

CLAIMS

1. A method comprising:

forming a titanium (Ti) seed layer from a Ti source directly on a surface of a substrate, the surface being substantially free of oxide and nitride; and

introducing a reactive nitrogen species from a nitrogen plasma source and additional Ti from the Ti source, the nitrogen plasma: (a) reacting with the Ti seed layer to form TiN and (b) reacting with the additional Ti to form additional TiN, the TiN and additional TiN collectively forming a TiN superconducting layer that directly contacts the surface of the substrate.

2. The method of claim 1, wherein the substrate is substantially free of both nitrogen and titanium.

3. The method of any one of the preceding claims, wherein the Ti seed layer has a thickness between 0.5 nm and 1 nm.

4. The method of claim 1, wherein the Ti seed layer has a first thickness between 0.5 nm and 1 nm, and the method further comprises:

increasing the temperature of the substrate to above 100 °C, and increasing thickness of the TiN layer from the first thickness to a second thickness.

5. The method of claim 4, wherein the second thickness is in the following range: 1 nm -2000 nm.

6. A device, comprising:

a substrate; and

a TiN superconducting layer overlying and in contact with the substrate, wherein the substrate is substantially free of both Ti and nitrogen, and wherein the TiN superconducting layer is formed by:

forming a titanium (Ti) seed layer from a Ti source directly on a surface of a substrate, the surface being substantially free of oxide and nitride; and

introducing a reactive nitrogen species from a nitrogen plasma source and additional Ti from the Ti source, the nitrogen plasma: (a) reacting with the Ti seed layer to form TiN and (b) reacting with the additional Ti to form additional TiN, the TiN and additional TiN collectively forming a TiN superconducting layer that directly contacts the surface of the substrate.

7. The device of claim 6, wherein the device is part of a superconducting resonator formed from the TiN superconducting layer, wherein the quality factor of the superconducting resonator is between 100,000 and 1 billion.

8. A method, comprising:

depositing titanium (Ti) onto a surface of an underlayer to form a Ti layer thereon, wherein the surface is selected to be substantially free of oxide and nitride; and

directing additional Ti, in the presence of a reactive nitrogen species, towards the Ti layer to form a TiN superconducting layer in contact with the surface of the underlayer, the nitrogen reacting with both the additional Ti and the Ti layer, thereby forming the TiN superconducting layer in contact with the surface of the underlayer.

9. The method of claim 8, wherein the surface of the underlayer is substantially free of both nitrogen and titanium.

10. The method of any one of claims 8 to 9, wherein the Ti layer has a thickness between 0.5 nm and 1 nm.

11. The method of any one of claims 8 to 10, wherein said directing additional Ti, in the presence of nitrogen, comprises:

forming the TiN layer having a first thickness between 0.5 nm and 2 nm; and

increasing the temperature of the underlayer to above 100 °C, and increasing the thickness of the TiN superconducting layer from the first thickness to a second thickness.

12. The method of claim 11, wherein the second thickness is in the following range: 2 nm -2000 nm.

13. A method comprising:

forming a titanium (Ti) seed layer from a Ti source directly on a surface of a substrate, the surface being substantially free of oxide and nitride;

introducing a reactive nitrogen species from a nitrogen plasma source and additional Ti from the Ti source, the nitrogen plasma: (a) reacting with the Ti seed layer to form TiN and (b) reacting with the additional Ti to form additional TiN, the TiN and additional TiN collectively forming a TiN superconducting layer of a first thickness that directly contacts the surface of the substrate; and

increasing the temperature of the substrate to above 100 °C, while increasing the thickness of the TiN layer to a second thickness.

14. The method of claim 13, wherein the substrate is substantially free of both nitrogen and titanium.

15. The method of any one of claims 13 to 14, wherein the Ti seed layer has a thickness between 0.5 nm and 1 nm.

16. The method of any one of claims 13 to 15, wherein the first thickness is between 1 nm and 2 nm.

17. The method of any one of claims 13 to 16, wherein the second thickness is between 2 nm and 2000 nm.

18. A method comprising:

forming a seed layer from a metal source directly on a surface of a substrate, the source picked from any of the following: Titanium (Ti), Vanadium (V), Zirconium (Zr), Tungsten (W), Tantalum (Ta) and Molybdenum (Mo), the surface being substantially free of oxide and nitride; and

introducing a reactive nitrogen species from a nitrogen plasma source and additional metal from the metal source, the nitrogen plasma: (a) reacting with the seed layer to form a nitride and (b) reacting with the additional metal picked from Titanium (Ti), Vanadium (V), Zirconium (Zr), Tungsten (W), Tantalum (Ta) and Molybdenum (Mo) to form an additional nitride, the nitride and the additional nitride collectively forming a nitride superconducting layer that directly contacts the surface of the substrate.

19. The method of claim 18, wherein the substrate is substantially free of both nitrogen and the source.

20. The method of any one of claims 18 to 19, wherein the seed layer has a thickness between 0.5 nm and 1 nm.

21. The method of any one of claims 18 to 19, wherein the seed layer has a first thickness between 0.5 nm and 1 nm, and the method further comprises:

increasing the temperature of the substrate to above 100 °C, while increasing the thickness of the nitride layer from the first thickness to a second thickness.

22. The method of claim 21, wherein the thickness of the nitride layer is increased to be in the following range: 2 nm -2000 nm.

23. A device, comprising:

a substrate; and

a TiN superconducting layer overlying and in contact with the substrate, wherein the substrate is substantially free of both Ti and nitrogen, and wherein the TiN superconducting layer is formed by:

forming a titanium (Ti) seed layer from a Ti source directly on a surface of a substrate, the surface being substantially free of oxide and nitride; and

introducing a reactive nitrogen species from a nitrogen plasma source and additional Ti from the Ti source, the nitrogen plasma: (a) reacting with the Ti seed layer to form TiN and (b) reacting with the additional Ti to form additional TiN, the TiN and additional TiN collectively forming a TiN superconducting layer that directly contacts the surface of the substrate, and

wherein the TiN superconducting layer has been etched to form a superconducting resonator, and

wherein the quality factor of the superconducting resonator is between 100,000 and 1 billion.

24. The device of claim 23, wherein the thickness of the Ti seed layer is 5 Angstroms – 7 Angstroms.

25. The device of claim 23, wherein the thickness of the Ti seed layer is less than 8 Angstroms.

26. The device of claim 23, wherein the thickness of the Ti seed layer is less than 1 nm.