from -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, -NR^0-, -SiR^0R^{00}-, -CF_2-, -CR^0=CR^{00}-, -CR^0=$CR^{00}{}_2$, -CY^1=CY^2-, and -C≡C-, and wherein one or more H atoms are optionally replaced by F.

7. The positive tone photoresist formulation according to claim 6, wherein

R' is selected from the group consisting of straight chain alkyl having 1 to 12 carbon atoms, branched-chain alkyl having 3 to 12 carbon atoms, cyclic alkyl having 3 to 12 carbon atoms, and aryl having 6 to 14 carbon atoms; and

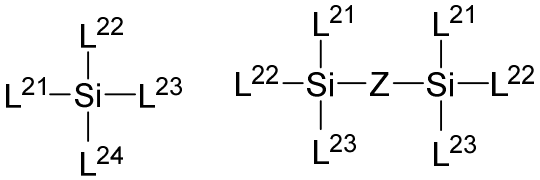
R^{11} is selected from the group consisting of $-CH_3$, $-CF_3$, $-C_2H_5$, $-C_2F_5$, $-C_3H_7$, $-C_3F_7$, $-C_4H_9$, $-C_4F_9$, $-C_5H_{11}$, $-C_5H_4F_7$, $-C_6H_{13}$, $-C_6H_4F_9$, $-C_7H_{15}$, $-C_7H_4F_{11}$, $-C_8H_{17}$, $-C_8H_4F_{13}$, $-CH=CH_2$, $-C(CH_3)=CH_2$, $-C_3H_6-O-C(=O)-CH=CH_2$, $-C_3H_6-O-C(=O)-C(CH_3)=CH_2$, $-C_6H_5$, and $-C_6F_5$.

8. The positive tone photoresist formulation according to claim 1,

wherein the siloxane polymer further comprises a third repeating unit, wherein the third repeating unit does not contain a maleimide group.

9. The positive tone photoresist formulation according to claim 8,

wherein the third repeating unit is derived from a third siloxane monomer represented by one of the following Structures T1 or T2:



T1 or T2 ;

wherein:

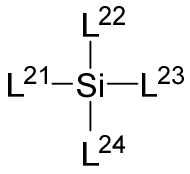
L^{21}, **L^{22}**, **L^{23}**, and **L^{24}** are the same or different from each other and each independently is selected from O**R''** and halogen;

R'' is selected from the group consisting of straight-chain alkyl having 1 to 30 carbon atoms, branched-chain alkyl having 3 to 30 carbon atoms, cyclic alkyl having 3 to 30

carbon atoms, and aryl having 6 to 20 carbon atoms, wherein one or more non-adjacent and non-terminal CH_2 groups are optionally replaced by -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, $-NR^0-$, $-SiR^0R^{00}-$, $-CF_2-$, $-CR^0=CR^{00}-$, $-CY^1=CY^2-$ or -C≡C-, and wherein one or more H atoms are optionally replaced by F;

Z is absent or denotes a straight-chain alkylene group having 1 to 20 carbon atoms, a branched-chain alkylene group having 3 to 20 carbon atoms or a cyclic alkylene group having 3 to 20 carbon atoms, in which one or more non-adjacent and non-terminal CH_2 groups are optionally replaced by -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, $-NR^0-$, $-SiR^0R^{00}-$, $-CF_2-$, $-CR^0=CR^{00}-$, $-CY^1=CY^2-$ or -C≡C-, and in which one or more H atoms are optionally replaced by F.

10. The positive tone photoresist formulation according to claim 9, wherein the third siloxane monomer is represented by the following Structure T1:



T1 ;

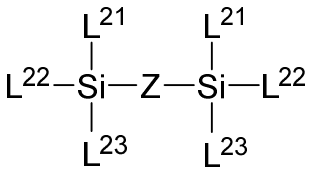
wherein:

$\mathbf{L^{21}}$, $\mathbf{L^{22}}$, $\mathbf{L^{23}}$, and $\mathbf{L^{24}}$ are the same or different from each other and each independently is selected from O**R''**;

R'' is selected from the group consisting of straight chain alkyl having 1 to 20, preferably 1 to 12, carbon atoms, branched-chain alkyl having 3 to 20, preferably 3 to 12, carbon atoms, cyclic alkyl having 3 to 20, preferably 3 to 12, carbon atoms, and aryl having 6 to 14 carbon atoms, wherein one or more non-adjacent and non-terminal CH_2 groups are optionally replaced by -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-

C(=O)-, -NR^0-, -SiR^0R^{00}-, -CF_2-, -CR^0=CR^{00}-, -CY^1=CY^2- or -C≡C-, and wherein one or more H atoms are optionally replaced by F.

11. The positive tone photoresist formulation according to claim 9, wherein the third siloxane monomer is represented by the following Structure T2:



T2 ;

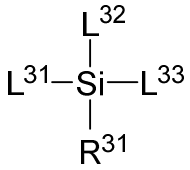
wherein

L^{21}, **L^{22}**, and **L^{23}** are the same or different from each other and each independently is selected from O**R''**;

R'' is selected from the group consisting of straight chain alkyl having 1 to 20, preferably 1 to 12, carbon atoms, branched-chain alkyl having 3 to 20, preferably 3 to 12, carbon atoms, cyclic alkyl having 3 to 20, preferably 3 to 12, carbon atoms, and aryl having 6 to 14 carbon atoms, wherein one or more non-adjacent and non-terminal CH_2 groups are optionally replaced by -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, -NR^0-, -SiR^0R^{00}-, -CF_2-, -CR^0=CR^{00}-, -CY^1=CY^2- or -C≡C-, and wherein one or more H atoms are optionally replaced by F;

Z is absent or denotes a straight-chain alkylene group having 1 to 12 carbon atoms, a branched-chain alkylene group having 3 to 12 carbon atoms or a cyclic alkylene group having 3 to 12 carbon atoms, in, which one or more non-adjacent and non-terminal CH_2 groups are optionally replaced by -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, -NR^0-, -SiR^0R^{00}-, -CF_2-, -CR^0=CR^{00}-, -CY^1=CY^2- or -C≡C-, and in, which one or more H atoms are optionally replaced by F.

12. The positive tone photoresist formulation according to claim 1, wherein the siloxane polymer further comprises one or more further repeating unit, wherein the one or more further repeating unit does not contain a maleimide group, and is preferably derived from one or more further siloxane monomer represented by the following Structure F1:



F1 ;

wherein:

L^{31}, **L^{32}**, and **L^{33}** are the same or different from each other and each independently is selected from O**R'''** and halogen;

R''' is selected from the group consisting of straight-chain alkyl having 1 to 30 carbon atoms, branched-chain alkyl having 3 to 30 carbon atoms, cyclic alkyl having 3 to 30 carbon atoms, and aryl having 6 to 20 carbon atoms, wherein one or more non-adjacent and non-terminal CH_2 groups are optionally replaced by -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, $-NR^0-$, $-SiR^0R^{00}-$, $-CF_2-$, $-CR^0=CR^{00}-$, $-CY^1=CY^2-$ or -C≡C-, and wherein one or more H atoms are optionally replaced by F;

R^{31} is selected from the group consisting of H, straight-chain alkyl having 1 to 30 carbon atoms, branched-chain alkyl having 3 to 30 carbon atoms, cyclic alkyl having 3 to 30 carbon atoms, and aryl having 6 to 20 carbon atoms, which optionally contain one or more functional groups selected from -O-, -S-, -C(=O)-, -C(=S)-, -C(=O)-O-, -O-C(=O)-, $-NR^0-$, $-SiR^0R^{00}-$, $-CF_2-$, $-CR^0=CR^{00}-$, $-CR^0=CR^{00}{}_2-$, $-CY^1=CY^2-$, and -C≡C-, and wherein one or more H atoms are optionally replaced by F; and

$\mathbf{R^0}$, $\mathbf{R^{00}}$, $\mathbf{Y^1}$, and $\mathbf{Y^2}$ are defined as in claim 2.

13. The positive tone photoresist formulation according to claim 1, wherein the mole fraction of the first repeating unit in the siloxane polymer is in the range from 1 to 90%, based on the total amount of repeating units in the siloxane polymer.

14. The positive tone photoresist formulation according to claim 1, wherein the mole fraction of the second repeating unit in the siloxane polymer is in the range from 10 to 90%, based on the total amount of repeating units in the siloxane polymer.

15. The positive tone photoresist formulation according to claim 8, wherein the mole fraction of the third repeating unit in the siloxane polymer is in the range from 5 to 40%, based on the total amount of repeating units in the siloxane polymer.

16. The positive tone photoresist formulation according to claim 1, comprising one or more further siloxane polymers, wherein the further siloxane polymers do not contain maleimide groups.

17. Method for manufacturing a microelectronic structure comprising the following steps:
(1) applying a positive tone photoresist formulation according to claim 1 to a surface of a substrate;
(2) photopatterning of the positive tone photoresist formulation applied in step (1) to obtain a photopatterned structure; and
(3) curing the photopatterned structure obtained in step (2) to obtain a cured photopatterned dielectric material on the surface of the substrate.

18. Electronic device comprising a microelectronic structure, obtainable by the method for manufacturing according to claim 17.