CLAIMS:

1. A method of transferring a silicon layer from a single crystal silicon donor substrate to a handle substrate, the method comprising:

(a) implanting H_2^+ ions, H^+ ions, or a combination of H_2^+ ions and H^+ ions through a silicon dioxide layer in contact with a front surface of the single crystal silicon donor substrate and through the front surface of the single crystal silicon donor substrate, the single crystal silicon donor substrate comprising two major, parallel surfaces one of which is the front surface and one of which is the back surface, a circumferential edge joining the front surface and the back surface, a central plane between the front surface and the back surface, a central axis perpendicular to the front surface, and a bulk region between the front surface and the back surface, wherein the H_2^+ ions are implanted at an implant energy between about 10 Kev and about 30 Kev and the H^+ ions are implanted at an implant energy between about 5 Kev and about 20 Kev, wherein a peak density, (D1), of H_2^+ ions, H^+ ions, or a combination of H_2^+ ions and H^+ ions is between about 100 Angstroms and about 3000 Angstroms as measured from the front surface of the single crystal silicon donor substrate and along the central axis;

(b) implanting He^+ ions through the silicon dioxide layer in contact with the front surface of a single crystal silicon donor substrate and through the front surface of the single crystal silicon donor substrate, wherein the He^+ ions are implanted at an implant energy between about 5 Kev and about 30 Kev, wherein a peak density, (D2), of He^+ ions is between about 100 Angstroms and about 3000 Angstroms as measured from the front surface of the single crystal silicon donor substrate and along the central axis and further wherein the peak density, (D1), of H_2^+ ions, H^+ ions, or a combination of H_2^+ ions and H^+ ions and the peak density, (D2), of He^+ ions are within about 450 Angstroms of each other;

(c) annealing the ion implanted single crystal silicon donor substrate at a temperature between about 200°C and about 350°C and for a duration sufficient to form a damage layer in the single crystal silicon donor substrate;

(d) bonding the silicon dioxide layer in contact with the front surface of the single crystal silicon donor substrate to a dielectric layer in contact with the handle substrate to thereby prepare the multilayer substrate;

(e) annealing the multilayer substrate at a temperature between about 200°C and about 400°C and for a duration sufficient to thermally activate the damage layer; and

(f) cleaving the annealed multilayer substrate at the damage layer in the single crystal silicon donor substrate to thereby transfer the silicon layer having a thickness between about 500 Angstroms and about 2500 Angstroms from the single crystal silicon donor substrate to the handle substrate.

2. The method of claim 1 wherein step (a) occurs before step (b).

3. The method of claim 1 wherein step (b) occurs before step (a).

4. The method of claim 1 wherein steps (a) and (b) occur simultaneously.

5. The method of claim 1 wherein step (a) comprises (i) implanting H_2^+ ions at a dosage between about $4.3x10^{15}$ ions/cm^2 and about $1.1x10^{16}$ ions/cm^2 at an implant energy between about 10 Kev and about 30 Kev, (ii) implanting H^+ ions at a dosage between about $5x10^{15}$ ions/cm^2 and about $2x10^{16}$ ions/cm^2 at an implant energy between about 5 Kev and about 20 Kev, or (iii) implanting H_2^+ ions at a dosage between about $4.3x10^{15}$ ions/cm^2 and about $1.1x10^{16}$ ions/cm^2 at an implant energy between about 10 Kev and about 30 Kev and implanting H^+ ions at a dosage between about $5x10^{15}$ ions/cm^2 and about $2x10^{16}$ ions/cm^2 at an implant energy between about 5 Kev and about 20 Kev.

6. The method of claim 1 wherein step (a) comprises (i) implanting H_2^+ ions at a dosage between about $4.3x10^{15}$ ions/cm^2 and about $1.1x10^{16}$ ions/cm^2 at an implant energy between about 10 Kev and about 30 Kev, (ii) implanting H^+ ions at a dosage between about $1.1x10^{16}$ ions/cm^2 and about $2x10^{16}$ ions/cm^2 at an implant energy between about 5 Kev and about 20 Kev, or (iii) implanting H_2^+ ions at a dosage between about $4.3x10^{15}$ ions/cm^2 and about $1.1x10^{16}$ ions/cm^2 at an implant energy between about 10 Kev and about 30 Kev and implanting H^+ ions at a dosage between about $1.1x10^{16}$

ions/cm^2 and about 2x10^{16} ions/cm^2 at an implant energy between about 5 Kev and about 20 Kev.

7. The method of claim 1 wherein step (a) comprises (i) implanting H_2^+ ions at a dosage between about 5.9x10^{15} ions/cm^2 and about 6.7x10^{15} ions/cm^2 at an implant energy between about 10 Kev and about 30 Kev, (ii) implanting H^+ ions at a dosage between about 6.1x10^{15} ions/cm^2 and about 6.8x10^{15} ions/cm^2 at an implant energy between about 5 Kev and about 20 Kev, or (iii) implanting H_2^+ ions at a dosage between about 5.9x10^{15} ions/cm^2 and about 6.7x10^{15} ions/cm^2 at an implant energy between about 10 Kev and about 30 Kev and implanting H^+ ions at a dosage between about 6.1x10^{15} ions/cm^2 and about 6.8x10^{15} ions/cm^2 at an implant energy between about 5 Kev and about 20 Kev.

8. The method of claim 1 wherein step (b) comprises implanting He^+ ions at a dosage between about 6x10^{15} ions/cm^2 and about 8x10^{15} ions/cm^2 at an implant energy between about 5 Kev and about 30 Kev.

9. The method of claim 1 wherein step (b) comprises implanting He^+ ions at a dosage between about 6x10^{15} ions/cm^2 and about 8x10^{15} ions/cm^2 at an implant energy between about 10 Kev and about 30 Kev.

10. The method of claim 1 wherein step (b) comprises implanting He^+ ions at a dosage between about 6.6x10^{15} ions/cm^2 and about 7x10^{15} ions/cm^2 at an implant energy between about 5 Kev and about 20 Kev

11. The method of claim 1 wherein a peak density, (D1), of H_2^+ ions, H^+ ions, or a combination of H_2^+ ions and H^+ ions is between about 500 Angstroms and about 2500 Angstroms, as measured from the front surface of the single crystal silicon donor substrate and along the central axis.

12. The method of claim 1 wherein a peak density, (D2), of He^+ ions is between about 500 Angstroms and about 3000 Angstroms, as measured from the front surface of the single crystal silicon donor substrate and along the central axis.

13. The method of claim 1 wherein the peak density, (D1), of H_2^+ ions, H^+ ions, or a combination of H_2^+ ions and H^+ ions and the peak density, (D2), of He^+ ions are within about 400 Angstroms of each other.

14. The method of claim 1 wherein the peak density, (D1), of H_2^+ ions, H^+ ions, or a combination of H_2^+ ions and H^+ ions and the peak density, (D2), of He^+ ions are within about 200 Angstroms of each other.

15. The method of any of claim 1 wherein step (c) comprises annealing the ion implanted single crystal silicon donor substrate at a temperature between about 250°C and about 300°C for a duration between 10 minutes and 60 minutes.

16. The method of claim 1 wherein step (e) comprises annealing the multilayer substrate at a temperature between about 300°C and about 400°C for a duration between 10 minutes and 60 minutes.

17. The method of claim 1 wherein the silicon layer having the thickness between about 500 Angstroms and about 2500 Angstroms transferred from the single crystal silicon donor substrate to the handle substrate has a thickness variation less than about 10 Angstroms.

18. A method of transferring a silicon layer from a single crystal silicon donor substrate to a handle substrate, the method comprising:

(a) implanting H^+ ions through a silicon dioxide layer in contact with a front surface of the single crystal silicon donor substrate and through the front surface of the single crystal silicon donor substrate, the single crystal silicon donor substrate comprising two major, parallel surfaces one of which is the front surface and one of which is the back surface, a circumferential edge joining the front surface and the back surface, a central plane between the front surface and the back surface, a central axis perpendicular to the front surface, and a bulk region between the front surface and the back surface, wherein the H^+ ions are implanted at an implant energy between about 5 Kev and about 20 Kev, wherein a peak density, (D1), of H^+ ions is between about 100 Angstroms and about 3000 Angstroms as measured from the front surface of the single crystal silicon donor substrate and along the central axis;

(b) implanting He^+ ions through the silicon dioxide layer in contact with the front surface of a single crystal silicon donor substrate and through the front surface of the single crystal silicon donor substrate, wherein the He^+ ions are implanted at an implant energy between about 5 Kev and about 30 Kev, wherein a peak density, (D2), of He^+ ions is between about 100 Angstroms and about 3000 Angstroms as measured from the front surface of the single crystal silicon donor substrate and along the central axis and further wherein the peak density, (D1), of H^+ ions and the peak density, (D2), of He^+ ions are within about 450 Angstroms of each other;

(c) annealing the ion implanted single crystal silicon donor substrate at a temperature between about 200°C and about 350°C and for a duration sufficient to form a damage layer in the single crystal silicon donor substrate;

(d) bonding the silicon dioxide layer in contact with the front surface of the single crystal silicon donor substrate to a dielectric layer in contact with the handle substrate to thereby prepare the multilayer substrate;

(e) annealing the multilayer substrate at a temperature between about 200°C and about 400°C and for a duration sufficient to thermally activate the damage layer; and

(f) cleaving the annealed multilayer substrate at the damage layer in the single crystal silicon donor substrate to thereby transfer the silicon layer having a thickness between about 500 Angstroms and about 2500 Angstroms from the single crystal silicon donor substrate to the handle substrate.

19. The method of claim 18 wherein step (a) occurs before step (b).

20. The method of claim 18 wherein step (b) occurs before step (a).

21. The method of claim 18 wherein steps (a) and (b) occur simultaneously.

22. The method of claim 18 wherein step (a) comprises implanting H^+ ions at a dosage between about $5x10^{15}$ ions/cm^2 and about $2x10^{16}$ ions/cm^2 at an implant energy between about 5 Kev and about 20 Kev.

23. The method of claim 18 wherein step (a) comprises implanting H^+ ions at a dosage between about $1.1x10^{16}$ ions/cm^2 and about $2x10^{16}$ ions/cm^2 at an implant energy between about 5 Kev and about 20 Kev.

24. The method of claim 18 wherein step (a) comprises implanting H^+ ions at a dosage between about $6.1x10^{15}$ ions/cm^2 and about $6.8x10^{15}$ ions/cm^2 at an implant energy between about 5 Kev and about 20 Kev.

25. The method of claim 18 wherein step (b) comprises implanting He^+ ions at a dosage between about $6x10^{15}$ ions/cm^2 and about $8x10^{15}$ ions/cm^2 at an implant energy between about 5 Kev and about 30 Kev.

26. The method of claim 18 wherein step (b) comprises implanting He^+ ions at a dosage between about $6x10^{15}$ ions/cm^2 and about $8x10^{15}$ ions/cm^2 at an implant energy between about 10 Kev and about 30 Kev.

27. The method of claim 18 wherein step (b) comprises implanting He^+ ions at a dosage between about $6.6x10^{15}$ ions/cm^2 and about $7x10^{15}$ ions/cm^2 at an implant energy between about 5 Kev and about 20 Kev.

28. The method of claim 18 wherein a peak density, (D1), of H^+ ions is between about 500 Angstroms and about 2500 Angstroms, as measured from the front surface of the single crystal silicon donor substrate and along the central axis.

29. The method of claim 18 wherein a peak density, (D2), of He^+ ions is between about 500 Angstroms and about 3000 Angstroms, as measured from the front surface of the single crystal silicon donor substrate and along the central axis.

30. The method of claim 18 wherein the peak density, (D1), of H^+ ions and the peak density, (D2), of He^+ ions are within about 400 Angstroms of each other.

31. The method of claim 18 wherein the peak density, (D1), of H^+ ions and the peak density, (D2), of He^+ ions are within about 200 Angstroms of each other.

32. The method of claim 18 wherein step (c) comprises annealing the ion implanted single crystal silicon donor substrate at a temperature between about 250°C and about 300°C for a duration between 10 minutes and 60 minutes.

33. The method of claim 18 wherein step (e) comprises annealing the multilayer substrate at a temperature between about 300°C and about 400°C for a duration between 10 minutes and 60 minutes.

34. The method of claim 18 wherein the silicon layer having the thickness between about 500 Angstroms and about 2500 Angstroms transferred from the single crystal silicon donor substrate to the handle substrate has a thickness variation less than about 10 Angstroms.

35. The method of claim 1 wherein step (e) comprises annealing the multilayer substrate at a pressure between about 0.5 MPa and about 200 MPa.

36. The method of claim 18 wherein step (e) comprises annealing the multilayer substrate at a pressure between about 0.5 MPa and about 200 MPa.