Compact Micromachined Infrared Bandpass Filters for Planetary Spectroscopy

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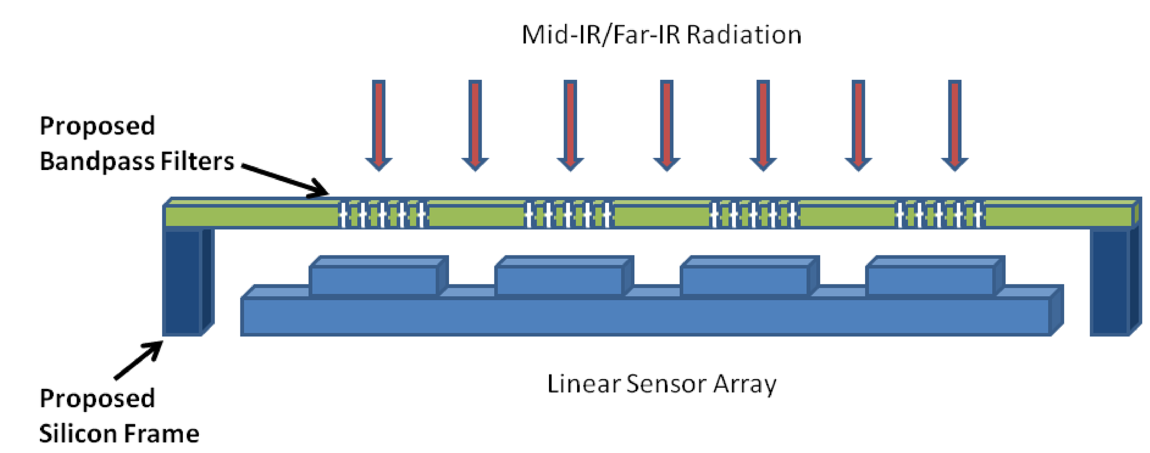
Introduction: Make bandpass filter arrays suspended on Si frames for integration with focal plane detector arrays

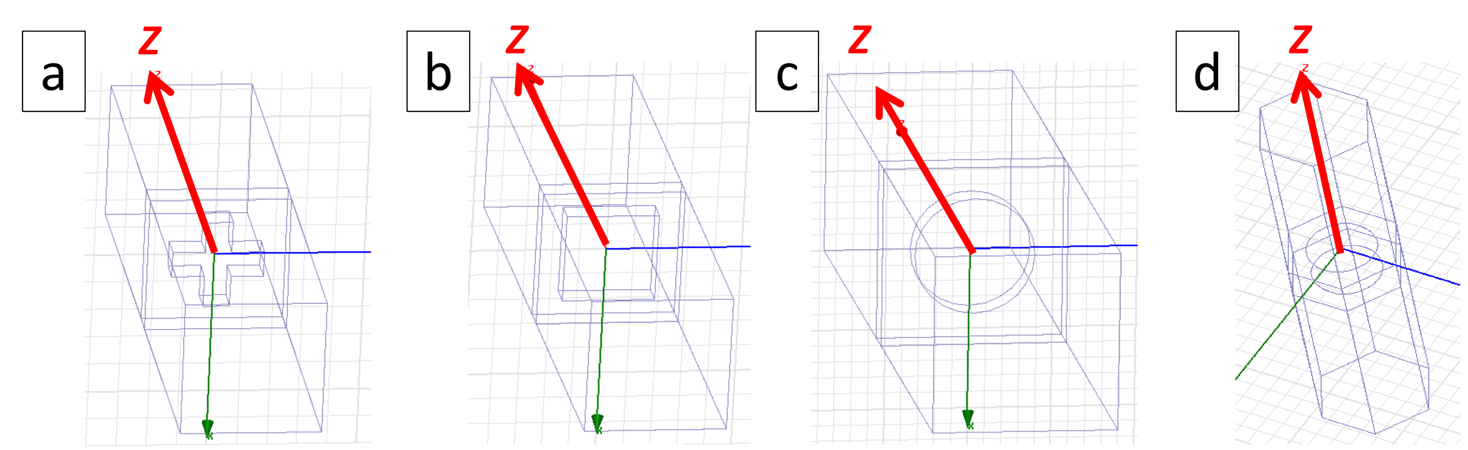
New Frontiers class missions to the outer icy planets and moons will require thermal mapping instrumentation to map out the thermal anomalies, structure, and atmospheric conditions in the FIR spectral range. These thermal mapping instruments have requirements for low mass and power. For instance, the recent call for a thermal instrument on the proposed JEO mission requires that the mass, not including that of radiation shielding, does not exceed 3.7 kg. Consequently, a new generation of light-weight miniaturized spectrometers needs to be developed. On the path toward developing these spectrometers is the development of ancillary miniaturized spectroscopic components.

We present a novel strategy for making radiation hard mid- and FIR band pass metal mesh filters in which one can customize the filter response in a high-throughput and cost-effective manner during fabrication by lithographically defining *multiple filter geometries on a single silicon wafer*. The silicon frame mitigates problems associated with differential thermal contraction between it and silicon substrates on which our cryogenic detectors are fabricated.



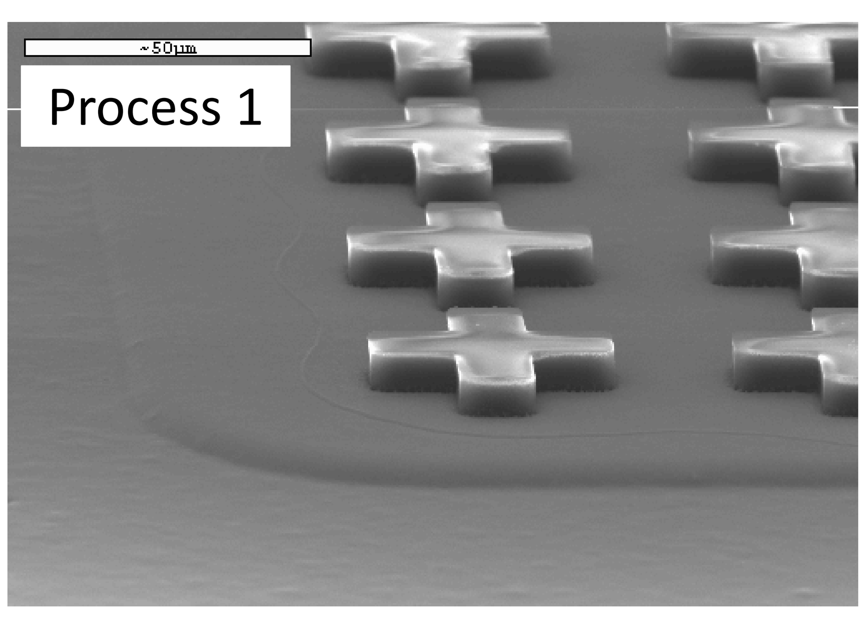
Design: Electromagnetic modeling

We use Ansoft's™ HFSS 3-D electromagnetic modeling software to guide us in metallic mesh bandpass filter design. Four basic hole designs are used, in which (a) crosses, (b) squares, and (c) circles are arranged in a square lattice. The fourth design (d) consists of circles arranged in a triangular lattice. The radiation propagates in the *Z* – direction.

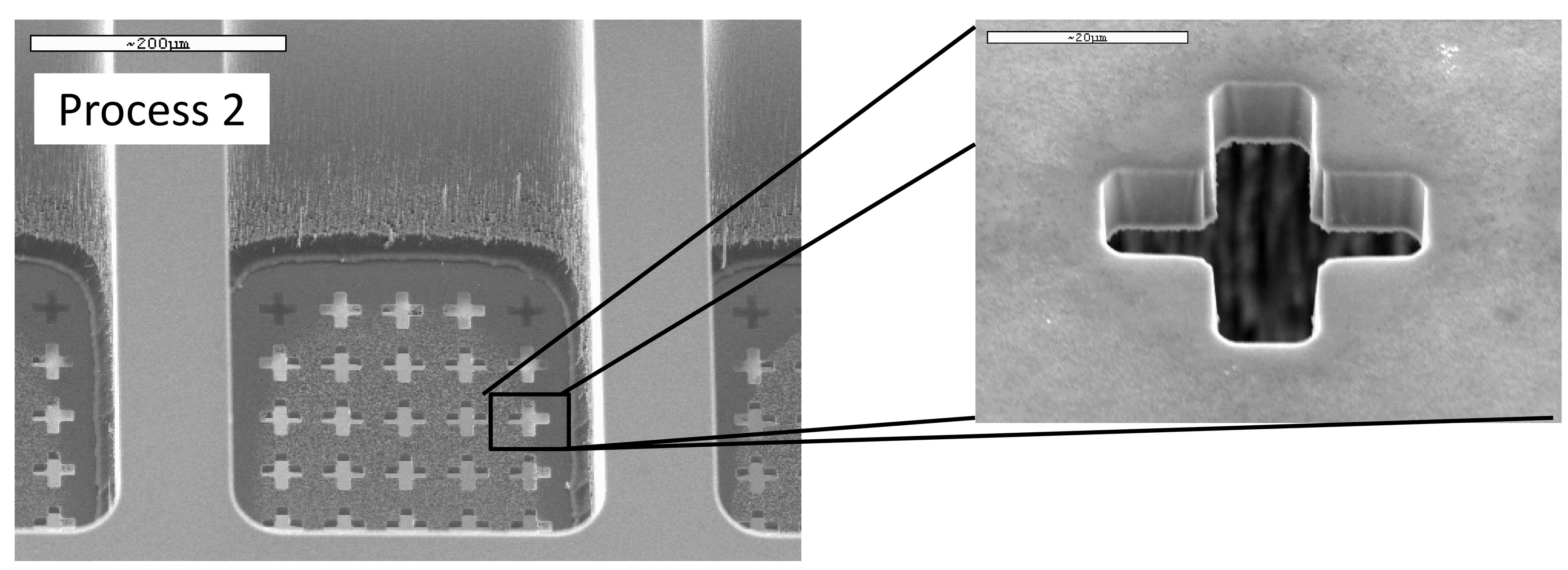


The bandpass response can be engineered by changing the hole geometry. For instance, in the case of cross-shaped holes, changing the ratio between the hole pitch and either hole dimensions will yield a different bandpass response.

Fabrication Strategy: Use photolithography to customize metal filter and Si frame geometry

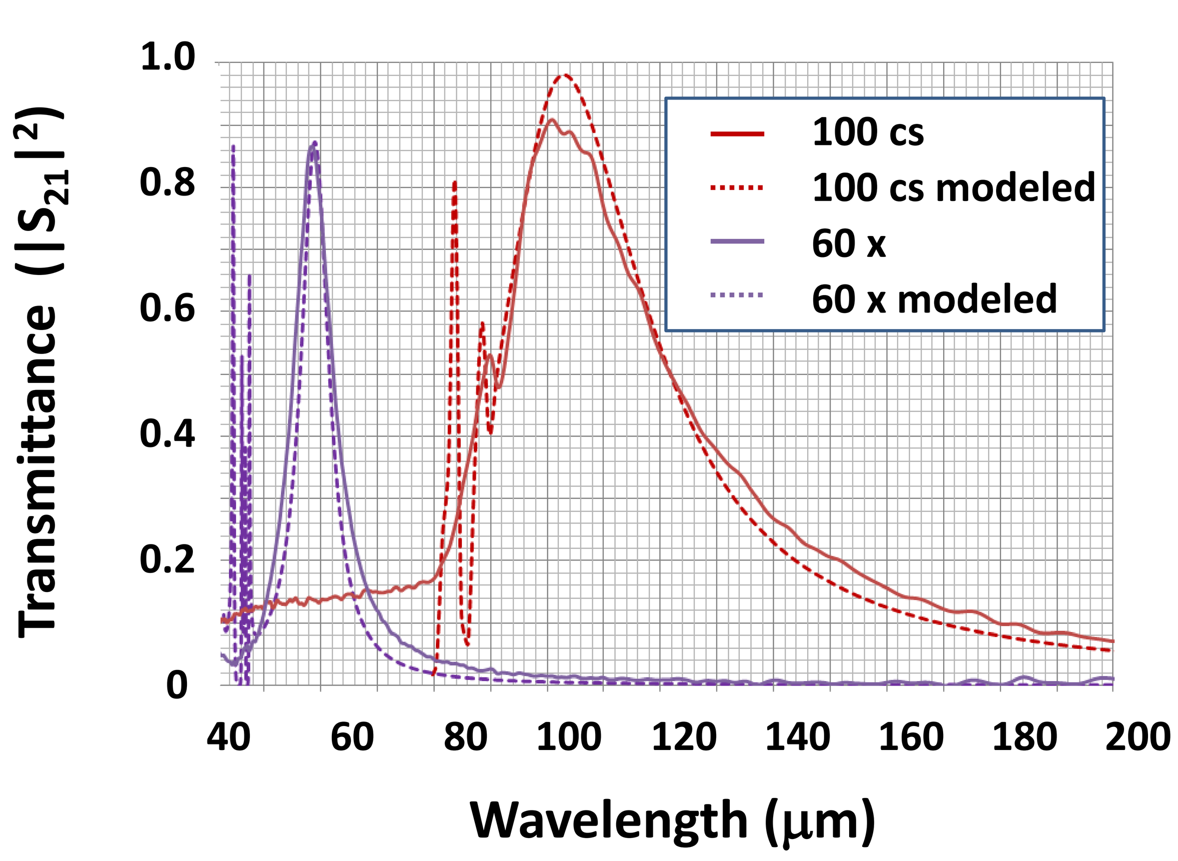


Electroplate Cu on top of Si wafer, which has Parylene-C as a sacrificial layer in the metal mesh containing regions. Use an SU-8 electroplating mold to define filter geometry.



Use a positive photoresist etch mask to define deep reactive ion etched Si frame. Reactive ion etch away SU-8 mold.

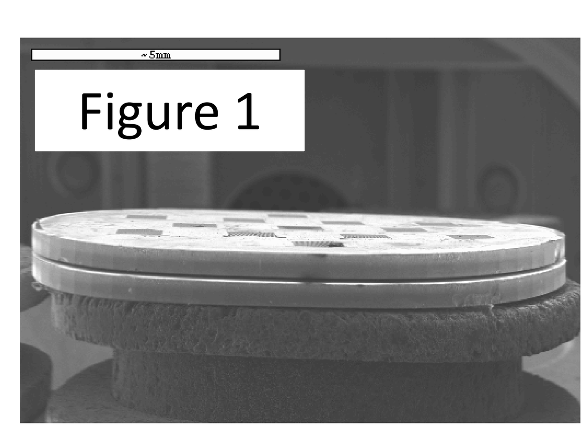
Achievement: Optical response

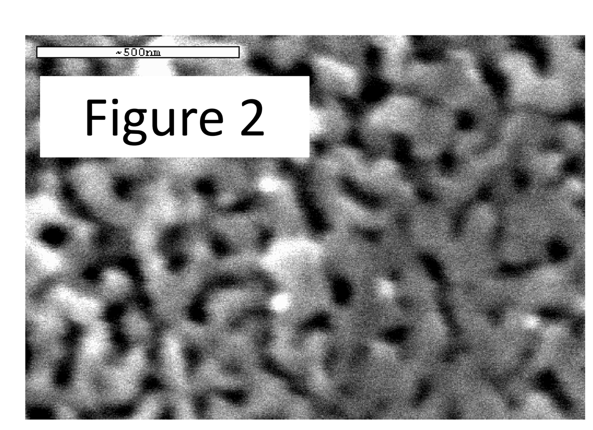


We characterized our Cu mesh bandpass filters – here the mesh patterns consist of circles and crosses – with a Fourier transform spectrometer at room temperature. The IR response is similar to our modeled data. The secondary low wavelength resonances will necessitate the inclusion of additional stacked filters.

Ongoing Work

- Stack filters in order to increase bandwidth and sharpen roll off (fig. 1).
- Coat walls of Si frame with absorbing material, nanoporous Cu in this instance (fig. 2), to control stray light.
- Make larger filter arrays and those with different aspect ratio for FIR and/or FUV astrophysics.





We have submitted a manuscript, describing this work, for peer review in *Applied Optics*.

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