CLAIMS

What is claimed is:

1. A fluorine ion implantation method, comprising:

flowing a composition comprising a fluorine compound to an ion implanter at a predetermined flow rate, wherein the fluorine compound comprises at least a non-fluorine atom and a plurality of fluorine atoms,

wherein the ion implanter is configured for fluorine ion implantation into a substrate;

operating the ion implanter to generate a fluorine ionic species from the fluorine compound at a predetermined arc power and a predetermined magnetic field,

wherein the fluorine ionic species includes a cluster species comprising a plurality of fluorine ions,

wherein the predetermined flow rate, the predetermined arc power, and the predetermined magnetic field are chosen to provide an optimized beam current for the fluorine ionic species,

wherein the fluorine ionic species includes at least one of F_2^+, SiF_2^+, SiF_3^+, SiF_4^+, Si_2F^+, $Si_2F_2^+$, $Si_2F_3^+$, $Si_2F_4^+$, $Si_2F_5^+$, $Si_2F_6^+$, BF_2^+, BF_3^+, B_2F^+, $B_2F_2^+$, $B_2F_3^+$, $B_2F_4^+$, PF_2^+, PF_3^+, PF_4^+, PF_5^+, AsF_2^+, AsF_3^+, AsF_4^+, AsF_5^+, SbF_2^+, SbF_3^+, SbF_4^+, SbF_5^+, WF_2^+, WF_3^+, WF_4^+, WF_5^+, WF_6^+, CF_2^+, CF_3^+, CF_4^+, $C_2F_2^+$, $C_2F_3^+$, $C_2F_4^+$, $C_2F_5^+$, $C_2F_6^+$, GeF_2^+, GeF_3^+, GeF_4^+, Ge_2F^+, $Ge_2F_2^+$, $Ge_2F_3^+$, $Ge_2F_4^+$, $Ge_2F_5^+$ or $Ge_2F_6^+$; and

implanting the fluorine ionic species into the substrate.

2. The fluorine ion implantation method of claim 1, wherein the fluorine ionic species comprise a species having a greatest number of fluorine atoms, and the predetermined flow rate, the predetermined arc power and the predetermined magnetic field are chosen so the species having the greatest number of fluorine atoms has a beam current that is greater than beam current(s) of specie(s) having a fewer number of fluorine atoms.

3. The fluorine ion implantation method of claim 1, wherein the implanting further comprises: the desired fluorine ionic specie being implanted in the substrate at a desired depth using the predetermined flow rate, the predetermined arc power and the predetermined magnetic field.

4. The fluorine ion implantation method of claim 1, wherein the predetermined arc power is in the range of 5 W to 2500 W.

5. The fluorine ion implantation method of claim 1, wherein the predetermined flow rate is not greater than 10 sccm.

6. The fluorine ion implantation method of claim 1, wherein the predetermined flow rate is in the range of 0.2 sccm to 6 sccm.

7. The fluorine ion implantation method of claim 1

wherein (a) the fluorine compound has formula Q_xF_y, wherein Q is an element capable of forming a bond with fluorine (F), and the fluorine ionic species includes a compound of formula $Q_uF_v^+$, and F+, F_2^+, wherein *x* is an integer that is greater than or equal to *u*, and *u* is an integer that is greater than or equal to 1; and wherein *y* is an integer that is greater than or equal to *v*, and *v* is an integer that is greater than or equal to 1;

wherein (b) the fluorine compound has formula $Q_xR_zF_y$, wherein Q and R are elements capable of forming a bond with fluorine (F), and the fluorine ionic species includes a compound of formula $Q_uR_wF_v^+$, and F+, F_2^+, wherein *x* is an integer that is greater than or equal to *u*, and *u* is an integer that is greater than or equal to 1; wherein *y* is an integer that is greater than or equal to *v*, and *v* is an integer that is greater than or equal to 1, and wherein *z* is an integer that is greater than or equal to *w*, and *w* is an integer that is greater than or equal to 1; or

wherein (c) the fluorine compound has formula F_y, and the fluorine ionic species includes a compound of formula F_v^+, wherein *y* is an integer that is greater than or equal to *v*, and *v* is an integer that is greater than or equal to 1; or

wherein (d) a mixture of two or more fluorine compounds of formulas Q_xF_y, $Q_xR_zF_y$ and F_y are used.

8. The fluorine ion implantation method of claim 1 wherein the fluorine compound is selected from the group consisting of F_2, BF_3, BHF, BHF_2, B_2F_4, SiF_4, Si_2F_6, $SiHF_3$, SiH_2F_2, SiH_3F, $Si_2H_3F_3$, Si_2H_5F, Si_2HF_5, GeF_4, Ge_2F_4, Ge_2F_6, $GeHF_3$, GeH_2F_2, GeH_3F, PF_3, PF_5, PHF_2, PH_2F, PH_3F_2, P_2HF, AsF_3, AsF_5, $AsHF_2$, AsH_2F, AsH_3F_2, SbF_3, SbF_5, XeF_2, XeF_4,

XeF_6, WF_6, MoF_6, C_nF_{2n+2}, C_nF_{2n}, C_nF_{2n-2}, $C_nH_xF_{2n+2-x}$, $C_nH_xF_{2n-x}$, $C_nH_xF_{2n-2-x}$, COF_2, SF_6, SF_4, SeF_6, NF_3, N_2F_4, NHF_2, NH_2F, NHF, N_2H_3F and HF, wherein n is an integer in the range of 1-3, and x is 0, 1, or 2.

9. The fluorine ion implantation method of claim 1, wherein the flowing further comprises flowing a hydrogen-containing compound which is different than the fluorine compound, to the ion implanter, wherein the hydrogen-containing compound is selected from the group consisting of H_2, B_2H_6, SiH_4, Si_2H_6, GeH_4, Ge_2H_6, PH_3, AsH_3 CH_4, C_2H_6, C_xH_y, $C_xH_yF_z$ (where x and y and z are equal or greater than 1), NH_3 and N_2H_4.

10. The fluorine ion implantation method of claim 9, wherein the hydrogen-containing compound is flowed to the ion implanter at a rate from 0.01 sccm to 10 sccm.

11. The fluorine ion implantation method of claim 1, wherein the flowing further comprises flowing an oxygen-containing compound which is different than the fluorine compound, to the ion implanter wherein the oxygen-containing compound is selected from the group consisting of O_2, O_3, H_2O, H_2O_2, CO, CO_2, NO, NO_2, N_2O, N_4O, N_2O_3, N_2O_4, N_2O_5, N_2O_6 and COF_2.

12. The fluorine ion implantation method of claim 1, wherein the flowing further comprises flowing an inert gas to the ion implanter, wherein the inert gas is selected from the group consisting of nitrogen, helium, neon, argon, krypton, and xenon.

13. The fluorine ion implantation method of claim 12, wherein the inert gas is selected from the group consisting of nitrogen, helium, neon, argon, krypton, and xenon.

14. The fluorine ion implantation method of claim 1, wherein flowing further comprises co-flowing two or more of a fluorine-containing gas, a hydrogen-containing gas, an oxygen-containing gas, or an inert gas.

15. A fluorine ion implantation method, comprising:

optimizing an optimized beam current for a fluorine ionic species by choosing to provide a predetermined flow rate, a predetermined arc power, and a predetermined magnetic field,

wherein the optimized beam current is optimized for at least one of F_2^+, SiF_2^+, SiF_3^+, SiF_4^+, Si_2F^+, $Si_2F_2^+$, $Si_2F_3^+$, $Si_2F_4^+$, $Si_2F_5^+$, $Si_2F_6^+$, BF_2^+, BF_3^+, B_2F^+, $B_2F_2^+$, $B_2F_3^+$, $B_2F_4^+$, PF_2^+, PF_3^+, PF_4^+, PF_5^+, AsF_2^+, AsF_3^+, AsF_4^+, AsF_5^+, SbF_2^+, SbF_3^+, SbF_4^+, SbF_5^+, WF_2^+, WF_3^+, WF_4^+, WF_5^+, WF_6^+, CF_2^+, CF_3^+, CF_4^+, $C_2F_2^+$, $C_2F_3^+$, $C_2F_4^+$, $C_2F_5^+$, $C_2F_6^+$, GeF_2^+, GeF_3^+, GeF_4^+, Ge_2F^+, $Ge_2F_2^+$, $Ge_2F_3^+$, $Ge_2F_4^+$, $Ge_2F_5^+$ or $Ge_2F_6^+$;

flowing a composition comprising a fluorine compound to an ion implanter at the predetermined flow rate, wherein the fluorine compound comprises at least a non-fluorine atom and a plurality of fluorine atoms,

wherein the ion implanter is configured for fluorine ion implantation into a substrate;

operating the ion implanter to generate the fluorine ionic species from the fluorine compound at the predetermined arc power and the predetermined magnetic field,

wherein the fluorine ionic species comprises a species having a greatest number of fluorine ions, and

the optimized beam current is greater than beam current(s) of specie(s) having a fewer number of fluorine ions; and

implanting the fluorine ionic species into the substrate.

16. A fluorine ion implantation method, comprising:

flowing a composition comprising a fluorine compound to an ion implanter at a predetermined flow rate,

wherein the fluorine compound comprises at least a non-fluorine atom and a plurality of fluorine atoms,

wherein the ion implanter is configured for fluorine ion implantation into a substrate,

wherein the predetermined flow rate is not greater than 10 sccm;

operating the ion implanter to generate a fluorine ionic species from the fluorine compound at a predetermined arc power and a predetermined magnetic field,

wherein the predetermined arc power ranges from 5 W to 2500 W,

wherein the predetermined flow rate, the predetermined arc power, and the predetermined magnetic field are chosen to provide an optimized beam current for the fluorine ionic species,

wherein the fluorine ionic species includes at least one of F_2^+, SiF_2^+, SiF_3^+, SiF_4^+, Si_2F^+, $Si_2F_2^+$, $Si_2F_3^+$, $Si_2F_4^+$, $Si_2F_5^+$, $Si_2F_6^+$, BF_2^+, BF_3^+, B_2F^+, $B_2F_2^+$, $B_2F_3^+$, $B_2F_4^+$, PF_2^+, PF_3^+, PF_4^+, PF_5^+, AsF_2^+, AsF_3^+, AsF_4^+, AsF_5^+, SbF_2^+, SbF_3^+, SbF_4^+, SbF_5^+, WF_2^+, WF_3^+, WF_4^+, WF_5^+, WF_6^+, CF_2^+, CF_3^+, CF_4^+, $C_2F_2^+$, $C_2F_3^+$, $C_2F_4^+$, $C_2F_5^+$, $C_2F_6^+$, GeF_2^+, GeF_3^+, GeF_4^+, Ge_2F^+, $Ge_2F_2^+$, $Ge_2F_3^+$, $Ge_2F_4^+$, $Ge_2F_5^+$ or $Ge_2F_6^+$; and

implanting the fluorine ionic species into the substrate.