## THE CLAIMS

1. An ion implantation system, comprising:
an ion source including an arc chamber, arranged to ionize gas therein;
a dopant gas source;
a dopant gas feed line for introducing dopant gas from the dopant gas source to the arc chamber; and a cooling structure associated with the dopant gas feed line, and arranged to cool dopant gas in the dopant gas feed line, to thereby combat heating of the dopant gas by heat generated in operation of the arc chamber, and decomposition of the dopant gas resulting from such heat.

2. The ion implantation system of claim 1, wherein the cooling structure includes a cooling passage arranged to cool the dopant gas feed line and dopant gas flowed therethrough.

3. The ion implantation system of claim 2, wherein the dopant gas feed line is arranged at a distal end thereof to discharge dopant gas into the arc chamber, and wherein the cooling passage is positioned at a distal end portion of the dopant gas feed line.

4. The ion implantation system of claim 3, further comprising a water cooling assembly for the ion source, wherein the water cooling assembly is operatively coupled to the cooling passage to flow water therethrough to cool the dopant gas feed line and dopant gas flowed therethrough.

5. The ion implantation system of claim 1, wherein the dopant gas source comprises a pressure-regulated gas storage and dispensing vessel.

6. The ion implantation system of claim 5, wherein the pressure-regulated gas storage and dispensing vessel contains a boron dopant gas.

7. The ion implantation system of claim 6, wherein the boron dopant gas comprises diboron tetrafluoride.

8. The ion implantation system of claim 7, wherein the cooling structure is operative to maintain temperature of diboron tetrafluoride in the dopant feed gas line below 700°C.

9. The ion implantation system of claim 1, wherein the cooling structure comprises a heat sink body including at least one passage therein through which coolant is flowable to effect cooling of the

dopant gas, and the heat sink body is adapted to be secured to the dopant gas feed line by a mechanical securement.

10. The ion implantation system of claim 9, wherein the ion implantation system comprises an ion source cooling flow circuitry through which coolant is circulated, wherein said flow circuitry is coupled in coolant supply relationship to the heat sink body for flow of coolant through said at least one passage therein.

11. The ion implantation system of claim 10, wherein the ion source comprises an arc chamber base liner, wherein said base liner has an opening therein in gas flow communication with the dopant gas feed line.

12. The ion implantation system of claim 1, further comprising at least one of a cleaning gas supply, a diluent gas supply, and a supplemental material supply,
wherein when the cleaning gas supply is present, the ion source is arranged to receive cleaning gas from said cleaning gas supply, during receipt by said ion source of said dopant gas from said dopant gas source, and/or when the ion source is not receiving said dopant gas from said dopant gas source,
wherein when the diluent gas supply is present, the ion source is arranged to receive diluent gas from said diluent gas supply during receipt by said ion source of said dopant gas from said dopant gas source, and
wherein when the supplemental material supply is present, the ion source is arranged to receive supplemental material from said supplemental material supply during receipt by said ion source of said dopant gas from said dopant gas source.

13. The ion implantation system of claim 12, wherein: the cleaning gas comprises at least one gas species selected from among $XeF_2$ and $NF_3$; the diluent gas comprises at least one diluent gas species selected from among $XeF_2$, inert gases, noble gases, $BF_3$, $H_2$, Ar, $N_2$, a mixture of Xe and $H_2$, $CH_4$, and $NH_3$; and the supplemental material comprises at least one of a supplemental material effective to shift ionization reaction equilibrium toward B+, hydrogen, methane, and material effective to combat deposition of decomposition species in the arc chamber, in the dopant gas feed line for flowing the dopant gas to the arc chamber, and/or in a region of an interface between the arc chamber and dopant gas feed line.

14. The ion implantation system of claim 1, further comprising at least one of features selected from the group consisting of:

(i) a controller arranged to maintain a predetermined temperature in the arc chamber or in an outside wall thereof, in the dopant gas feed line, or in a region of an interface between the arc chamber and dopant gas feed line, to combat deposition therein;

(ii) the arc chamber being arranged to dissipate heat by radiation heat transfer;

(iii) the arc chamber including heat dissipation extended surface;

(iv) the arc chamber comprising structure formed of tungsten or molybdenum;

(v) the arc chamber and/or a feed tube thereto comprising a deposition-combating coating or shielding;

(vi) the arc chamber being coated, wrapped or covered with a higher emissivity material than material of construction of the arc chamber;

(vii) the arc chamber being formed of at least two materials of construction, and including materials having differing emissivity;

(viii) a controller arranged to maintain process conditions combating deposition in the arc chamber and/or dopant gas feed line;

(ix) the arc chamber comprising at least one graphite wall and/or tungsten wall;

(x) the arc chamber comprising at least one wall having an emissivity of 0.7-0.8;

(xi) the arc chamber comprising at least one wall having an emissivity of 0.1-0.2;

(xii) the arc chamber comprising at least one tungsten wall;

(xiii) a controller arranged to control emissivity in operation of the ion source;

(xix) a controller comprising a cooler;

(xx) a thermally non-conductive adaptor between the dopant gas feed line and arc chamber;

(xxi) a coaxial adaptor between the dopant gas feed line and arc chamber;

(xxii) an adaptor between the dopant gas feed line and arc chamber that is of a different conductivity and/or emissivity than material of construction of at least one of the dopant gas feed line and arc chamber;

(xxiii) a radiation shield between the source tube and arc chamber;

(xxiv) the dopant gas feed line being constructed of material having lower thermal conductivity than material of construction of the arc chamber;

(xxv) the arc chamber comprising cylindrical protrusions, and optionally an adaptor between the dopant gas feed line and arc chamber that is connected to one of said cylindrical protrusions, arranged to provide a molecular flow regime in the protrusion;

(xxvi) the dopant gas feed line comprising a coaxial tube;

(xxvii) the dopant gas feed line having a diameter greater than 0.635 cm; and

(xxviii) multiple inlets for flow of dopant gas into the arc chamber.

15. The ion implantation system of claim 1, wherein a flow passage of the ion implantation system is susceptible to deposition of solids deriving from the dopant gas in operation of the ion

implantation system, further comprising a solids deposition monitoring and control system comprising:

a monitoring device arranged to detect and provide an output indicative of accumulation of deposition solids deriving from said dopant gas in the flow passage; and

a control assembly responsive to said output of said monitoring device to modulate operation of the ion implantation system so as to prevent, reduce or reverse said accumulation of deposition solids deriving from said dopant gas in subsequent operation of the ion implantation system.

16. The ion implantation system of claim 15, wherein the solids deposition monitoring and control system is characterized by at least one of the features of:

(i) the monitoring device comprising a pressure transducer arranged to monitor pressure in said flow passage;

(ii) the monitoring device comprising a mass flow controller arranged to output a signal indicative of valve position of the mass flow controller, wherein a valve defining said valve position opens in response to solids accumulation in the flow passage to maintain a predetermined flow rate through the passage;

(iii) the control assembly comprising a flow control valve operable to modulate flow of dopant gas though the flow passage;

(iv) the control assembly comprising a flow control valve operable to modulate flow of a cleaning fluid through the flow passage;

(v) the control assembly comprising a flow control valve operable to modulate flow of a diluent fluid though the flow passage;

(vi) the control assembly being operable to modulate residence time of the dopant gas in the flow passage and/or the ion source of the ion implantation system; and

(vii) the control assembly being operable to modulate power input to the arc chamber of the ion source.

17. A method of implanting ions in a substrate, comprising passing dopant gas from a source of same to an arc chamber of an ion source, under conditions producing ionization of the dopant gas, and cooling the dopant gas prior to entry to the arc chamber, to thereby combat heating of the dopant gas by heat generated in operation of the arc chamber, and decomposition of the dopant gas resulting from such heat.

18. The method of claim 17, wherein the cooling includes flowing coolant medium through a cooling passage arranged to cool the dopant gas feed line and dopant gas flowed therethrough.

19. The method of claim 17, wherein the dopant gas source comprises a pressure-regulated gas storage and dispensing vessel.

20. The method of claim 17, wherein the dopant gas comprises diboron tetrafluoride.

21. The method of claim 17, characterized by at least one of the features of:
(i) the boron dopant gas comprising diboron tetrafluoride and the cooling being operative to maintain temperature of diboron tetrafluoride flowed to the arc chamber below 700°C;
(ii) the boron dopant gas comprising diboron tetrafluoride and the cooling comprising flowing coolant from an ion source coolant supply in heat exchange relationship to said diboron tetrafluoride prior to its entering the arc chamber;
(iii) the dopant gas comprising at least one boron compound selected from among $B_2F_4$, $B_2H_6$, $B_5H_9$, $B_3F_5$, $BHF_2$, and $BH_2F$;
(iv) cleaning the ion source with a cleaning gas, during ionizing of the dopant gas and/or when ionizing of the dopant gas is not being carried out in the ion source;
(v) introducing a diluent gas to the ion source during said ionizing; and
(vi) introducing a supplemental material to the ion source during said ionizing.

22. The method of claim 21, wherein the cleaning gas comprises at least one gas species selected from among $XeF_2$ and $NF_3$; the diluent gas comprises at least one diluent gas species selected from among $XeF_2$, inert gases, noble gases, $BF_3$, $H_2$, Ar, $N_2$, and a mixture of Xe and $H_2$, $CH_4$, and $NH_3$; and the supplemental material comprises at least one of a supplemental material effective to shift ionization reaction equilibrium toward B+, hydrogen, methane, and material effective to combat deposition of decomposition species in the arc chamber, in a dopant gas feed line for flowing the dopant gas to the arc chamber, and/or in a region of an interface between the arc chamber and the dopant gas feed line.

23. The method of claim 17, characterized by at least one of the features of:
(i) maintaining a predetermined temperature in the arc chamber, a dopant gas feed line, or in a region of an interface between the arc chamber and dopant gas feed line, to combat deposition therein;
(ii) controlling arc voltage and current of the arc chamber;
(iii) dissipating heat from the arc chamber by radiation heat transfer;
(iv) controlling outside wall temperature of the arc chamber;
(v) the arc chamber comprising structure formed of tungsten or molybdenum;
(vi) the arc chamber and/or dopant gas feed line comprising a deposition-combating coating or shielding;

(vii) the arc chamber being coated, wrapped or covered with a higher emissivity material than material of construction of the arc chamber;

(viii) the arc chamber being formed of at least two materials of construction, and including materials having differing emissivity;

(ix) maintaining process conditions combating deposition in the arc chamber and/or dopant gas feed line;

(x) controlling residence time of the boron source dopant gas;

(xi) mediating lower residence time in regions of the ion source susceptible to greater deposition of solids deriving from the dopant gas;

(xii) the arc chamber comprising at least one graphite wall;

(xiii) the arc chamber comprising at least one wall having an emissivity of 0.7-0.8;

(xiv) the arc chamber comprising at least one wall having an emissivity of 0.1-0.2;

(xv) the arc chamber having at least one tungsten and/or graphite wall;

(xvi) controlling emissivity in operation of the ion source;

(xvii) conducting said cooling using a coolant fluid;

(xviii) said cooling comprising forced convection cooling;

(xix) disposing a thermally non-conductive adaptor between the dopant gas feed line and arc chamber;

(xx) disposing a coaxial adaptor between the dopant gas feed line and arc chamber;

(xxi) disposing an adaptor between the dopant gas feed line and arc chamber that is of a different conductivity and/or emissivity than material of construction of at least one of the dopant gas feed line and arc chamber;

(xxii) disposing a radiation shield between the source tube and arc chamber;

(xxiii) constructing the dopant gas feed line of material having lower thermal conductivity than material of construction of the arc chamber;

(xxiv) the arc chamber comprising cylindrical protrusions, optionally disposing an adaptor between the dopant gas feed line and arc chamber that is connected to one of said cylindrical protrusions, arranged to provide a molecular flow regime in the protrusion;

(xxv) the dopant gas feed line comprising a coaxial tube;

(xxvi) the dopant gas feed line having a diameter greater than 0.635 cm.;

(xxvii) disposing an adaptor between the dopant gas feed line and arc chamber having a diameter greater than 0.635 cm.;

(xxviii) providing multiple inlets for flow of the dopant gas into the arc chamber; and

(xxix) controlling arc voltage, electron behavior, beam transmission, and/or fractionation of the dopant gas.

24. The method of claim 17, as conducted in an ion implantation system including a flow path susceptible to deposition of solids deriving from the dopant gas in operation of the ion implantation system, said method comprising:

monitoring and responsively generating an output indicative of accumulation of deposition solids from said dopant gas in the flow path; and

responsively modulating operation of the ion implantation system so as to prevent, reduce or reverse said accumulation of deposition solids from said dopant gas in subsequent operation of the ion implantation system.

25. The method of claim 24, characterized by at least one of the features of:

(i) the monitoring comprising monitoring pressure in said flow path;

(ii) disposing a mass flow controller in said flow path, and generating a signal indicative of valve position of the mass flow controller, wherein a valve defining said valve position opens in response to solids accumulation in the flow path to maintain a predetermined flow rate through the flow path;

(iii) said responsively modulating operation of the ion implantation system comprises modulating flow of dopant gas though the flow path;

(iv) said responsively modulating operation of the ion implantation system comprises modulating flow of cleaning fluid though the flow path;

(v) said responsively modulating operation of the ion implantation system comprises modulating flow of diluent fluid though the flow path;

(vi) said responsively modulating operation of the ion implantation system comprises modulating residence time of the dopant source material in the flow path and/or the ion source of the ion implantation apparatus; and

(vii) said responsively modulating operation of the ion implantation system comprises modulating power input to the arc chamber of the ion source of the ion implantation system.

## CLAIMS

**1**. An ion implantation system, comprising:

an ion source including an arc chamber, arranged to ionize gas therein;

a dopant gas source;

a dopant gas feed line for introducing a dopant gas from the dopant gas source to the arc chamber under conditions producing ionization of the dopant gas; and a cooling structure associated with the dopant gas feed line, and arranged to cool dopant gas in the dopant gas feed line, to thereby combat heating of the dopant gas by heat generated in operation of the arc chamber, and decomposition of the dopant gas resulting from such heat.

**2**. The ion implantation system of claim **1**, wherein the cooling structure includes a cooling passage arranged to cool the dopant gas feed line and dopant gas flowed therethrough.

**3**. The ion implantation system of claim **2**, wherein the dopant gas feed line is arranged at a distal end thereof to discharge dopant gas into the arc chamber, and wherein the cooling passage is positioned at a distal end portion of the dopant gas feed line.

**4**. The ion implantation system of claim **3**, further comprising a water cooling assembly for the ion source, wherein the water cooling assembly is operatively coupled to the cooling passage to flow water therethrough to cool the dopant gas feed line and dopant gas flowed therethrough.

**5**. The ion implantation system of claim **1**, wherein the dopant gas comprises a boron dopant gas.

**6**. The ion implantation system of claim **5**, wherein the boron dopant gas comprises diboron tetrafluoride.

**7**. The ion implantation system of claim **6**, wherein the cooling structure is operative to maintain temperature of diboron tetrafluoride in the dopant feed gas line below 700° C.

**8**. The ion implantation system of claim **1**, wherein the cooling structure comprises a heat sink body including at least one passage therein through which coolant is flowable to effect cooling of the dopant gas, wherein the heat sink body is adapted to be secured to the dopant gas feed line by a mechanical securement.

**9**. The ion implantation system of claim **8**, comprising an ion source cooling flow circuitry through which coolant is circulated, wherein said flow circuitry is coupled in coolant supply relationship to the heat sink body for flow of coolant through said at least one passage therein.

**10**. The ion implantation system of claim **1**, wherein the ion source chamber comprises a base liner having an opening therein in gas flow communication with the dopant feed gas line.

**11**. The ion implantation system of claim **1**, further comprising at least one of a cleaning gas supply, a diluent gas supply, and a supplemental material supply,

wherein when the cleaning gas supply is present, the ion source is arranged to receive cleaning gas from said cleaning gas supply, during receipt by said ion source of said dopant gas from said dopant gas source, and/or when the ion source is not receiving said dopant gas from said dopant gas source,

wherein when the diluent gas supply is present, the ion source is arranged to receive diluent gas from said diluent gas supply during receipt by said ion source of said dopant gas from said dopant gas source, and

wherein when the supplemental material supply is present, the ion source is arranged to receive supplemental material from said supplemental material supply during receipt by said ion source of said dopant gas from said dopant gas source.

**12**. The ion implantation system of claim **11**, wherein: the cleaning gas comprises at least one gas species selected from among XeF2 and NF3; the diluent gas comprises at least one diluent gas species selected from among XeF2, inert gases, noble gases, BF3, H2, Ar, N2, a mixture of Xe and H2, CH4, and NH3; and the supplemental material comprises at least one of a supplemental material effective to shift ionization reaction equilibrium toward B+, hydrogen, methane, and material effective to combat deposition of decomposition species in the arc chamber, in the dopant gas feed line for flowing the dopant gas to the arc chamber, and/or in a region of an interface between the arc chamber and dopant gas feed line.

**13**. The ion implantation system of claim **1**, further comprising at least one of features selected from the group consisting of:

(i) a controller arranged to maintain a predetermined temperature in the arc chamber or in an outside wall thereof, in the dopant gas feed line, or in a region of an interface between the arc chamber and dopant gas feed line, to combat deposition therein;

(ii) the arc chamber being arranged to dissipate heat by radiation heat transfer;

(iii) the arc chamber including heat dissipation extended surface;

(iv) the arc chamber comprising structure formed of tungsten or molybdenum;

(v) the arc chamber and/or a feed tube thereto comprising a deposition-combating coating or shielding;

(vi) the arc chamber being coated, wrapped or covered with a higher emissivity material than material of construction of the arc chamber;

(vii) the arc chamber being formed of at least two materials of construction, and including materials having differing emissivity;

(viii) a controller arranged to maintain process conditions combating deposition in the arc chamber and/or dopant gas feed line;

(ix) the arc chamber comprising at least one graphite wall and/or tungsten wall;
(x) the arc chamber comprising at least one wall having an emissivity of 0.7-0.8;
(xi) the arc chamber comprising at least one wall having an emissivity of 0.1-0.2;
(xii) the arc chamber comprising at least one tungsten wall;
(xiii) a controller arranged to control emissivity in operation of the ion source;
(xix) a controller comprising a cooler;
(xx) a thermally non-conductive adaptor between the dopant gas feed line and arc chamber;
(xxi) a coaxial adaptor between the dopant gas feed line and arc chamber;
(xxii) an adaptor between the dopant gas feed line and arc chamber that is of a different conductivity and/or emissivity than material of construction of at least one of the dopant gas feed line and arc chamber;
(xxiii) a radiation shield between the source tube and arc chamber;
(xxiv) the dopant gas feed line being constructed of material having lower thermal conductivity than material of construction of the arc chamber;
(xxv) the arc chamber comprising cylindrical protrusions, and optionally an adaptor between the dopant gas feed line and arc chamber that is connected to one of said cylindrical protrusions, arranged to provide a molecular flow regime in the protrusion;
(xxvi) the dopant gas feed line comprising a coaxial tube;
(xxvii) the dopant gas feed line having a diameter greater than 0.635 cm; and
(xxviii) multiple inlets for flow of dopant gas into the arc chamber.

**14**. The ion implantation system of claim **1**, wherein a flow passage of the ion implantation system is susceptible to deposition of solids deriving from the dopant gas in operation of the ion implantation system, further comprising a solids deposition monitoring and control system comprising:

a monitoring device arranged to detect and provide an output indicative of accumulation of deposition solids deriving from said dopant gas in the flow passage; and

a control assembly responsive to said output of said monitoring device to modulate operation of the ion implantation system so as to prevent, reduce or reverse said accumulation of deposition solids deriving from said dopant gas in subsequent operation of the ion implantation system.

**15**. The ion implantation system of claim **14**, wherein the solids deposition monitoring and control system is characterized by at least one of the features of:

(i) the monitoring device comprising a pressure transducer arranged to monitor pressure in said flow passage;

(ii) the monitoring device comprising a mass flow controller arranged to output a signal indicative of valve position of the mass flow controller, wherein a valve defining said valve position opens in response to solids accumulation in the flow passage to maintain a predetermined flow rate through the passage;

(iii) the control assembly comprising a flow control valve operable to modulate flow of dopant gas though the flow passage;

(iv) the control assembly comprising a flow control valve operable to modulate flow of a cleaning fluid through the flow passage;

(v) the control assembly comprising a flow control valve operable to modulate flow of a diluent fluid though the flow passage;

(vi) the control assembly being operable to modulate residence time of the dopant gas in the flow passage and/or the ion source of the ion implantation system; and

(vii) the control assembly being operable to modulate power input to the arc chamber of the ion source.

**16**. A method of implanting ions in a substrate, the method comprising passing a dopant gas from a source of same to an arc chamber of an ion source, under conditions producing ionization of the dopant gas, and cooling the dopant gas prior to entry to the arc chamber, to thereby combat heating of the dopant gas by heat generated in operation of the arc chamber, and decomposition of the dopant gas resulting from such heat.

**17**. The method of claim **16**, wherein the dopant gas is flowed to the arc chamber in a dopant gas feed line arranged at a distal end thereof to discharge dopant gas into the arc chamber, and the dopant gas is cooled at a distal end portion of the dopant gas feed line.

**18**. The method of claim **17**, wherein the cooling comprises flowing coolant medium through a cooling passage arranged to cool the distal end portion of the dopant gas feed line and dopant gas flowed therethrough.

**19**. The method of claim **16**, wherein the dopant gas comprises a boron dopant gas.

**20**. The method of claim **16**, wherein the dopant gas comprises diboron tetrafluoride, and said cooling is operative to maintain temperature of the diboron tetrafluoride in the distal end portion of the dopant gas feed line below 700° C.

**21**. The method of claim **16**, further comprising flowing at least one of a cleaning gas, a diluent gas, and the supplemental material to the arc chamber, wherein the cleaning gas comprises at least one gas species selected from among XeF2 and NF3; the diluent gas comprises at least one diluent gas species selected from among XeF2, inert gases, noble gases, BF3, H2, Ar, N2, and a mixture of Xe and H2, CH4, and NH3; and the supplemental material comprises at least one of a supplemental material effective to shift ionization reaction equilibrium toward B+, hydrogen, methane, and material effective to combat deposition of decomposition species in the arc chamber, in a dopant gas feed line for flowing the dopant gas to the arc chamber, and/or in a region of an interface between the arc chamber and the dopant gas feed line.