Tunable Antireflection Layers for Planar Bolometer Arrays

Ari-David Brown, David Chuss, Edward Wollack, James Chervenak, Ross Henry, and James Wray

It remains a challenge to obtain high-efficiency coupling of far-infrared through millimeter radiation to large-format detector arrays. The conventional approach of increasing detector coupling is to use reflective backshorts. However, this approach often results in excessive systematic errors resulting from reflections off the backshort edge. An alternate approach to both increasing quantum efficiency and reducing systematics associated with stray light is to place an antireflective coating near the front surface of the array. When incorporated with a resistive layer and placed behind the detector focal plane, the AR coating can serve to prevent optical ghosting by capturing radiation transmitted through the detector. By etching a hexagonal pattern in silicon, in which the sizes of the hexes are smaller than the wavelength of incident radiation, it is possible to fabricate a material that has a controllable dielectric constant, thereby allowing for simple tunable optical device fabrication. To this end, we have fabricated and tested tunable silicon “honeycomb” AR layers and AR/resistive layer devices. These devices were fabricated entirely out of silicon in order to eliminate problems associated with differential contraction upon detector cooling.
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NASA Goddard Space Flight Center

Ari-David Brown* (Code 553), David Chuss (PL Code 665), Edward Wolack (Code 665), James Chervenak (Code 553), Ross Henry (Code 551), and James Wray (2006 NASA Academy)

Introduction:

It remains a challenge to obtain high-efficiency coupling of far-infrared through millimeter radiation to large-format detector arrays. The conventional approach of increasing detector coating is to use reflective backcoatings. However, this approach often results in excessive systematic errors resulting from reflections off the backcoating.

An alternate approach to both increasing quantum efficiency and reducing systematics associated with stray light is to place an antireflective coating near the front surface of the array. When incorporated with a reflective layer and placed behind the detector focal plane, the AR coating can serve to prevent optical feedback by capturing radiation transmitted through the detector.

By using a hexagonal pattern in silicon, in which the axes of the hexes are smaller than the wavelength of infrared radiation, it is possible to fabricate a material that has a controllable dielectric constant, thereby allowing for simple tunable optical device fabrication.

To this end, we have fabricated and tested tunable silicon "honeycomb" AR layers and AR-resistive layer devices. These devices were fabricated entirely out of silicon in order to eliminate problems associated with differential expansion upon detector coating.

Envisioned Absorber/AR Coating Strategy:

- Radiation
- AR layer
- Vacuum gap
- Resistive layer
- AR layer
- Resistive layer

Effective medium theory* ($\epsilon = \epsilon_m$):

$$\epsilon_m = \left(\epsilon_s + 6\epsilon_0\right)^{1/3}$$

$$\epsilon_s = 1 + \omega r / (0.737\epsilon_0 - 0.521)$$

$$\epsilon_0 = 1 + \omega r / (0.671\epsilon_0 - 0.4615)$$

Expected AR Coating Performance:

- Best-fit model:
  - $r = 270$ microns
  - $\epsilon = 2.3$
- Anticipated:
  - $r = 300$ microns
  - $\epsilon = 2.3$

Optical Measurement of Implanted Silicon Resistance:

- Target sheet resistance: 30 $\Omega$/sq (T = 0.4 K)
- Measured sheet resistance: 60 $\Omega$/sq (T = 295 K)
- 30 $\Omega$/sq (cold)
- New implant recipe works.

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Plan view SEM micrograph of silicon dielectric honeycombs, $r = 13$ microns, $r = 40$ microns, and $r = 300$ microns. Dashed $r = 40$ microns, $r = 121$ microns and $r = 40$ microns. In both cases, the honeycomb array extended over a 1cm x 1cm area.

Si Dielectric Honeycomb Fabrication:

- Bond to wafer
- Pattern via photolithography
- Deep Reactive Ion Etch
- Release parts

Si Backside Absorber/Resistive Layer Fabrication:

- Photolithography
- Deep Reactive Ion Etch
- Implant activation
- Photoresist

Implantation Recipe:

We constructed an implantation model in order to achieve results for obtaining backside absorbers possessing a desired sheet resistance. The ion energy and dose, as well as oxide (used as a diffusion barrier) thickness were inputs, and were used to obtain a desired implant concentration profile. We then sweep activation temperature and time and modeled implant diffusion using Flit's second law in order to obtain a parameter set that results in a desired sheet resistance.

$$R_{sheet} = \frac{1}{\epsilon_m} \left[ \epsilon_s \epsilon_0 \epsilon_{ref} \right]^{1/2}$$

$$dR = R_{sheet} - D (dR/dz)$$

$$D = \frac{\alpha_d \epsilon_m}{\pi}$$

Future Work:

- Simulate annealing of implanted layers for obtaining desired sheet resistance

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