

WHAT IS CLAIMED IS:

- 1 1. A device comprising:
2 a substrate;
3 a dielectric layer on the substrate;
4 a waveguide within the dielectric layer; and
5 a photodetector disposed above the waveguide and monolithically
6 integrated with the substrate, the photodetector optically coupled to the waveguide and
7 configured to operate at temperatures below 50 K.
- 1 2. The device of claim 1, further comprising a heater disposed
2 proximate to the waveguide and configured to thermally tune a portion of the
3 waveguide.
- 1 3. The device of claim 2, wherein the waveguide and the heater
2 form a single photon generator, a ring oscillator, an optical filter, an optical switch, or
3 an optical interferometer.
- 1 4. The device of claim 2, further comprising a thermal isolation
2 structure surrounding the heater, the thermal isolation structure including a trench in the
3 dielectric layer and an undercut in the substrate.
- 1 5. The device of claim 4, wherein the undercut extends horizontally
2 in the substrate and is under the portion of the waveguide.
- 1 6. The device of claim 4, wherein the trench and the undercut form a
2 vacuum region.
- 1 7. The device of claim 4, further comprising a cooling structure
2 disposed to be in thermal contact with the substrate, wherein the undercut is disposed
3 between the heater and the cooling structure.
- 1 8. The device of claim 1, further comprising a plurality of light
2 isolation structures in at least one of the substrate or the dielectric layer, the plurality of
3 light isolation structures configured to prevent photons from reaching the photodetector
4 other than through the waveguide.

1 9. The device of claim 8, wherein the plurality of light isolation
2 structures includes at least one of:

3 a metal trench in the dielectric layer and partially extending into the
4 substrate;

5 a metal trench in the dielectric layer;

6 an array of metal vias in the dielectric layer;

7 a metal cover in the dielectric layer and on top of the photodetector; or

8 a deep trench in the substrate, the deep trench including an air gap or
9 filled with a reflective or absorptive material.

1 10. The device of claim 9, wherein the metal cover is in a metal layer
2 and is aligned with or coupled to the metal trench or the array of metal vias to form a
3 contiguous structure surrounding the photodetector.

1 11. The device of claim 9, wherein:
2 the waveguide includes an input port; and
3 the metal trench or the array of metal vias is located at a region including
4 the input port.

1 12. The device of claim 1, wherein the photodetector includes a
2 superconducting nanowire single photon detector.

1 13. The device of claim 1, wherein the dielectric layer includes an
2 oxide layer.

1 14. A method comprising:
2 receiving a wafer, the wafer including:
3 a substrate,
4 a dielectric layer on the substrate;
5 a waveguide formed in the dielectric layer; and
6 a photodetector in the dielectric layer and coupled to the
7 waveguide;
8 etching a first set of vias or a first trench in the dielectric layer to expose
9 a first portion of the substrate, the first set of vias or the first trench surrounding the
10 photodetector;
11 etching, through the first set of vias or the first trench, the substrate to
12 form a second set of vias or a second trench in the substrate; and
13 filling the first set of vias or the first trench, and the second set of vias or
14 the second trench with a light reflective or light absorptive material.

1 15. The method of claim 14, wherein the wafer further comprises a
2 heating structure formed in the dielectric layer and configured to thermally tune a
3 portion of the waveguide.

1 16. The method of claim 15, further comprising:
2 etching a third set of vias or a third trench in the dielectric layer to
3 expose a second portion of the substrate, the third set of vias or the third trench
4 surrounding the heating structure;
5 etching, through the third set of vias or the third trench, the substrate to
6 form an undercut in the substrate, the undercut positioned below the second portion of
7 the waveguide; and
8 depositing an oxide layer on the dielectric layer to seal the third set of
9 vias or the third trench and the undercut.

1 17. The method of claim 15, further comprising:
2 etching the dielectric layer to form contact holes for the heating structure;
3 and
4 filling the contact holes with a conducting material to form electrical
5 contacts for the heating structure.

1 18. The method of claim 14, further comprising, before the filling,
2 forming an oxide liner layer in the second set of vias or the second trench.

1 19. The method of claim 18, further comprising depositing a barrier
2 and seed layer on the oxide liner layer.

1 20. The method of claim 14, further comprising forming a top metal
2 cover on the dielectric layer and on top of the photodetector.

1 21. The method of claim 20, wherein the top metal cover is in a metal
2 1 layer.

1 22. The method of claim 14, further comprising:
2 etching the dielectric layer to form contact holes for the photodetector;
3 and
4 filling the contact holes with a conducting material to form electrical
5 contacts for the photodetector.

1 23. The method of claim 22, wherein filling the contact holes
2 comprises depositing a liner layer on sidewalls of the contact holes.

1 24. The method of claim 23, wherein the liner layer includes
2 tungsten, tungsten carbide, or tungsten nitride.