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 1000ºC 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 800ºC and about 1000ºC; and

bonding a donor dielectric layer on a front surface of a single crystal semiconductor donor substrate to the handle dielectric layer comprising the 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 comprises single crystal silicon.

3. The method of claim 1 wherein the single crystal semiconductor handle 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 claim 1 wherein the single crystal semiconductor donor substrate comprises single crystal silicon.

5. The method of claim 1 wherein 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.

6. The method of claim 1 wherein the reflowable insulating layer comprises a borophosphosilicate glass.

7. The method of claim 1 wherein the reflowable insulating layer has a thickness between about 500 nanometers and about 1 micrometer.

8. The method of claim 1 wherein the reflowable insulating layer has a thickness between about 100 nanometers and about 1 micrometer.

9. The method of claim 1 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.

10. The method of claim 1 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.

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

12. The method of claim 1 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.

13. The method of claim 1 wherein the donor dielectric layer comprises an insulating layer having a thickness of at least about 10 nanometer thick.

14. The method of claim 1 further comprising depositing a second insulating layer on the cured reflowable insulating layer.

15. The method of claim 14 wherein the second insulating layer comprises a material selected from the group consisting of silicon dioxide, silicon oxynitride, silicon nitride, and a combination thereof.

16. The method of claim 1 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.

17. The method of claim 16 wherein annealing the bonded structure occurs at a temperature between about 300ºC and about 700ºC.

18. The method of claim 16 wherein annealing the bonded structure occurs at a pressure between about 0.5 MPa and about 200 MPa.

19. The method of claim 16 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.

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

depositing a handle dielectric layer comprising a flowable 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 flowable insulating layer comprises a flowable silazane;

curing the flowable insulating layer by annealing the flowable 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 flowable 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.

21. The method of claim 20 wherein the single crystal semiconductor handle substrate comprises single crystal silicon.

22. The method of claim 20 wherein the single crystal semiconductor handle substrate comprises a single crystal silicon wafer sliced from a single crystal silicon ingot grown by the Czochralski method or the float zone method.

23. The method of claim 20 wherein the single crystal semiconductor donor substrate comprises single crystal silicon.

24. The method of claim 20 wherein 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.

25. The method of claim 20 wherein the flowable insulating layer is deposited by contacting the front surface of the single crystal semiconductor handle substrate with a solution comprising oxide precursor and/or non-oxide precursor.

26. The method of claim 20 wherein the flowable insulating layer has a thickness between about 500 nanometers and about 1 micrometer.

27. The method of claim 20 wherein the flowable insulating layer has a thickness between about 100 nanometers and about 1 micrometer.

28. The method of claim 20 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.

29. The method of claim 20 wherein the donor dielectric layer comprises a material selected from the group consisting of silicon dioxide, silicon oxynitride, silicon nitride, and any combination thereof.

30. The method of claim 20 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.

31. The method of claim 20 wherein the donor dielectric layer comprises an insulating layer having a thickness of at least about 10 nanometer thick.

32. The method of claim 20 further comprising depositing a second insulating layer on the flowable insulating layer.

33. The method of claim 32 wherein the second insulating layer comprises a material selected from the group consisting of silicon dioxide, silicon oxynitride, silicon nitride, and a combination thereof.

34. The method of claim 20 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 flowable insulating layer on the front surface of the single crystal semiconductor handle substrate.

35. The method of claim 34 wherein annealing the bonded structure occurs at a temperature between about 300°C and about 700°C.

36. The method of claim 34 wherein annealing the bonded structure occurs at a pressure between about 0.5 MPa and about 200 MPa.

37. The method of claim 34 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 flowable insulating layer, the donor dielectric layer, and a single crystal semiconductor device layer.

38. 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 flowable insulating layer comprising a flowable silazane or 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.

39. The multilayer structure of claim 38 wherein the single crystal semiconductor handle substrate comprises single crystal silicon.

40. The multilayer structure of claim 38 wherein the single crystal semiconductor handle substrate comprises a single crystal silicon wafer sliced from a single crystal silicon ingot grown by the Czochralski method or the float zone method.

41. The multilayer structure of claim 38 wherein the single crystal semiconductor device layer comprises single crystal silicon.

42. The multilayer structure of claim 38 wherein the single crystal semiconductor device layer comprises a single crystal silicon wafer sliced from a single crystal silicon ingot grown by the Czochralski method or the float zone method.

43. The multilayer structure of claim 38 wherein the handle dielectric layer comprises the flowable insulating layer, and wherein the flowable insulating layer comprises the flowable silazane.

44. The multilayer structure of claim 38 wherein the handle dielectric layer comprises the reflowable insulating layer, and wherein the reflowable insulating layer comprises the silicate glass selected from the group consisting of phosphosilicate glass, borosilicate glass, borophosphosilicate glass, and any combination thereof.

45. The multilayer structure of claim 38 wherein the handle dielectric layer further comprises second 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.

46. The multilayer structure of claim 38 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.

47. The multilayer structure of claim 38 wherein the donor dielectric layer comprises a material selected from the group consisting of silicon dioxide, silicon oxynitride, silicon nitride, and any combination thereof.

48. The multilayer structure of claim 38 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.