THE CLAIMS

What is claimed is:

1. A method of ion implanting silicon, comprising ionizing a silicon dopant composition to form ionized silicon, and contacting the ionized silicon with a substrate to implant silicon therein, wherein the silicon dopant composition comprises at least one silicon compound that is isotopically enriched above natural abundance in at least one of ^{28}Si, ^{29}Si, and ^{30}Si, and wherein when the silicon dopant composition consists of silicon tetrafluoride enriched in ^{29}Si, the level of enrichment is above 50 atomic % and up to 100 atomic %.

2. The method of claim 1, wherein the silicon dopant composition comprises: (i) a said silicon compound in gaseous form as a silicon dopant gas, and (ii) a supplemental gas including at least one of a co-species gas and a diluent gas.

3. The method of claim 1, wherein the silicon dopant composition is ionized using an ionization apparatus to generate an ion beam of silicon ions, and comprising accelerating the ion beam by electric field to implant silicon in the substrate in said contacting.

4. The method of claim 1, wherein the ionized silicon is contacted with the substrate in a plasma immersion process to implant silicon therein.

5. The method of claim 1, wherein the silicon dopant composition comprises a silicon compound selected from the group consisting of silicon tetrafluoride (SiF_4), silane (SiH_4), disilane (Si_2H_6), C_1-C_8 alkylsilanes, fluorosilanes, and chlorosilanes.

6. The method of claim 5, wherein said silicon compound is isotopically enriched above natural abundance in ^{28}Si.

7. The method of claim 6, wherein said silicon compound comprises silicon tetrafluoride, isotopically enriched in ^{28}Si in a range of concentration that is greater than 92.3 atomic % and up to 100 atomic %.

8. The method of claim 7, wherein said silicon tetrafluoride is homoisotopic in ^{28}Si.

9. The method of claim 2, wherein said supplemental gas comprises a diluent gas selected from the group consisting of argon, hydrogen, fluorine, krypton, neon, helium, ammonia, amines, water, phosphine, arsine, germane, hydrogen selenide, hydrogen sulfide, nitrogen, oxygen, carbon monoxide, xenon difluoride, diborane, methane, and xenon.

10. The method of claim 1, wherein the dopant gas composition comprises a gas composition selected from the group consisting of:
(i) isotopically enriched silicon tetrafluoride with xenon and hydrogen;
(ii) isotopically enriched silicon tetrafluoride with silane;
(iii) isotopically enriched silicon tetrafluoride and isotopically enriched silane;
(iv) isotopically enriched silicon tetrafluoride with argon;
(v) isotopically enriched silicon tetrafluoride with disilane;
(vi) isotopically enriched silicon tetrafluoride and isotopically enriched disilane;
(vii) isotopically enriched silicon tetrafluoride with hydrogen;
(viii) isotopically enriched silicon tetrafluoride with ammonia;
(ix) isotopically enriched silicon tetrafluoride with ammonia and xenon;
(x) isotopically enriched silicon tetrafluoride with hydrogen and krypton;
(xi) isotopically enriched silicon tetrafluoride with ammonia and krypton;
(xii) isotopically enriched silicon tetrafluoride with nitrogen;
(xiii) isotopically enriched silicon tetrafluoride with nitrogen and xenon;
(xiv) isotopically enriched silicon tetrafluoride with nitrogen and krypton; and
(xv) isotopically enriched silicon tetrafluoride with one or more of the following: hydrogen, nitrogen, ammonia, xenon, and argon.

11. A dopant gas composition supply for ion implantation of silicon, said supply being selected from the group consisting of:

(A) a gas storage and dispensing vessel containing a silicon dopant composition comprising silicon dopant gas in mixture with supplemental gas comprising at least one of a diluent gas and a co-species gas, wherein the silicon dopant composition comprises at least one gaseous silicon compound that is isotopically enriched above natural abundance in at least one of ^{28}Si, ^{29}Si, and ^{30}Si; and

(B) a gas supply kit comprising (i) a first gas storage and dispensing vessel containing silicon dopant gas, and (ii) a second gas storage and dispensing vessel holding supplemental gas comprising at least one of a diluent gas and a co-species gas, wherein at least one of the

silicon dopant gas and, when present, a co-species gas, is isotopically enriched above natural abundance in at least one of ^{28}Si, ^{29}Si, and ^{30}Si.

12. The dopant gas composition supply according to claim 11, comprising a silicon compound selected from the group consisting of silicon tetrafluoride (SiF_4), silane (SiH_4), disilane (Si_2H_6), C_1-C_8 alkylsilanes, fluorosilanes, and chlorosilanes.

13. The dopant gas composition supply according to claim 12, wherein said silicon compound is isotopically enriched above natural abundance in ^{28}Si.

14. The dopant gas composition supply according to claim 13, wherein said silicon compound comprises silicon tetrafluoride, isotopically enriched in ^{28}Si in a range of concentration that is greater than 92.3 atomic % and up to 100 atomic %.

15. The dopant gas composition supply according to claim 14, wherein said silicon tetrafluoride is homoisotopic in ^{28}Si.

16. The dopant gas composition supply according to claim 11, wherein said supplemental gas comprises a diluent gas selected from the group consisting of argon, hydrogen, fluorine, krypton, neon, helium, ammonia, amines, water, phosphine, arsine, germane, hydrogen selenide, hydrogen sulfide, nitrogen, oxygen, carbon monoxide, xenon difluoride, diborane, methane, and xenon.

17. The dopant gas composition supply according to claim 11, wherein the dopant gas composition comprises a gas composition selected from the group consisting of:
(i) isotopically enriched silicon tetrafluoride with xenon and hydrogen;
(ii) isotopically enriched silicon tetrafluoride with silane;
(iii) isotopically enriched silicon tetrafluoride and isotopically enriched silane;
(iv) isotopically enriched silicon tetrafluoride with argon;
(v) isotopically enriched silicon tetrafluoride with disilane;
(vi) isotopically enriched silicon tetrafluoride and isotopically enriched disilane;
(vii) isotopically enriched silicon tetrafluoride with hydrogen;
(viii) isotopically enriched silicon tetrafluoride with ammonia;
(ix) isotopically enriched silicon tetrafluoride with ammonia and xenon;
(x) isotopically enriched silicon tetrafluoride with hydrogen and krypton;
(xi) isotopically enriched silicon tetrafluoride with ammonia and krypton;
(xii) isotopically enriched silicon tetrafluoride with nitrogen;

(xiii) isotopically enriched silicon tetrafluoride with nitrogen and xenon;
(xiv) isotopically enriched silicon tetrafluoride with nitrogen and krypton; and
(xv) isotopically enriched silicon tetrafluoride with one or more of the following: hydrogen, nitrogen, ammonia, xenon, and argon.

18. The dopant gas composition supply according to claim 11(A).

19. The dopant gas composition supply according to claim 11(B).

20. An ion implantation system, comprising an ion implanter arranged in gas-receiving flow communication with a dopant gas composition supply according to claim 11.

21. The ion implantation system of claim 20, wherein the ion implanter is adapted to:
(A) ionize the silicon dopant composition from said dopant gas composition supply and form ionized silicon, and to contact the ionized silicon with a substrate to implant silicon therein; and
(B) (i) generate an ion beam of said ionized silicon, and accelerate the ion beam by electric field to the substrate for implantation of silicon therein, or (ii) conduct a plasma immersion process for implantation of silicon in the substrate.

22. A method for enhancing operation of an ion implantation system, comprising providing for use in the ion implantation system a dopant gas composition supply according to claim 11.

23. The method of claim 22, wherein the dopant gas composition supply comprises a silicon compound selected from the group consisting of silicon tetrafluoride (SiF_4), silane (SiH_4), disilane (Si_2H_6), C_1-C_8 alkylsilanes, fluorosilanes, and chlorosilanes.

24. The method of claim 23, wherein said silicon compound comprises silicon tetrafluoride (SiF_4), isotopically enriched above natural abundance in ^{28}Si, in a range of concentration that is greater than 92.3 atomic % and up to 100 atomic %.

25. The method of claim 24, wherein said silicon tetrafluoride is homoisotopic in ^{28}Si.

26. The method of claim 22, wherein said supplemental gas comprises a diluent gas selected from the group consisting of argon, hydrogen, fluorine, krypton, neon, helium, ammonia, amines, water, phosphine, arsine, germane, hydrogen selenide, hydrogen sulfide, nitrogen, oxygen, carbon monoxide, xenon difluoride, diborane, methane, and xenon.

27. The method of claim 22, wherein the dopant gas composition comprises a gas composition selected from the group consisting of:

(i) isotopically enriched silicon tetrafluoride with xenon and hydrogen;

(ii) isotopically enriched silicon tetrafluoride with silane;

(iii) isotopically enriched silicon tetrafluoride and isotopically enriched silane;

(iv) isotopically enriched silicon tetrafluoride with argon;

(v) isotopically enriched silicon tetrafluoride with disilane;

(vi) isotopically enriched silicon tetrafluoride and isotopically enriched disilane;

(vii) isotopically enriched silicon tetrafluoride with hydrogen;

(viii) isotopically enriched silicon tetrafluoride with ammonia;

(ix) isotopically enriched silicon tetrafluoride with ammonia and xenon;

(x) isotopically enriched silicon tetrafluoride with hydrogen and krypton;

(xi) isotopically enriched silicon tetrafluoride with ammonia and krypton;

(xii) isotopically enriched silicon tetrafluoride with nitrogen;

(xiii) isotopically enriched silicon tetrafluoride with nitrogen and xenon;

(xiv) isotopically enriched silicon tetrafluoride with nitrogen and krypton; and

(xv) isotopically enriched silicon tetrafluoride with one or more of the following: hydrogen, nitrogen, ammonia, xenon, and argon.

THE CLAIMS

What is claimed is:

1. A method of ion implanting silicon, comprising ionizing a silicon dopant composition to form ionized silicon, and contacting the ionized silicon with a substrate to implant silicon therein, wherein the silicon dopant composition comprises at least one silicon compound that is isotopically enriched above natural abundance in at least one of ^{28}Si, ^{29}Si, and ^{30}Si, and wherein when the silicon dopant composition consists of silicon tetrafluoride enriched in ^{29}Si, the level of enrichment is above 50 atomic % and up to 100 atomic %.

2. The method of claim 1, wherein the silicon dopant composition comprises: (i) a said silicon compound in gaseous form as a silicon dopant gas, and (ii) a supplemental gas including at least one of a co-species gas and a diluent gas.

3. The method of claim 1, wherein the silicon dopant composition is ionized using an ionization apparatus to generate an ion beam of silicon ions, and comprising accelerating the ion beam by electric field to implant silicon in the substrate in said contacting.

4. The method of claim 1, wherein the ionized silicon is contacted with the substrate in a plasma immersion process to implant silicon therein.

5. The method of claim 1, wherein the silicon dopant composition comprises a silicon compound selected from the group consisting of silicon tetrafluoride (SiF_4), silane (SiH_4), disilane (Si_2H_6), C_1-C_8 alkylsilanes, fluorosilanes, and chlorosilanes.

6. The method of claim 5, wherein said silicon compound is isotopically enriched above natural abundance in ^{28}Si.

7. The method of claim 6, wherein said silicon compound comprises silicon tetrafluoride, isotopically enriched in ^{28}Si in a range of concentration that is greater than 92.3 atomic % and up to 100 atomic %.

8. The method of claim 7, wherein said silicon tetrafluoride is homoisotopic in ^{28}Si.

9. The method of claim 2, wherein said supplemental gas comprises a diluent gas selected from the group consisting of argon, hydrogen, fluorine, krypton, neon, helium, ammonia, amines, water, phosphine, arsine, germane, hydrogen selenide, hydrogen sulfide, nitrogen, oxygen, carbon monoxide, xenon difluoride, diborane, methane, and xenon.

10. The method of claim 1, wherein the dopant gas composition comprises a gas composition selected from the group consisting of:
(i) isotopically enriched silicon tetrafluoride with xenon and hydrogen;
(ii) isotopically enriched silicon tetrafluoride with silane;
(iii) isotopically enriched silicon tetrafluoride and isotopically enriched silane;
(iv) isotopically enriched silicon tetrafluoride with argon;
(v) isotopically enriched silicon tetrafluoride with disilane;
(vi) isotopically enriched silicon tetrafluoride and isotopically enriched disilane;
(vii) isotopically enriched silicon tetrafluoride with hydrogen;
(viii) isotopically enriched silicon tetrafluoride with ammonia;
(ix) isotopically enriched silicon tetrafluoride with ammonia and xenon;
(x) isotopically enriched silicon tetrafluoride with hydrogen and krypton;
(xi) isotopically enriched silicon tetrafluoride with ammonia and krypton;
(xii) isotopically enriched silicon tetrafluoride with nitrogen;
(xiii) isotopically enriched silicon tetrafluoride with nitrogen and xenon;
(xiv) isotopically enriched silicon tetrafluoride with nitrogen and krypton; and
(xv) isotopically enriched silicon tetrafluoride with one or more of the following: hydrogen, nitrogen, ammonia, xenon, and argon.

11. A dopant gas composition supply for ion implantation of silicon, said supply being selected from the group consisting of:

(A) a gas storage and dispensing vessel containing a silicon dopant composition comprising silicon dopant gas in mixture with supplemental gas comprising at least one of a diluent gas and a co-species gas, wherein the silicon dopant composition comprises at least one gaseous silicon compound that is isotopically enriched above natural abundance in at least one of ^{28}Si, ^{29}Si, and ^{30}Si; and

(B) a gas supply kit comprising (i) a first gas storage and dispensing vessel containing silicon dopant gas, and (ii) a second gas storage and dispensing vessel holding supplemental gas comprising at least one of a diluent gas and a co-species gas, wherein at least one of the silicon dopant gas and, when present, a co-species gas, is isotopically enriched above natural abundance in at least one of ^{28}Si, ^{29}Si, and ^{30}Si.

12. The dopant gas composition supply according to claim 11, comprising a silicon compound selected from the group consisting of silicon tetrafluoride (SiF_4), silane (SiH_4), disilane (Si_2H_6), C_1-C_8 alkylsilanes, fluorosilanes, and chlorosilanes.

13. The dopant gas composition supply according to claim 12, wherein said silicon compound is isotopically enriched above natural abundance in ^{28}Si.

14. The dopant gas composition supply according to claim 13, wherein said silicon compound comprises silicon tetrafluoride, isotopically enriched in ^{28}Si in a range of concentration that is greater than 92.3 atomic % and up to 100 atomic %.

15. The dopant gas composition supply according to claim 14, wherein said silicon tetrafluoride is homoisotopic in ^{28}Si.

16. The dopant gas composition supply according to claim 11, wherein said supplemental gas comprises a diluent gas selected from the group consisting of argon, hydrogen, fluorine, krypton, neon, helium, ammonia, amines, water, phosphine, arsine, germane, hydrogen selenide, hydrogen sulfide, nitrogen, oxygen, carbon monoxide, xenon difluoride, diborane, methane, and xenon.

17. The dopant gas composition supply according to claim 11, wherein the dopant gas composition comprises a gas composition selected from the group consisting of:
(i) isotopically enriched silicon tetrafluoride with xenon and hydrogen;
(ii) isotopically enriched silicon tetrafluoride with silane;
(iii) isotopically enriched silicon tetrafluoride and isotopically enriched silane;
(iv) isotopically enriched silicon tetrafluoride with argon;
(v) isotopically enriched silicon tetrafluoride with disilane;
(vi) isotopically enriched silicon tetrafluoride and isotopically enriched disilane;
(vii) isotopically enriched silicon tetrafluoride with hydrogen;

(viii) isotopically enriched silicon tetrafluoride with ammonia;
(ix) isotopically enriched silicon tetrafluoride with ammonia and xenon;
(x) isotopically enriched silicon tetrafluoride with hydrogen and krypton;
(xi) isotopically enriched silicon tetrafluoride with ammonia and krypton;
(xii) isotopically enriched silicon tetrafluoride with nitrogen;
(xiii) isotopically enriched silicon tetrafluoride with nitrogen and xenon;
(xiv) isotopically enriched silicon tetrafluoride with nitrogen and krypton; and
(xv) isotopically enriched silicon tetrafluoride with one or more of the following: hydrogen, nitrogen, ammonia, xenon, and argon.

18. The dopant gas composition supply according to claim 11, wherein said supply is (A).

19. The dopant gas composition supply according to claim 11, wherein said supply is (B).

20. An ion implantation system, comprising an ion implanter arranged in gas-receiving flow communication with a dopant gas composition supply according to claim 11.

21. The ion implantation system of claim 20, wherein the ion implanter is adapted to:
(A) ionize the silicon dopant composition from said dopant gas composition supply and form ionized silicon, and to contact the ionized silicon with a substrate to implant silicon therein; and
(B) (i) generate an ion beam of said ionized silicon, and accelerate the ion beam by electric field to the substrate for implantation of silicon therein, or (ii) conduct a plasma immersion process for implantation of silicon in the substrate.

22. A method for enhancing operation of an ion implantation system, comprising providing for use in the ion implantation system a dopant gas composition supply according to claim 11.

23. The method of claim 22, wherein the dopant gas composition supply comprises a silicon compound selected from the group consisting of silicon tetrafluoride (SiF_4), silane (SiH_4), disilane (Si_2H_6), C_1-C_8 alkylsilanes, fluorosilanes, and chlorosilanes.

24. The method of claim 23, wherein said silicon compound comprises silicon tetrafluoride (SiF_4), isotopically enriched above natural abundance in ^{28}Si, in a range of concentration that is greater than 92.3 atomic % and up to 100 atomic %.

25. The method of claim 24, wherein said silicon tetrafluoride is homoisotopic in ^{28}Si.

26. The method of claim 22, wherein said supplemental gas comprises a diluent gas selected from the group consisting of argon, hydrogen, fluorine, krypton, neon, helium, ammonia, amines, water, phosphine, arsine, germane, hydrogen selenide, hydrogen sulfide, nitrogen, oxygen, carbon monoxide, xenon difluoride, diborane, methane, and xenon.

27. The method of claim 22, wherein the dopant gas composition comprises a gas composition selected from the group consisting of:
(i) isotopically enriched silicon tetrafluoride with xenon and hydrogen;
(ii) isotopically enriched silicon tetrafluoride with silane;
(iii) isotopically enriched silicon tetrafluoride and isotopically enriched silane;
(iv) isotopically enriched silicon tetrafluoride with argon;
(v) isotopically enriched silicon tetrafluoride with disilane;
(vi) isotopically enriched silicon tetrafluoride and isotopically enriched disilane;
(vii) isotopically enriched silicon tetrafluoride with hydrogen;
(viii) isotopically enriched silicon tetrafluoride with ammonia;
(ix) isotopically enriched silicon tetrafluoride with ammonia and xenon;
(x) isotopically enriched silicon tetrafluoride with hydrogen and krypton;
(xi) isotopically enriched silicon tetrafluoride with ammonia and krypton;
(xii) isotopically enriched silicon tetrafluoride with nitrogen;
(xiii) isotopically enriched silicon tetrafluoride with nitrogen and xenon;
(xiv) isotopically enriched silicon tetrafluoride with nitrogen and krypton; and
(xv) isotopically enriched silicon tetrafluoride with one or more of the following: hydrogen, nitrogen, ammonia, xenon, and argon.

28. A silicon dopant composition comprising silicon dopant gas in mixture with supplemental gas comprising at least one of a diluent gas and a co-species gas, wherein the silicon dopant composition comprises at least one gaseous silicon compound that is isotopically enriched above natural abundance in at least one of ^{28}Si, ^{29}Si, and ^{30}Si.

29. The silicon dopant composition of claim 28, wherein the at least one silicon compound is isotopically enriched above natural abundance level in:

(i) ^{28}Si, with a concentration of ^{28}Si that is greater than at least one of 92.2%, 93%, 94%, 95%, 96%, 97%, 98%, 99%, and 99.9%, and up to 100%;
(ii) ^{29}Si, e.g., with concentration of ^{29}Si that is greater than at least one of 4.7%, 5%, 7%, 10%, 12%, 15%, 20%, 25%, 30%, 35%, 40%, 50%, 51%, 52%, 53%, 54%, 55%, 56%, 57%, 58%, 59%, 60%, 70%, 80%, 90%, 95%, 96%, 97%, 98%, 99%, or 99.9%, and up to 100%; or
(iii) ^{30}Si, e.g., with a concentration of ^{30}Si that is greater than at least one of 3.1%, 3.5%, 4%, 5%, 7%, 10%, 12%, 15%, 20%, 25%, 30%, 35%, 40%, 50%, 60%, 70%, 80%, 90%, 95%, 96%, 97%, 98%, 99%, or 99.9%, and up to 100%.

30. The silicon dopant composition of claim 28, wherein the at least one silicon compound comprises silicon tetrafluoride, wherein silicon tetrafluoride is present in the mixture at concentration in a range of from 5 to 98% by volume, based on total volume of the mixture.

31. The silicon dopant composition of claim 29, wherein the at least one silicon compound comprises silicon tetrafluoride, wherein silicon tetrafluoride is present in the mixture at concentration in a range of from 5 to 98% by volume, based on total volume of the mixture.

32. The silicon dopant composition of claim 28, wherein the at least one silicon compound comprises silicon tetrafluoride, wherein silicon tetrafluoride is present in the mixture at concentration in a range of from 5 to 35 % by volume, based on total volume of the mixture.

33. The silicon dopant composition of claim 29, wherein the at least one silicon compound comprises silicon tetrafluoride, wherein silicon tetrafluoride is present in the mixture at concentration in a range of from 5 to 35 % by volume, based on total volume of the mixture.

34. The silicon dopant composition of claim 28, wherein the at least one silicon compound comprises silicon tetrafluoride, wherein silicon tetrafluoride is present in the mixture at concentration in a range of from 80 to 98% by volume, based on total volume of the mixture.

35. The silicon dopant composition of claim 29, wherein the at least one silicon compound comprises silicon tetrafluoride, wherein silicon tetrafluoride is present in the mixture at concentration in a range of from 80 to 98% by volume, based on total volume of the mixture.

36. The silicon dopant composition of claim 28, wherein the mixture comprises a diluent gas selected from the group consisting of argon, hydrogen, fluorine, krypton, neon, helium, ammonia, amines, water, phosphine, arsine, germane, hydrogen selenide, hydrogen sulfide, nitrogen, oxygen, carbon monoxide, xenon difluoride, diborane, methane, and xenon.

37. The silicon dopant composition of claim 29, wherein the mixture comprises a diluent gas selected from the group consisting of argon, hydrogen, fluorine, krypton, neon, helium, ammonia, amines, water, phosphine, arsine, germane, hydrogen selenide, hydrogen sulfide, nitrogen, oxygen, carbon monoxide, xenon difluoride, diborane, methane, and xenon.

38. A method of ion implantation, comprising providing to an ion implantation tool for doping of silicon therein, a silicon dopant composition according to any one of claims 28 to 37.