CLAIMS

1. A method for improving lifetime and coherence time of a qubit in a quantum mechanical device, comprising:

providing a substrate having a frontside and a backside, the frontside having at least one qubit formed thereon, the at least one qubit comprising ~~capacitor pads~~ ~~pads~~a first capacitor pad and a second capacitor pad having a gap reserved therebetween; and

~~at least one of~~ removing an amount of substrate material from the backside of the substrate at least at an area ~~opposite the at least one qubit or depositing a superconducting metal layer at the backside of the substrate at the area opposite the at least one qubit~~below said gap to reduce radiofrequency electrical current loss due to at least one of silicon-air (SA) interface, metal-air (MA) interface or silicon-metal (SM) interface so as to enhance a lifetime (T1) and a coherence time (T2) in the at least one qubit.

2. The method according to ~~the preceding~~ claim 1, wherein reducing radiofrequency electrical current loss comprises reducing the radiofrequency electrical current loss by increasing radiofrequency overlap with lower loss geometric features in the quantum mechanical device and decreasing radiofrequency overlap with higher loss geometric features in the quantum mechanical device.

3. The method according to ~~any of the preceding~~ claim 1~~s~~, wherein removing the amount of the substrate material from the backside of the substrate at least at the area ~~opposite the at least one qubit~~below said gap comprises chemically etching the backside of the substrate selectively using a chemical etchant selected depending on the substrate material.

4. The method according to ~~the preceding~~ claim 3, ~~further comprising,~~ wherein prior to chemically etching the backside of the substrate, forming an initial cavity in the backside of the substrate in a vicinity of the at least one qubit by mechanically removing material from the backside of the substrate and then chemically etching the backside of the substrate at the formed initial cavity with the chemical etchant.

5. The method according to ~~the preceding~~ claim 4, wherein forming the initial cavity in the backside of the substrate comprises defining faces of the initial cavity having one or more first crystal planes and one or more second crystal planes so that the chemical etchant preferentially etches the substrate material from said one or more first crystal planes while substantially not etching substrate material from said one or more second crystal planes to form an etched final cavity in the vicinity of the at least one qubit.

6. The method according to ~~any of the preceding~~ claim~~s~~ 1, wherein removing the amount of substrate material from the backside of the substrate comprises removing the amount of substrate material in an area of the backside of the substrate to form a trench ~~in a vicinity of a~~ below the gap between the first capacitor pad and the second capacitor pad~~s~~ of the at least one qubit.

7. The method according to ~~the preceding~~ claim 6, wherein removing the amount of substrate material in the area of the backside of the substrate to form the trench ~~in the vicinity of~~below the gap between the first capacitor pad~~s~~ and the second capacitor pad of the at least one qubit comprises removing the amount of substrate material so that the trench is substantially centered around the gap between the first capacitor pad~~s~~ and the second capacitor pad of the at least one qubit.

8. The method according to ~~the preceding~~ claim 7, wherein removing the amount of substrate material so that the trench is substantially centered around the gap between the first capacitor pad~~s~~ and the second capacitor pad of the at least one qubit comprises forming the trench to reduce a participation rate of surface states with RF energy density for silicon-metal (SM) interface~~s~~ and increasing a participation rate of surface states with the RF energy density for silicon-air (SA) interface~~s~~.

9. The method according to ~~any of the preceding claims and with features of~~ claim 6, wherein a surface state RF energy density overlap ~~with surface states~~ in silicon-metal (SM) interface~~s~~ is reduced and the surface state RF energy density overlap for silicon-air (SA) interface~~s~~ is increased with increasing depth of the trench.

10. The method according to ~~any of the preceding~~ claim~~s~~ 1, wherein removing the amount of substrate material from the backside of the substrate comprises ~~removing the amount of substrate material in an area of the backside of the substrate to form~~forming a trench ~~in a vicinity of a~~below the gap between the first capacitor pad~~s~~ and the second capacitor pad of the at least one qubit; and further comprising depositing ~~the~~ a superconducting metal layer within the trench ~~so as to reduce the radiofrequency electrical current loss due to metal-air (MA) interfaces~~at the backside of the substrate.

11. The method according to ~~the preceding~~ claim 10, wherein forming the trench ~~in the vicinity of~~below the gap between the first capacitor pad~~s~~ and the second capacitor pad of the at least one qubit comprises forming the trench below and centered around one of the first capacitor pad~~s~~ and the second capacitor pad of the at least one qubit.

12. The method according to ~~any of the two preceding claims~~claim 10, wherein the radiofrequency electrical current loss due to metal-air (MA) interface is decreased based on a backside width of the trench.

13. The method according to ~~any of the preceding~~ claim~~s~~ 1, wherein removing the amount of the substrate material from the backside of the substrate ~~at the area opposite the at least one qubit~~ comprises applying an etch mask film to the backside of the substrate and etching ~~the~~ a selected area at the backside of the substrate opposite the at least one qubit.

14. The method according to ~~the preceding~~ claim 13, further comprising: subsequent to applying the etch mask film ~~mask~~ to the backside of the substrate and prior to etching the selected area at the backside of the substrate, forming one or more openings in the etch mask film ~~mask~~ at the selected area.

15. The method according to ~~any of the two preceding~~ claim~~s~~ 13, wherein etching the selected area at the backside of the substrate opposite the at least one qubit comprises

chemically etching a desired thickness of the substrate ~~at the selected areas~~ to form a trench at the selected area.

16. The method according to ~~the preceding~~ claim 15, further comprising depositing ~~the~~ a superconducting metal layer within the trench.

17. The method according to ~~any of the preceding~~ claim~~s~~ 1, wherein removing the amount of the substrate material from the backside of the substrate at the area opposite the at least one qubit comprises applying a mask film to the backside of the substrate and depositing a metal superconductor layer on masked areas of the backside of the substrate.

18. A quantum mechanical device, comprising:

a substrate having a frontside and a backside; and

a plurality of qubits formed on the frontside of the substrate, the plurality of qubits comprising a ~~plurality of capacitor pads~~first capacitor pad and a second capacitor pad having a gap reserved therebetween,

wherein the substrate comprises at least one trench formed on the backside of the substrate opposite at least one qubit of the plurality of qubits, at least at an area below said gap, and

wherein at least one of a size, a shape, or a position of the at least one trench ~~or a superconducting material deposited therein~~ are selected to reduce radiofrequency electrical current loss due to at least one of silicon-air (SA) interface, metal-air (MA) interface or silicon-metal (SM) interface, or any combination thereof, so as to enhance a lifetime (T1) and a coherence time (T2) in the at least one qubit.

19. The quantum mechanical device according to ~~the preceding~~ claim 18, wherein the substrate is selected from the group consisting of silicon, ~~high resistivity silicon,~~ and sapphire.

20. The quantum mechanical device according to ~~the preceding~~ claim 19, wherein the ~~plurality of~~first capacitor pad~~s~~ and the second capacitor pad are made from a superconducting material.

21. The quantum mechanical device according to ~~the preceding~~ claim 20, wherein the superconducting material is selected from the group consisting of aluminum (Al) and niobium (Nb).

22. The quantum mechanical device according to ~~any of the four preceding~~ claim~~s~~ 18, wherein the at least one trench is provided ~~in a vicinity of a~~below the gap between ~~two~~ the first capacitor pad~~s of~~ and the ~~plurality of~~second capacitor pad~~s~~.

23. The quantum mechanical device according to ~~the preceding~~ claim 22, wherein the at least one trench is substantially centered around the gap so as to reduce surface state energy density for silicon-metal (SM) interface and to increase surface state energy density for silicon-air (SA) interface.

24. The quantum mechanical device according to ~~any of the six preceding claims, wherein the~~claim 18, further comprising a superconducting metal layer ~~is~~ provided within the at least one trench so as to reduce the radiofrequency electrical current loss due to metal-air (MA) interface.

25. The quantum mechanical device according to ~~the preceding~~ claim 24, wherein the at least one trench is formed below and centered around ~~one or more of~~ the ~~plurality of~~first capacitor pad~~s~~ or the second capacitor pad.