CLAIMS

1. A method of preparing a multilayer structure, the method comprising:

depositing a handle dielectric layer comprising a reflowable insulating layer on a front surface of a single crystal semiconductor handle substrate, wherein the single crystal semiconductor handle substrate comprises two major, generally parallel surfaces, one of which is the front surface of the single crystal semiconductor handle substrate and the other of which is a back surface of the single crystal semiconductor handle substrate, a circumferential edge joining the front surface and the back surface of the single crystal semiconductor handle substrate, a central plane between the front surface and the back surface of the single crystal semiconductor handle substrate, and a bulk region between the front and back surfaces of the single crystal semiconductor handle substrate, wherein the reflowable insulating layer is capable of flowing at a temperature of less than about 1000°C and further wherein the reflowable insulating layer comprises a silicate glass selected from the group consisting of phosphosilicate glass, borosilicate glass, borophosphosilicate glass, and any combination thereof;

curing the reflowable insulating layer by annealing the reflowable insulating layer at a temperature between about 800°C and about 1000°C; and

bonding a donor dielectric layer on a front surface of a single crystal semiconductor donor substrate to the handle dielectric layer comprising the cured reflowable insulating layer to thereby form a bonded structure, wherein the single crystal semiconductor donor substrate comprises two major, generally parallel surfaces, one of which is the front surface of the semiconductor donor substrate and the other of which is a back surface of the semiconductor donor substrate, a circumferential edge joining the front and back surfaces of the semiconductor donor substrate, a central plane between the front and back surfaces of the semiconductor donor substrate, and a bulk region between the front and back surfaces of the semiconductor donor substrate, and further wherein the single crystal semiconductor donor substrate comprises a cleave plane.

2. The method of claim 1 wherein the single crystal semiconductor handle substrate and/or the single crystal semiconductor donor substrate comprises single crystal silicon.

3. The method of claim 1 wherein the single crystal semiconductor handle substrate and/or the single crystal semiconductor donor substrate comprises a single crystal silicon wafer sliced from a single crystal silicon ingot grown by the Czochralski method or the float zone method.

4. The method of any of claims 1 to 3 wherein the reflowable insulating layer comprises borophosphosilicate glass.

5. The method of any of claims 1 to 4 wherein the handle dielectric layer comprises the reflowable insulating layer having a thickness between about 500 nanometers and about 1 micrometer, or between about 100 nanometers and about 1 micrometer.

6. The method of any one of claims 1 to 3 wherein the cured reflowable insulating layer has a maximum surface roughness of less than about 2 angstroms, as measured by the root mean square method over a surface area of at least about 2 micrometers by about 2 micrometers.

7. The method of claim 6 further comprising depositing a second insulating layer on the cured reflowable insulating layer, wherein the second insulating layer comprises a material selected from the group consisting of silicon dioxide, silicon oxynitride, silicon nitride, and a combination thereof.

8. The method of any of claims 1 to 7 wherein the donor dielectric layer comprises a material selected from the group consisting of silicon dioxide, silicon oxynitride, silicon nitride, hafnium oxide, titanium oxide, zirconium oxide, lanthanum oxide, barium oxide, and any combination thereof.

9. The method of any of claims 1 to 7 wherein the donor dielectric layer comprises a material selected from the group consisting of silicon dioxide, silicon oxynitride, silicon nitride, and any combination thereof.

10. The method of any of claims 1 to 7 wherein the donor dielectric layer comprises a multilayer, each insulating layer within the multilayer comprising a material selected from the group consisting of silicon dioxide, silicon oxynitride, and silicon nitride.

11. The method of any of claims 1 to 7 wherein the donor dielectric layer comprises an insulating layer having a thickness of at least about 10 nanometer thick, such as between about 10 nanometers and about 10,000 nanometers, between about 10 nanometers and about 5,000 nanometers, between 50 nanometers and about 400 nanometers, or between about 100 nanometers and about 400 nanometers, such as about 50 nanometers, 100 nanometers, or 200 nanometers.

12. The method of any of claims 1 to 3 further comprising depositing a second insulating layer on the reflowable insulating layer, wherein the second insulating layer comprises a material selected from the group consisting of silicon dioxide, silicon oxynitride, silicon nitride, and a combination thereof.

13. The method of any of claims 1 to 11 further comprising annealing the bonded structure at a temperature and for a duration sufficient to strengthen the bond between the donor dielectric layer of the single crystal semiconductor donor substrate and the handle dielectric layer comprising the reflowable insulating layer on the front surface of the single crystal semiconductor handle substrate.

14. The method of claim 13 wherein annealing occurs at a temperature between about 300°C and about 700°C, such as from about 400°C to about 600°C, such as between about 400°C and about 450°C, or even between about 450°C and about 600°C, or between about 350°C and about 450°C.

15. The method of claim 13 or claim 14 wherein annealing occurs at a pressure between about 0.5 MPa and about 200 MPa, Such as between about 0.5 MPa and about 100 MPa, such as between about 0.5 MPa and about 50 MPa, or between about 0.5 MPa and about 10 MPa, or between about 0.5 MPa and about 5MPa.

16. The method of any of claims 13 to 15 further comprising mechanically cleaving the bonded structure at the cleave plane of the single crystal semiconductor donor substrate to thereby prepare a cleaved structure comprising the single crystal semiconductor handle substrate, the handle dielectric layer comprising the reflowable insulating layer, the donor dielectric layer, and a single crystal semiconductor device layer.

17. A multilayer structure comprising:

a single crystal semiconductor handle substrate, wherein the single crystal semiconductor handle substrate comprises two major, generally parallel surfaces, one of which is a front surface of the single crystal semiconductor handle substrate and the other of which is a back surface of the single crystal semiconductor handle substrate, a circumferential edge joining the front surface and the back surface of the single crystal semiconductor handle substrate, a central plane between the front surface and the back surface of the single crystal semiconductor handle substrate, and a bulk region between the front and back surfaces of the single crystal semiconductor handle substrate;

a handle dielectric layer comprising a reflowable insulating layer comprising a silicate glass selected from the group consisting of phosphosilicate glass, borosilicate glass, borophosphosilicate glass, and any combination thereof, the handle dielectric layer being in interfacial contact with the front surface of the single crystal semiconductor handle substrate;

a donor dielectric layer in interfacial contact with the handle dielectric layer; and

a single crystal semiconductor device layer.

18. The multilayer structure of claim 17 wherein the single crystal semiconductor handle substrate and/or the single crystal semiconductor donor substrate comprises single crystal silicon.

19. The multilayer structure of claim 17 wherein the single crystal semiconductor handle substrate and/or the single crystal semiconductor donor substrate comprises a single crystal silicon wafer sliced from a single crystal silicon ingot grown by the Czochralski method or the float zone method.