Radiation Hard Bandpass Filters for Mid- to Far-IR Planetary Instruments. A. D. Brown[1], S. Aslam[1], J. A. Chervenak[1], W.-C. Huang[1], W. C. Merrell[1,*], M. Quijada[1], R. Steptoe-Jackson[1], and E. J. Wollack[1], [1]NASA Goddard Space Flight Center, 8800 Greenbelt Rd., Greenbelt, MD 20771 U.S.A.

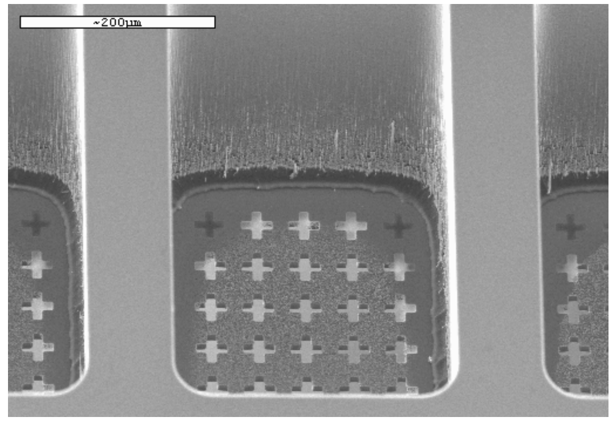
Introduction: We present a novel method to fabricate compact metal mesh bandpass filters for use in mid- to far-infrared planetary instruments operating in the 20-600 micron wavelength spectral regime. Our target applications include thermal mapping instruments on ESA's JUICE as well as on a de-scoped JEO.

These filters are novel because they are compact, customizable, free-standing copper mesh resonant bandpass filters with micromachined silicon support frames. The filters are well suited for thermal mapping mission to the outer planets and their moons because the filter material is radiation hard. Furthermore, the silicon support frame allows for effective hybridization with sensors made on silicon substrates. Using a Fourier Transform Spectrometer, we have demonstrated high transmittance within the passband as well as good out-of-band rejection [1].

In addition, we have developed a unique method of filter stacking in order to increase the bandwidth and sharpen the roll-off of the filters. This method allows one to reliably control the spacing between filters to within 2 microns. Furthermore, our method allows for reliable control over the relative position and orientation between the shared faces of the filters.

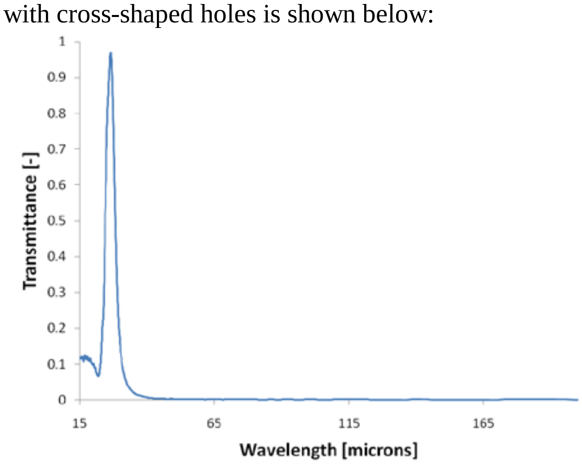
Filter Fabrication: The filters were fabricated on Si(001) substrates. Photoresist was patterned on top of a Cu electroplating seed layer so as to define the shape of the mesh. Additional Cu was electroplated, and the Cu membranes were defined by deep reactive ion etching the Si from the back of the substrate. The photoresist was subsequently removed via reactive ion and chemical etching.

A scanning electron micrograph of three filters is shown below. In this case the mesh consists of a copper sheet with cross-shaped holes. The Si frame separates the individual filters, which allows arrays to be defined. Using our technique, we were able to fabricate filters or filter arrays with 19 different mesh geometries on a single Si wafer.



Filter Characterization: The filters were charactierzed in the mid-to far-infrared spectral band using a Bruker IFS 125 Fourier Transform Spectrometer (FTS). The instrument is configured to perform measurements both at room temperature and at temperature below 10 K.

A representative transmittance curve of a mesh filter with cross-shaped holes is shown below:



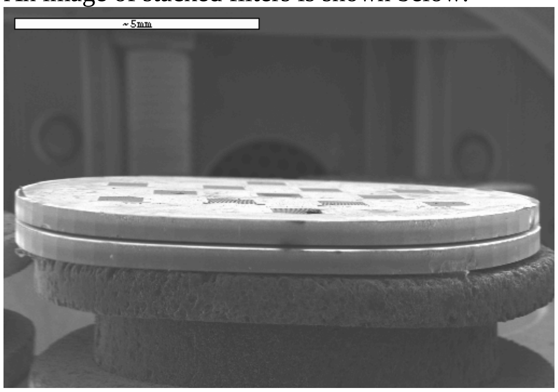
The curve exhibits a high peak transmittance at the design frequency, which, guided by electromagnetic modeling software, is 28.5 microns. Furthermore, the roll-off is sharp and the out-of-band rejection is high. The feature exhibited at low wavelength is a consequence of scattering into higher order modes.

Of note is that the filter response improves slightly upon cooling to 7 K.

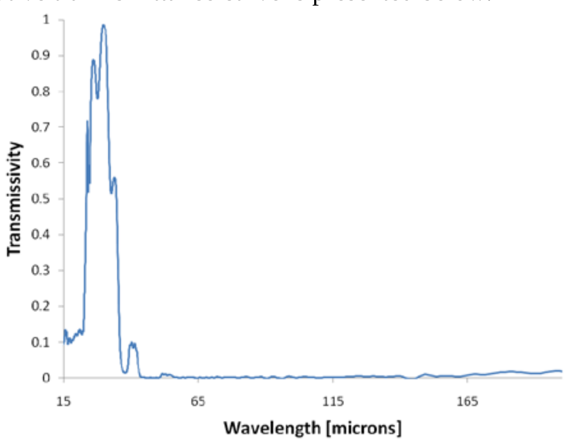
Filter Stacking: During filter fabrication we defined alignment marks on one side of the filters using photoresist. These marks allowed us to align the filters between their shared faces.

The process of bonding the filters together consisted of applying small droplets of polystyrene-loaded epoxy. The polystyrene consisted of spheres of a well-defined diameter. Thus, we were able to set the spacing between filters. Once the epoxy was applied to one filter, the other filter was aligned and bonded to it using a fine-placer tool.

An image of stacked filters is shown below:



The stacked filters were found to remain bonded after cryogenic thermal cycling. Furthermore, the size of the passband is larger for the stacked filters; a representative tranmsmittance curve is presented below:



Other stacking techniques which are being considered include the use of ultrathin silicon spacers or the use of the silicon frame itself.

Summary: We have demonstrated fabrication of and characterization of individual and stacked bandpass filters. The filters are made out of copper, which makes them radiation hard. Furthermore, their Si frames are lightweight and allow for low form factor. Consequently, they are suitable for instrumentation which uses arrayed detectors in high-radiation environments found near the outer planets and their moons.

References:

[1] Merrell W. C. et al. (2012) *Applied Optics* 51, 3046-3053.

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