

CLAIMS

1. A method of making a Josephson junction in a superconducting qubit comprising:
providing a substrate having a convex structure, the convex structure having a first face and a second face meeting at an edge;
depositing a first layer of superconducting material on the first face of the substrate material;
oxidizing the first layer of superconducting material to form a layer of oxide material on a surface of said first layer of superconducting material; and
depositing a second layer of the superconducting material on the second face of the substrate material, wherein a portion of said second layer is in contact with a portion of the layer of oxide material at or in the vicinity of said edge such that the portion of the layer of oxide material is sandwiched between a portion of the first layer of superconducting material and the portion of the second layer of superconducting material to define a Josephson junction at or in the vicinity of said edge.
2. The method according to the preceding claim, further comprising:
depositing superconducting material on a surface of the substrate; and
removing portions of the superconducting material to uncover a first portion of the surface of the substrate to form a plurality of buses and readout resonators on the substrate.
3. The method according to the preceding claim, further comprising:
depositing a sacrificial material layer on the superconducting material and on the uncovered first portion of the surface of the substrate;
applying electron beam or optical beam lithography to expose a portion of the sacrificial material layer; and
removing the exposed portion of the sacrificial material layer to uncover a second portion of the surface of the substrate to define a qubit pocket.
4. The method according to the preceding claim, wherein depositing said sacrificial material layer on the superconducting material and on the uncovered first portion of the substrate comprises depositing Germanium (Ge) on the superconducting material and on the uncovered first portion of the substrate.

5. The method according to any of the preceding claims and with features of claim 3, wherein the uncovered second portion of the surface of the substrate has two mirror symmetric shapes.
6. The method according to the preceding claim, wherein the uncovered second portion of the surface of the substrate has a H-like shape.
7. The method according to any of the preceding claims and with features of claim 5, wherein the two mirror symmetric shapes of the uncovered second portion of the surface of the substrate are separated by a narrower strip of the sacrificial material layer at a median of said two mirror symmetric shapes.
8. The method according to any of the preceding claims and with features of claim 3, further comprising:
etching the second portion of the surface of the substrate to form the convex shape in the substrate.
9. The method according to the preceding claim, wherein etching the second portion of the surface of the substrate comprises etching using potassium hydroxide (KOH) or Tetramethylammonium hydroxide (TMAH).
10. The method according to any of the preceding claims and with features of claim 8, further comprising removing remaining sacrificial material layer to form the Josephson Junction.
11. The method according to any of the preceding claims, wherein the first face and the second face are formed in a (111) crystal plane of the substrate.
12. The method according to any of the preceding claims, wherein the substrate comprises Silicon (Si).
13. The method according to any of the preceding claims, wherein the superconducting material is selected from the group consisting of Aluminum (Al) and Niobium (Nb).

14. The method according to any of the preceding claims, wherein the oxide material is selected from the group consisting of Aluminum oxide and Niobium oxide.
15. A qubit device, comprising:
a substrate having a convex structure, the convex structure having a first face and second face meeting at an edge and forming an angle therebetween;
a first layer of superconducting material deposited on the first face of the substrate material;
a layer of oxide material on a surface of said first layer of superconducting material; and
a second layer of the superconducting material on the second face of the substrate material,
wherein a portion of said second layer is in contact with a portion of the layer of oxide material at or in the vicinity of said edge such that the portion of the layer of oxide material is sandwiched between a portion of the first layer of superconducting material and a portion of the second layer of superconducting material to define a Josephson junction at or in the vicinity of said edge.
16. The qubit device according to the preceding claim, wherein the substrate comprises Silicon (Si).
17. The qubit device according to any of the preceding claims 15 to 16, wherein the superconducting material is selected from the group consisting of Aluminum (Al) and Niobium (Nb).
18. The qubit device according to any of the preceding claims 15 to 17, wherein the oxide material is selected from the group consisting of Aluminum oxide and Niobium oxide.
19. A method of making a Josephson junction in a superconducting qubit comprising:
providing a substrate;
depositing superconducting material on a surface of the substrate;

depositing a sacrificial material layer on the superconducting material;
removing a portion of the sacrificial material layer to uncover a portion of the surface of the substrate to define a qubit pocket;
etching the portion of the surface of the substrate to form a convex shape in the substrate, the convex shape having a first face and a second face meeting at an edge; and
forming a Josephson Junction at or in the vicinity of the edge without applying electron beam or optical beam lithography to connect capacitor pads connected to the Josephson Junction to a plurality of buses.

20. The method according to the preceding claim, wherein forming the Josephson Junction comprises:

depositing a first layer of superconducting material on the first face of the convex shape in the substrate material;

oxidizing the first layer of superconducting material to form a layer of oxide material on a surface of said first layer of superconducting material; and

depositing a second layer of the superconducting material on the second face of the convex shape in the substrate material,

wherein a portion of said second layer is in contact with a portion of the layer of oxide material at or in the vicinity of said edge such that the portion of the layer of oxide material is sandwiched between a portion of the first layer of superconducting material and the portion of the second layer of superconducting material to define the Josephson junction at or in the vicinity of said edge.

21. The method according to any of the preceding claims 19 to 20, further comprising:

defining the plurality of buses and a plurality of readout resonators using lithography;

removing portions of the superconducting material to form the plurality of buses and readout resonators on the substrate.

22. The method according to any of the preceding claims 19 to 21, wherein removing a portion of the sacrificial material layer comprises applying a single lithography step.