Novel Microfabricated Infrared Optical Filters

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We have designed and fabricated narrow-band, optical filters using a simple silicon technology. The advantage of these filters is that (a) they can be made in a matrix with different central wavelengths and (b) their central wavelength can be tuned post-processing. Some of the key applications include environmental monitoring, security cameras, medical analyzers.

The simplest narrowband optical filter that can be fabricated consists of two metal layers separated by a spacer. This Fabry-Perot (FP) structure is straightforward to fabricate and low cost, but they have a few important limitations. Firstly, the maximum transmission is limited by the intrinsic absorption in the metal layers. This limits the combination of transmission and linewidth *i.e*. narrow linewidth filter has a poor transmission and vice versa. Secondly, after fabrication the position of the center wavelength cannot be tuned, creating yield problems if the spacer layer is not homogeneous. Thirdly, it is difficult to create a matrix of filters with different central wavelengths without varying the thickness of the spacer layer which in practice prohibits their fabrication due to the added complexity. Finally, in the infrared, metal filters are unpractical because a metal layer thin enough to transmit some light, would be so thin that metal could not be deposited as a continuous film.

It is possible to overcome these drawbacks by using small apertures in metal and spacer layers as shown in Figure 1. The apertures allow for simultaneously high reflectivity and good ratio between transmission and absorption. This increases the figure of merit for metal FP filters, particularly at infrared wavelengths. In addition, when a porous layer has features much smaller than the wavelength then its effective refractive index varies with the porosity. If the porosity is two dimensional, then it is rather easy to vary the porosity in-plane though processing (mask design).

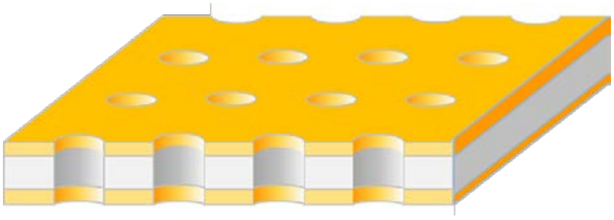

Figure 1: Basic filter consists of continuous metal membranes with apertures and a solid optically transparent spacer layer with holes.

There are few simple design rules which should be met when engineering these optical filters. The metal layer should be continuous to allow a high reflectivity. The spacer layer should be transparent in the IR and porous such that its effective index can be tailored by varying the porosity. Silicon and gold are well known microfabrication materials that can be easily processed to meet all these requirements.

Microfabrication follows a straight forward process consisting of a photolithography, dry etching and HF release. Figure 2 shows a close-up SEM of a filter made of 5 µm Si spacer layer metalized on both sides with 50 nm of Au.

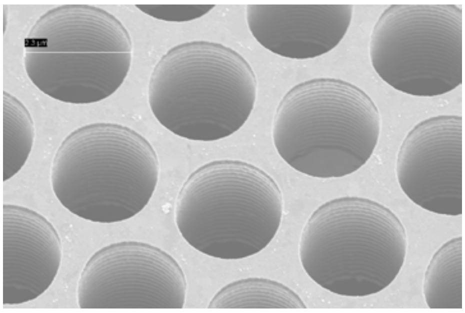

Figure 2: Fabricated optical filter with 50 nm of Au as a metal layer and 5 µm of crystaline Si as a spacer layer. Hole diameter is 2.2 µm and the period is 2.5 µm.

The filters were measured in transmission using a MCT detector in a Fourier transform infrared spectrometer microscope (Bruker-Hyperion). The FP filter measured has a central silicon spacer of 5 µm. There is a 50 nm Au layer on both sides. The hole diameters are 2 µm and arranged in a hexagonal lattice with a period of 3.6 µm. Figure 3 shows a typical example of the transmission properties of the filter. The two FP peaks have approximately 10% transmission and a 1.5% linewidth. Ideally a metal / silicon / metal FP in this configuration having a similar linewidth would have a transmission of only 0.2%! Thus showing that we have a factor of 50 improvement.

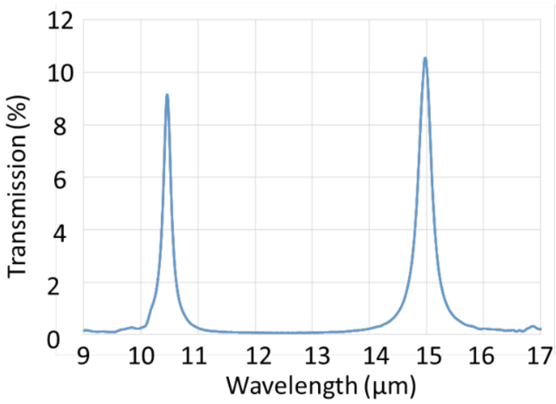

Figure 3: Measured transmission of the FP optical filter made from a 3.6 µm period hexagonal array with a 2 µm diameter hole size.

We have designed, fabricated and tested FP optical filters using gold porous mirrors and a silicon spacer layer. Traditional metal / spacer / metal FPs without apertures could achieve the same linewidth but this would come at the cost of 50 times lower transmission. In addition, these filters have a great potential in possibility of the post-process engineering of the central wavelength and in making the filter matrix with different central wavelengths.