Claims

1. An apparatus comprising: a silicon emitter, wherein the silicon emitter has a diameter of 100 nm or less; and a protective cap layer disposed on an exterior surface of the silicon emitter, wherein the protective cap layer includes ruthenium.

2. The apparatus of claim 1, wherein the silicon emitter has an emitting area of less than 1 mm^2.

3. The apparatus of claim 1, wherein the protective cap layer has a thickness from 1 nm to 100 nm.

4. The apparatus of claim 3, wherein the protective cap layer has a thickness from 1 nm to 20 nm.

5. The apparatus of claim 4, wherein the silicon emitter has a tip radius from 1 nm to 50 nm.

6. The apparatus of claim 1, wherein the protective cap layer is free of pinholes in at least an emitting area.

7. The apparatus of claim 1, wherein the protective cap layer is free of bubbles and inclusions in at least an emitting area.

8. The apparatus of claim 1, wherein the protective cap layer has imperfections only with a diameter or length dimension less than 1 nm.

9. The apparatus of claim 1, wherein the protective cap layer has fewer than 10^4 impurities.

10. The apparatus of claim 9, wherein the impurities include carbon, oxides, oxygen as a dissolved gas, sodium, or potassium.

11. The apparatus of claim 1, wherein the protective cap layer has a porosity less than or equal to 25%.

12. The apparatus of claim 1, wherein the protective cap layer has a packing density of greater than or equal to 0.92.

13. A method comprising: providing a silicon emitter having an exterior surface, wherein the silicon emitter has a diameter of 100 nm or less; applying a protective cap layer to the exterior surface of the silicon emitter, wherein the protective cap layer includes ruthenium.

14. The method of claim 13, wherein the applying includes sputter deposition.

15. The method of claim 13, wherein the applying includes atomic layer deposition.

16. The method of claim 13, wherein the applying includes ion sputtering.

17. A method comprising: providing a silicon emitter that includes a protective cap layer disposed on an exterior surface of the silicon emitter, wherein the silicon emitter has a diameter of 100 nm or less, and wherein the protective cap layer includes ruthenium; applying an electric field to the silicon emitter; and generating an electron beam from the silicon emitter.

18. The method of claim 17, wherein the silicon emitter operates in a vacuum of 10^{-9} Torr or less.

19. A system comprising: an electron beam source; a silicon emitter in the electron beam source, wherein the silicon emitter has a diameter of 100 nm or less; a protective cap layer disposed on an exterior surface of the silicon emitter, wherein the protective cap layer includes ruthenium; and a detector.

20. The system of claim 19, wherein the protective cap layer is free of pinholes in at least an emitting area.