Deep reactive Ion Etching of Nb_2O_5/SiO_2 multilayer structures for multispectral imaging devices

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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 thin film 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 rotating filters wheel placed inside the imaging system. However, it is obvious that these rotating filters wheels are a bulky and heavy solution that make them non optimal solution for onboard applications. To overcome this problem, a solution is the fabrication of pixelated optical filters, similar to the Bayer filters used for color cameras but using specific thin film filters technologies (Fig. 1).

The approach that have implemented consists in combining thin film physical vapor deposition and Deep reactive Ion Etching (DRIE). The deposition of the filter was obtained by Plasma-assisted electron beam deposition using a Bühler SYRUSpro 710 machine. The depositions 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 in order to secure thickness errors within a few tenth of percent for each layer. 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 [1]. The filter was composed by 31 alternated Nb_2O_5/SiO_2 layers and the total filter thickness was 3.1 µm. The DRIE etching process was achieved on plasma ICP tool STS-APS equipment and the mask used for the plasma etching was Nickel (Ni) electroplated [2]. The Ni thickness was 4 µm. The ICP coil power was fixed at 1500 W, the bias power was varied and optimized at 300 W, and the chamber pressure was 6 mTorr. The temperature was set to 10°C and the gas ratio CF4/02/Ar was kept at 80 ccm /10 sccm/2 sccm. The process developed ensures to get anisotropic (vertical) profile of the multilayers and when reaching the glass wafer, the etching profile is also anisotropic but slightly tapered. Following the over-etch time, the average profile angle will change. In order to detect the end of etching of the multilayers, an optical emission spectroscopy system [3,4] (Jobin Yvon EV 140C) was used. An end point detection (EPD) recipe was designed and used to control the over-etch time as shown in the figure 2.

The structures were first observed using scanning electron microscopy (Figure 3).One can see that very sharp edges with close to 90° angle with the substrate surface are obtained using this process. Achieving such high anisotropy allows securing minimum diffraction on the edge of each of the pixels. In order to quantify this effect, the structures were then optically characterized using the system described in ref. [1]. This system, which is at the same time a spectrophotometer and a microscope allows a local measurement of the transmission of one pixel with a 2 µm spatial resolution and a 0.5 nm spectral resolution. Mapping of the local transmission in the spectral bandpass of the filter (i.e. 770 nm) of several consecutive pixels is shown in Figure 4. One can see that all the coated and uncoated regions of the pixelated filter transmit 100% of the light, except a narrow region surrounding each pixel with size of 1-2 µm, confirming that diffraction effects on the side of each pixel is minimum.

References:

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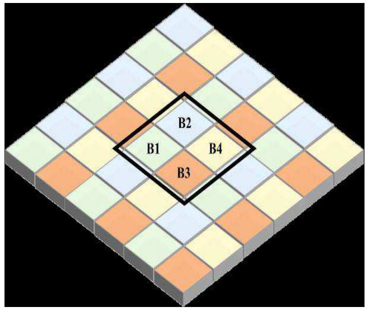

Figure 1. Example of 2×2 pixelated filter.

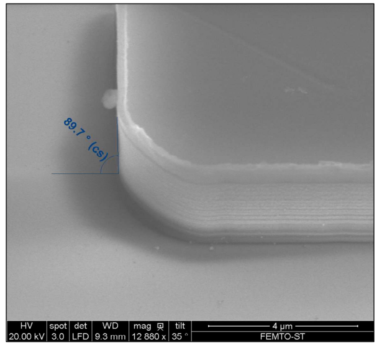

Figure 3. SEM cross section of etched Nb_2O_5/SiO_2 multilayer.

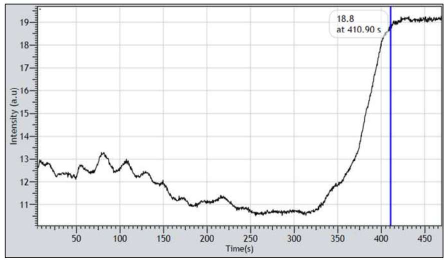

Figure 2. EPD detection of etching of the multilayers Nb_2O_5/SiO_2.

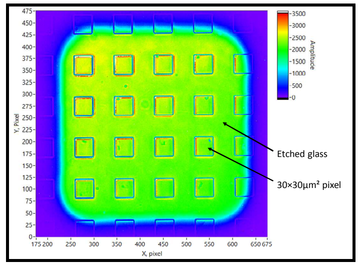

Figure 4. Transmission at 770 nm of a pixelated filters.