Optimized UV grayscale process for high vertical resolution applied to spectral imagers

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Nanocarb is a miniature Fourier transform imaging spectrometer based on the ImSpoc concept invented by ONERA and IPAG[1]. It is developed within the framework of the European project Scarbo aiming at the measurement of greenhouse gases (CO_2 and CH_4) from a constellation of small satellites. The key element of the NanoCarb spectral imager is an array of Fabry-Perrot micro-interferometers that has a stepcase shape as illustrated on figure 1. Lateral dimensions and heights of each steps depend, among others, on the used material, the focusing lenses and the partial interferogram to be measured[2]. Resist patterning by grayscale lithography, combined to a plasma etching step, is an efficient and quick way for the realization of such arrays into silicon. E-beam grayscale lithography is well known to be able to provide the required high resolution (a few tens of nm) along the vertical direction[3], but is not compatible with the lateral dimensions of each interferometer (hundreds of microns). The conventional UV exposure is more suitable for the patterning of such large surfaces, but it is less adapted for sub-100 nm vertical resolution.

The purpose of the current work is to develop a UV greyscale lithography process combining large surface patterning with high vertical resolution. We used a laser lithography equipment (Heidelberg µPG 101) with a modulation of beam power. A low contrast resist (Ma-P1225G) supplied by Micro Resist Technology^{GmbH} was used for a better control of the step height. Its processing method was optimized in order to decrease the contrast curve slope. For instance, the impact of its Soft Bake (SB) and Post Exposure Bake (PEB) annealing conditions on its contrast curve was investigated. The results illustrated on figure 2 show that a higher SB temperature decreases the resist contrast probably in reason of a densification of the resist polymer. In order to transfer the as-obtained resist patterns into the silicon substrate, a plasma etching process using Cl_2, He/O_2, HBr chemistry was developed and will be described at the conference. Its selectivity was shown to be equal to 2.5. The preliminary results depicted on Figure 3 demonstrate that the combination of both processes can lead to step heights on the range of 50nm as required by the Nanocarb design.

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[1] N. Guerineau et al. Fourier transform multi-channel spectral imager. FR2019/051777.

[2] S. Gousset et al. *International Conference on Space Optics—ICSO 2018* vol. 11180 111803Q (International Society for Optics and Photonics, 2019).

[3] J. Kim et al. *Microelectron. Eng.* **84**, 2859–2864 (2007).

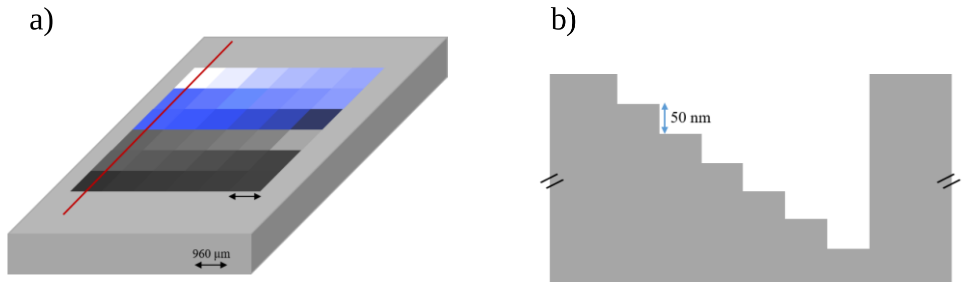

Figure 1: (a) Illustration of 2D micro-interferometers array of 960*960µm² each elaborated in a silicon substrate, (b): cross section along the red line showing the targeted typical step height

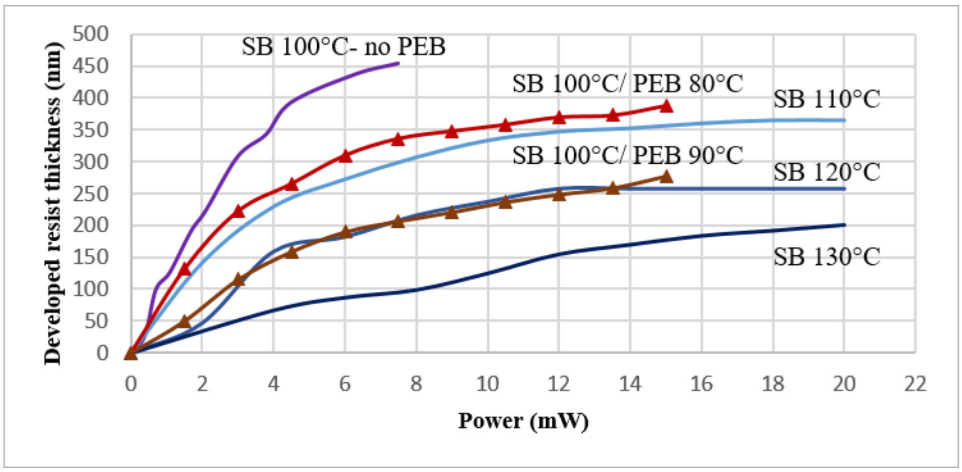

Figure 2: Improvement of the contrast curve using various SB and PEB conditions in a 460 nm thick Ma-P1225G resist film. Additional impact of the PEB on the resist morphology was investigated by FTIR analysis and will be detailed at the conference venue

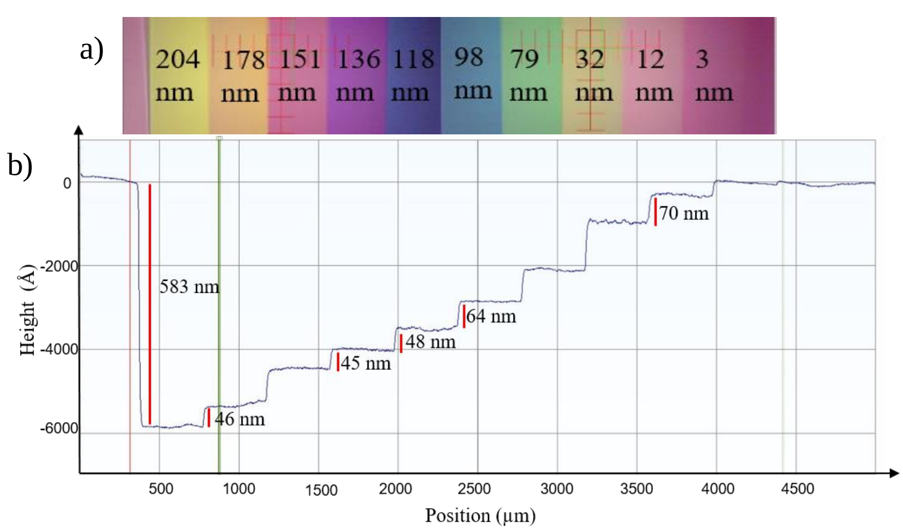

Figure 3: (a): heights (in nm) and optical microscopy image of 10 strips patterned in the resist with various power exposure ratios, (b) the profile obtained by etching those resist patterns into silicon.