Towards complex structured multilayer optical elements

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Topic : *Etching – Lithography – Nano-patterning*

***Abstract*—The combination of multilayer optical interference filter and Deep Reactive Ion Etching using Inductance Coupled Plasma is demonstrated. Advantages and limitations of these approached are presented. A path towards complex structured multilayer optical elements such as pixelated filters is demonstrated.**

I. Introduction

Multispectral or hyperspectral images allow acquiring new information that could not be acquired using colored images and, for example, identifying chemical species on an observed scene using specific highly selective filters. Those images are commonly used in numerous fields, e.g. in agriculture or homeland security and are of prime interest for imaging systems for onboard scientific applications (e.g. for planetology). Those instruments are generally composed with a computer controlled rotating filter wheel placed right in front of a CCD camera [1]. This technology allows integrating on a single camera a large number of filters and therefore to acquire images at very specific wavelengths or within a well-defined spectral range. Those spectral selections are generally obtained using optical interference filters. Therefore, a large range of optical functions can be achieved for these filters. Another advantage of thin film filters compared to colored organic materials is that they are compatible with space applications. However, it is obvious that these rotating filter wheels are a bulky and heavy solution for hyperspectral imaging that make them non optimal solution for onboard applications while CCD cameras are lighter and lighter. To overcome this problem, a solution is the fabrication of pixelated optical filters, similar to the one used for color cameras but using specific filters technologies. This way, filters wheels are no longer required and filter size becomes negligible compared to camera size [2-4]. There have been numerous works over the past few years on the development of this new technology. One of the main approach is based on plasmonic filters [5], especially for mid-IR application or metal dielectric coatings [6]. However, with these approaches, it is difficult to obtain high performances optical functions while multilayer dielectric filters appear as a more versatile solution. In this paper, we therefore present the first results related to the fabrication of a pixelated filters prototype based on optical interference filters.

In this work, pixelated filters were defined as a matrices of macropixels, each macropixel being composed with 2 × 2 micropixels with a Bayer-type structure. A typical representation of this type of filters is shown in Figure 1.

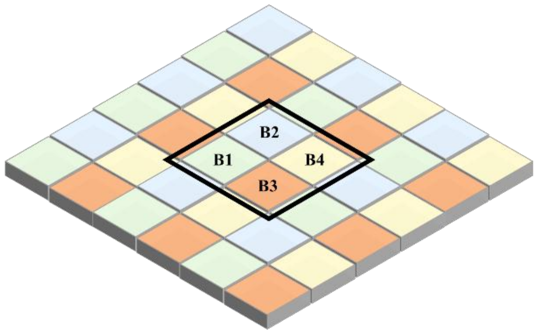


Figure 1. Example of a 2 × 2 pixelated filter

Each micropixel was associated with a specific bandpass filter centered at a specific wavelength (that will later be associated with a dedicated application) and with the following specifications shown in Table 1.

Table 1. Specifications of the four pixelated filters.

Filter #	$\lambda_{central}$	$\Delta\lambda$	$\delta\lambda$
B1	550	50	500-900
B2	700	40	500-900
B3	770	40	500-900
B4	840	40	500-900

where the central wavelength ($\lambda_{central}$), the spectral bandwidth ($\Delta\lambda$) and the rejection band ($\delta\lambda$) of the filters are expressed in nanometers. We designed filters that meet with these requirements. We used a dual-side coating approach that was described in ref. [7]. Each filter is composed with between 20 and 30 layer associated with a total thickness between 2 and 3 microns. The size of each elementary pixel was fixed to be between $5 \times 5\ \mu m^2$ and $30 \times 30\ \mu m^2$.

II. Experimental results

The approach that have implemented consists on combining thin film physical vapor deposition and Deep Reactive Ion Etching using Inductance Coupled Plasma (ICP) system.

The deposition of the filter was obtained by Plasma-assisted electron beam deposition using a Bühler SYRUSpro 710 machine. The deposition were carried out within the thin film facility (Espace Photonique) of the Institut Fresnel. The high refractive index material was Nb_2O_5 while the low refractive index materials was SiO_2. These filters were optically monitored during deposition. Optical monitoring was not performed directly on the pixelated filters but on a witness sample placed in the sample holder next to the pixelated filter. Preliminary tests showed that the spectral response obtained on the witness samples is within the measurement errors, identical to the one of the pixelated filter [8].

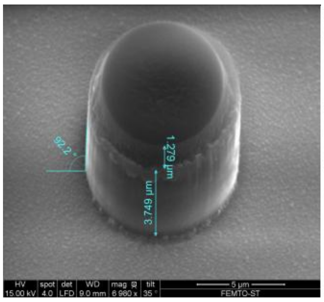
The etching process was achieved on STS-APS ICP equipment. The ICP coil power was fixed at 1400W, the bias power was varied and optimized at 300W, the chamber pressure was 10mTorr. The temperature was set to 20° and the mixture gas used was SF6/Ar/O2.

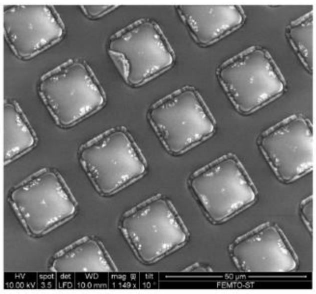
The structures were then characterized by using profilometer and SEM microscopy.

Within this work, two parallel approaches were developed:

- the first consists in etching on a glass substrate 3 µm deep square apertures with 5 to 15 µm lateral sizes and then depositing the filter in the hole before removing the photoresist, and then remove the photoresist in order to leave the non-etched parts of the substrate uncoated and repeat this procedure 3 times more.
- The second consists in depositing a first filter (the most complex), and then edge on the filter 3 µm deep square apertures with 5 to 50 µm lateral sizes, deposit a new filter in the hole before removing the photoresist, remove the photoresist in order to leave the non-etched parts of the substrate uncoated and repeat this procedure 2 times more.

In this paper we review the methods that have been implemented in order to make compatible both thin film deposition and Deep Reactive Ion Etching procedures. First results of the combination of these two distinct procedures are presented (Fig. 2) and further development and technological locks are presented.





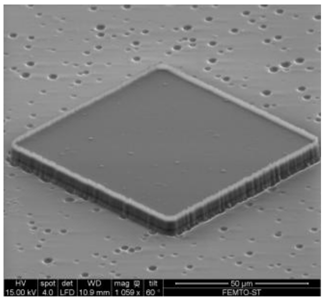


Figure 2. Examples of the combination of thin film deposition and RIE. A – example of an etched glass substrate before deposition, B – example of an etched glass substrate before deposition, C – example of an etched 31-layer filter after mask removal

ACKNOWLEDGMENT

This work was done within a CNES R&T funded project and has been supported by the french RENATECH network and its FEMTO-ST technological facility.

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