Claims

What is claimed is:

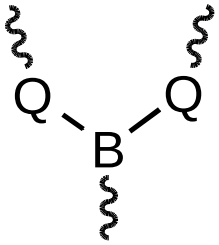
1. A reversible epoxy polymer obtainable by the reaction between at least one epoxy compound and at least one curing agent, wherein

at least part of the epoxy compound contains one reversible borate moiety or derivative thereof per molecule, wherein the derivative of borate moiety represents a moiety with the oxygen in the borate moiety being replaced with other element of the sixth main group; and/or

at least part of the curing agent contains one reversible borate moiety or derivative thereof per molecule, wherein the derivative of borate moiety represents a moiety with the oxygen in the borate moiety being replaced with other element of the sixth main group; and/or

the reaction system further comprises at least one compound containing hydroxyl and epoxy group and at least one BQH-containing compound or its ester derivative, wherein said BQH-containing compound contains two or more B-QH moieties, wherein each Q is independently an element of the sixth main group.

2. The reversible epoxy polymer according to claim 1, wherein the reversible borate moiety or derivative thereof has a structure of Formula (**I**):

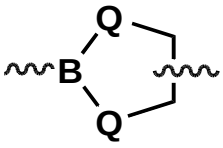


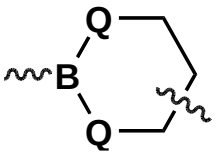
(**I**),

wherein each Q is independently an element of the sixth main group.

3. The reversible epoxy polymer according to claim 2, wherein the -Q-B-Q- moiety in Formula (**I**) forms a boron-containing ring having 5 to 8 ring members together with 2 to 5 carbon atoms, preferably forms a boron-containing ring containing 5 or 6 ring members together with 2 or 3 carbon atoms, optionally the boron-containing ring is fused with a further ring to form a fused ring system.

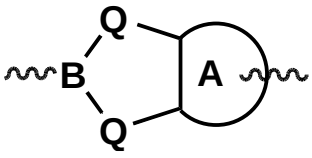
4. The reversible epoxy polymer according to claim 3, wherein the boron-containing ring has the following structure:

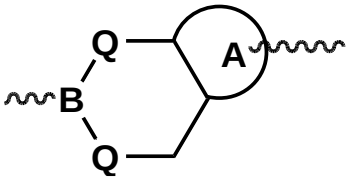


(a), or


(b),

the fused ring system containing the boron-containing ring has the following structure:



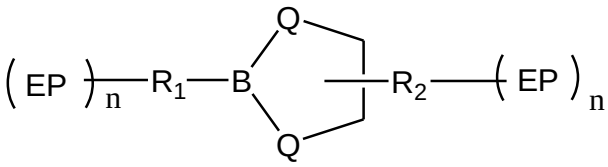
(c), or


(d)

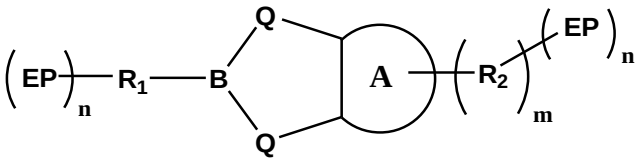
wherein A is a ring having 5 to 10 ring members and wherein each Q is independently an element of the sixth main group.

5. The reversible epoxy polymer according to any of claims 1 to 4, wherein the epoxy compound containing one reversible borate moiety or derivative thereof per molecule contains two or more epoxy groups, preferably the epoxy group is selected from ethylene oxide group and oxetane group.

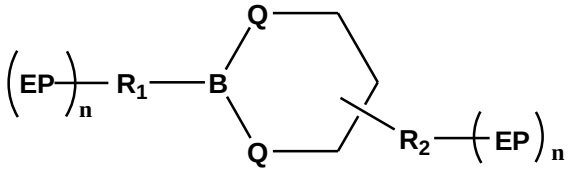
6. The reversible epoxy polymer according to any of claims 1 to 5, wherein the epoxy compound containing one reversible borate moiety or derivative thereof per molecule is selected from at least one compound having following structure:



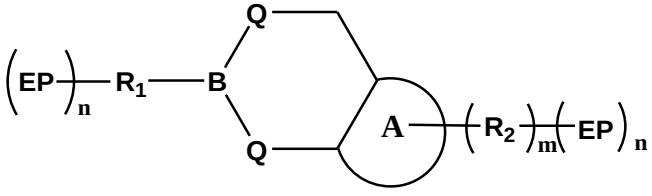
(e)



(f)



(g), or



(h)

wherein

m is 0 or 1;

each n is independently at least 1, preferably 1, 2 or 3;

EP is an ethylene oxide group or oxetane group;

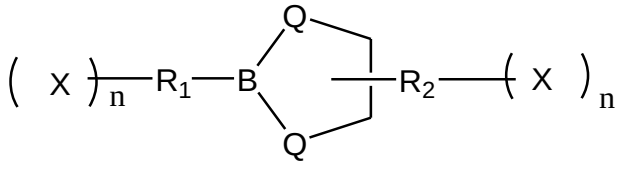
each Q is independently an element of the sixth main group;

each R_1 and R_2 is independently a divalent C_1 to C_{20} hydrocarbyl; and

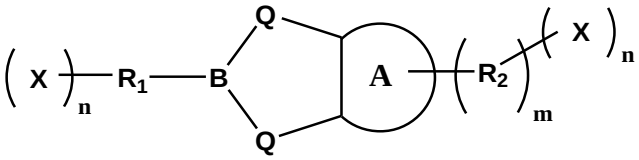
wherein A is a ring having 5 to 10 ring members, preferably a ring having 5 or 6 ring members.

7. The reversible epoxy polymer according to any of claims 1 to 6, wherein the curing agent containing one reversible borate moiety or derivative thereof per molecule contains two or more functional groups capable of reacting with epoxy group, preferably selected from carboxyl, amino, sulfhydryl or acid anhydride.

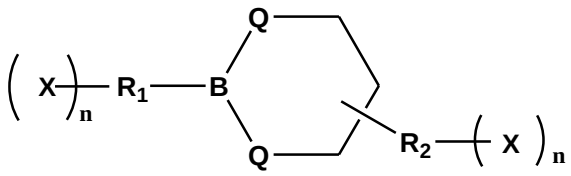
8. The reversible epoxy polymer according to any of claims 1 to 7, wherein the curing agent containing one reversible borate moiety or derivative thereof per molecule is selected from at least one compound having following structure:



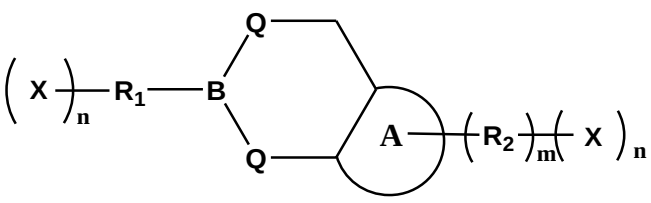
(i)



(j)



(k), or



(l)

wherein

m is 0 or 1;

each n is independently at least 1, preferably 1, 2 or 3;

each R_1 and R_2 is independently a divalent C_1 to C_{20} hydrocarbyl;

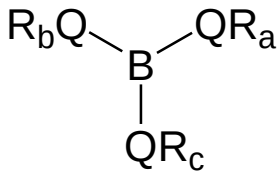
each Q is independently an element of the sixth main group;

X is a functional group capable of reacting with epoxy group, preferably carboxyl, amino, sulfhydryl or acid anhydride; and

A is a ring having 5 to 10 ring members, preferably a ring having 5 or 6 ring members.

9. The reversible epoxy polymer according to any of claims 1 to 8, wherein the BQH-containing compound or its ester derivative is selected from a compound containing at least two B-Q ester bonds, a compound containing at least one $B(QH)_2$ group, boric acid, and pyroboric acid, and wherein each Q is independently an element of the sixth main group.

10. The reversible epoxy polymer according to claim 9, wherein the compound containing at least two B-Q ester bonds comprises a compound containing three B-Q ester bonds, preferably a compound having following structure:



wherein R_a, R_b and R_c are independently hydrocarbyl, preferably alkyl or aryl and wherein each Q is independently an element of the sixth main group.

11. The reversible epoxy polymer according to any of claims 1 to 8, wherein the reversible epoxy polymer is obtained by the reaction between at least one epoxy compound and at least one curing agent, wherein at least part of the epoxy compound contains one reversible borate moiety or derivative thereof per molecule and/or at least part of the curing agent contains one reversible borate moiety or derivative thereof per molecule, and wherein at least one of the water absorption rate and the weight loss rate after water soaking of the reversible epoxy polymer is less than 5 wt%, preferably less than 2 wt% after being soaked in water for 24 hours at room temperature.

12. The reversible epoxy polymer according to any of claims 1 to 11, wherein the derivative of borate moiety represents a moiety with the oxygen in the borate moiety being replaced with

S and/or Q is O or S, preferably O.

13. The reversible epoxy polymer according to any of claims 1 to 12, wherein the reversible epoxy polymer has self-healing property.

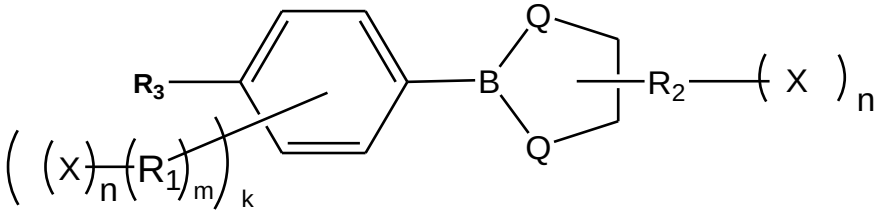
14. A process for preparing the reversible epoxy polymer according to any of claims 1 to 13, which comprises reacting at least one epoxy compound and at least one curing agent, wherein

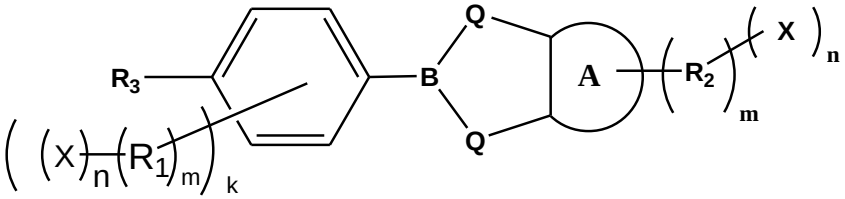
at least part of the epoxy compound contains one reversible borate moiety or derivative thereof per molecule, wherein the derivative of borate moiety represents a moiety with the oxygen in the borate moiety being replaced with other element of the sixth main group; and/or

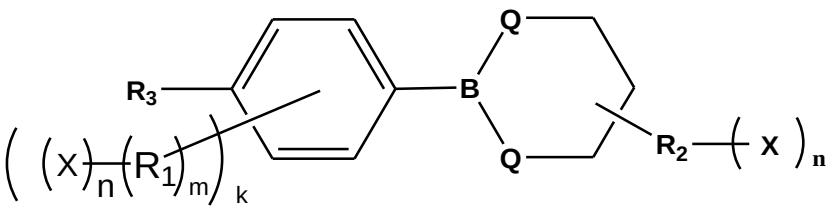
at least part of the curing agent contains one reversible borate moiety or derivative thereof per molecule, wherein the derivative of borate moiety represents a moiety with the oxygen in the borate moiety being replaced with other element of the sixth main group; and/or

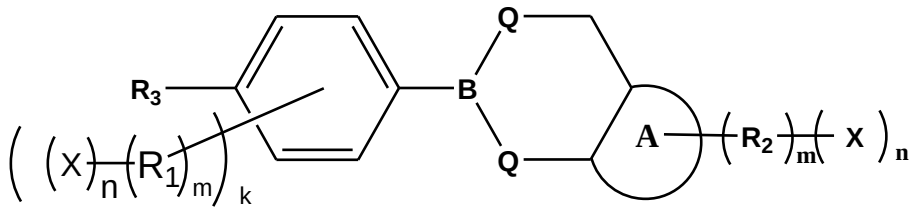
the reaction system further comprises at least one compound containing hydroxyl and epoxy group and at least one BQH-containing compound or its ester derivative, wherein said BQH-containing compound contains two or more B-QH moieties, wherein each Q is independently an element of the sixth main group.

15. A compound having one of following structures:









wherein

each m is independently 0 or 1;

k is from 1 to 4;

each n is independently at least 1;

each R_1 is independently a divalent C_1 to C_{20} hydrocarbyl;

R_2 is a divalent C_1 to C_{20} hydrocarbyl;

R_3 is H or C_1 to C_{20} hydrocarbyl;

each Q is independently an element of the sixth main group;

X is a functional group capable of reacting with epoxy group; and

A is a ring having 5 to 10 ring members.

16. The compound according to claim 15, wherein each

m is independently 0 or 1;

k is 1 or 2;

each n is independently 1, 2 or 3;

each R_1 is independently a divalent C_1 to C_{20} hydrocarbyl;

R_2 is a divalent C_1 to C_{20} hydrocarbyl;

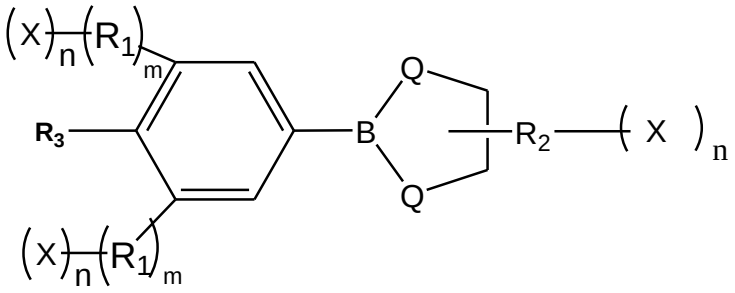
R_3 is H or C_1 to C_{20} hydrocarbyl;

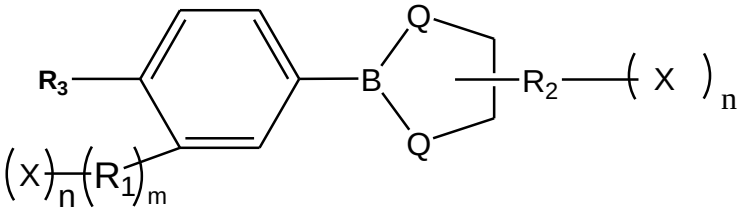
each Q is independently O or S, preferably O;

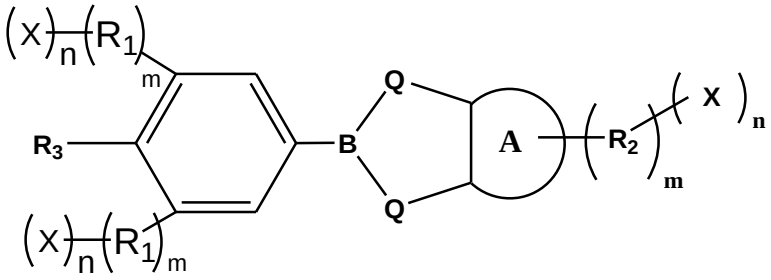
X is a functional group selected from carboxyl, amino, sulfhydryl or acid anhydride; and

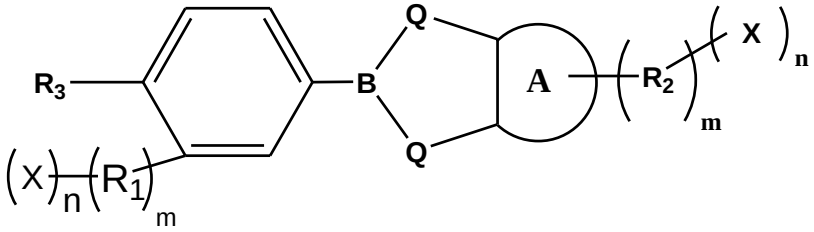
A is a ring having 5 or 6 ring members.

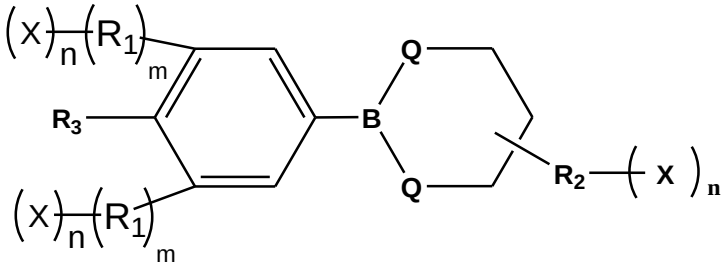
17. The compound according to claim 15 or 16, wherein said compound has one of following structures:

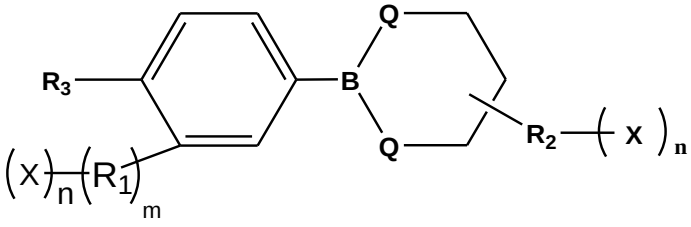


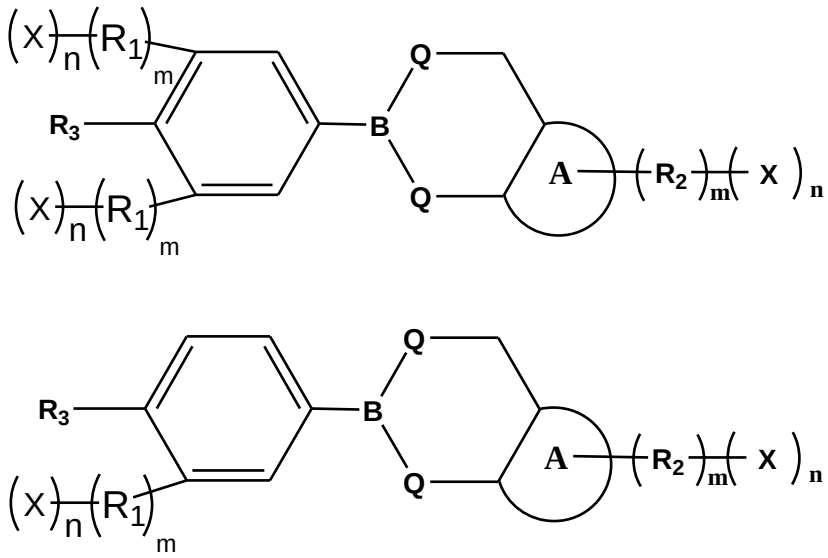












wherein m, n, R_1, R_2, R_3, Q, X and A are as defined in claim 15 or 16.