Infrared metal mesh bandpass filter supported by ultrathin polyimide

Bruce Lairson[1], Dave Grove[1], Heidi Lopez[1], Travis Ayers[1], and Joe Adams[2]

1) Luxel Corporation, Friday Harbor, WA 2) Cornell University, Ithaca, NY

Metal slot meshes are useful as infrared bandpass filters for space-based and high altitude astronomy at wavelengths between 10 and 1000 microns. However, for short wavelengths, freestanding metal meshes are fragile, while supported meshes suffer from substrate losses, as well as unwanted peak shifts and optical interference. An ultrathin, low-absorption substrate support offers the opportunity for using thinner metal layers, with improved durability, flatness, and usable aperture. Polyimide is a good candidate due to its space heritage, strength, durability, and low absorption. We have prepared metal meshes from both aluminum and gold, supported by 0.2 micron thick polyimide for use in the FORCAST instrument on SOFIA.

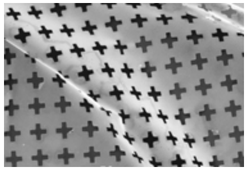
Recently, Sato, et al.[1], demonstrated good filter performance at 30 micron center wavelength (CWL) with patterned 0.1micron gold mesh, showing peak transmission of over 60%, using a 1 micron thick polyimide film support. For this polyimide thickness, roughly 10-20% of the intensity loss was ascribable to the substrate. Here, we demonstrate somewhat higher peak transmission (91% with $\Delta\lambda/\lambda$=3.3) using a 0.2 micron thick polyimide support film. At this polyimide thickness, losses due to the substrate are modeled to be less than 5%.

Acceptable transmission was also measured for aluminum metal meshes with a $\Delta\lambda/\lambda$ of 7 and CWL of 31 microns. Good agreement between modeled and measured peak placement and bandwidth was obtained.

Table 1 summarizes the advantages and disadvantages of different designs and illustrates the motivation for this work. If the substrate is thin enough to reduce losses and peak shift to negligible levels, advantages in durability and usability exist. They also offer the opportunity for incorporation into dichroic filter designs.

Table 1: Advantages and disadvantages of various metal mesh structures for a center wavelength of about 30 microns.

	Thick Metal	Thin Metal/ Thick Substrate	Thin Metal/ Thin Substrate
Transmission	+	-	+
Spurious Peaks	-	-	+
Durability	-	+	+
Wavelength Shift	+	-	+
Short Wavelengths	-	+	+
Dichroic Capability	-	-	+



Initial meshes were prepared by patterning 0.2 micron Au onto 0.2micron thick polyimide films. Slots were 14 microns long, 4 microns wide, and spaced by 8 microns. Patterning fidelity was good with about a 1 micron resolution. The mesh was stretched over a 25mm aperture and mounted into an outer (Luxel TF114) frame. Figure 1 shows an SEM image of the mesh and the infrared transmission obtained.

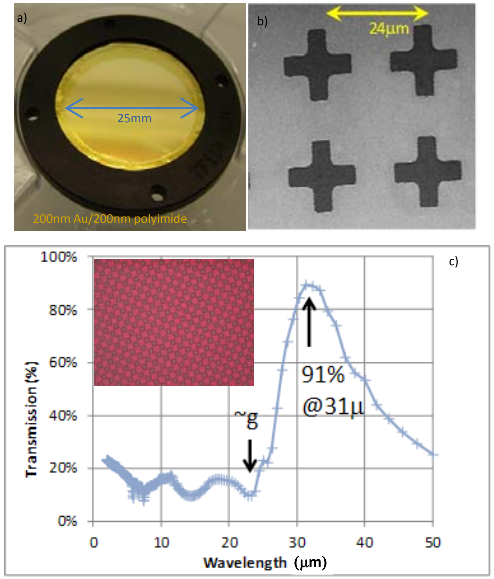


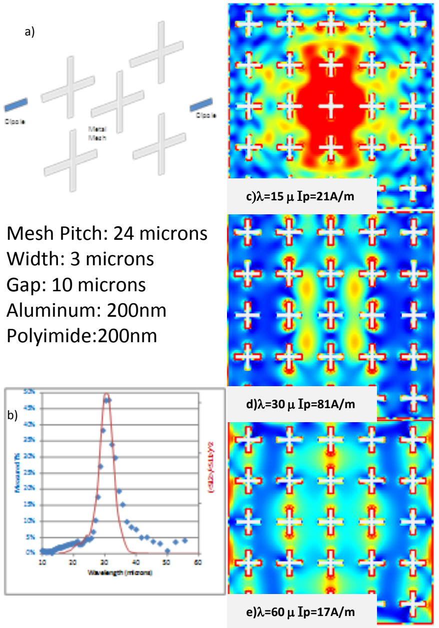
Figure 1: a) Image of finished Au/polyimide filter on a 25mm aperture. b) SEM of Au metal mesh c) Measured transmission of Au mesh on 200nm thick polyimide. Arrows indicate the transmission peak at 31 microns and the Wood's anomaly near the mesh pitch g=24 microns.

Based on these results, additional filters were designed for use in FORCAST on the SOFIA mission. SONNET software[2] was used to model 5x5 and 9x9 metal mesh arrays between a short dipole radiator and antenna, each separated by 30 microns from the mesh within a conducting waveguide. The localized source allowed simulation of beam divergence.

REFERENCES

[1] S. Sako, et al, "Developing Metal Mesh Filters for Mid-Infrared Astronomy of 25 to 40 micron", SPIE Vol 7018 (2008).
[2] http://www.sonnetsoftware.com/

Figure 2 shows agreement between the transmission modeled on the photomask dimensions, and the measured transmission using a Perkin Elmer 983 with a resolution of $10cm^{-1}$ and a beam divergence of f/4. The current density maps on the right show a strong peak in the current density at the resonant wavelength, with notable changes in the current pattern above and below the resonant wavelength.



Mesh Pitch: 24 microns
Width: 3 microns
Gap: 10 microns
Aluminum: 200nm
Polyimide:200nm

Figure 2: a) Illustration of the model geometry. b) Modeled (red) and measured (blue) mesh transmission. c-e) Modeled current distribution at CWL/2, CWL, and 2*CWL for the metal mesh.

Resonant metal meshes on ultrathin polyimide support offer excellent transmission and good conformance to numerical models. The low loss, modeling predictability, and good geometry control allows for increased design complexity, for instance incorporation into dichroic designs.