Multistep Aztec profile by an iteration process using 3D electron beam lithography for angle resolved micro-spectrometers

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Miniaturized opto-components such as micro-spectrometers are of important applications in environmental monitoring, bioscience and technology, agriculture and space science, etc. In this work, we propose to develop an angle resolved spectrometer using multistep surface-relief structure, Aztec profile as a wavelength selector, as shown in figure 1. According to our theoretical calculation, the step height decides the wavelength range of the spectrometer either in optical frequencies (step-height ~250 nm) or near-infrared ones (step-height ~500 nm), which can be readily achieved by the modern 3D electron beam lithography technique, as have been substantially reported. However, in our work, we recognized four key technical challenges to be overcome before such a novel chip-based micro-spectrometer can be accepted for commercialization, i.e. influence of proximity effect, step flatness, the surface roughness and the accuracy of the height.

To achieve precisely defined multi-steps without the influence of proximity effect, both contrast curves and dissolution rates with different developing times on a 1.3 μm thick PMMA (MW 350K) coated on a Si wafer were first measured (figure 2). With the dissolution rates measured, Monte Carlo simulation using GenlSys issued BEAMER was then carried out to calculate charge distributions in the resist according to the designed multistep configuration. Figure 3 shows the simulated charge distributions, which were used as exposure dose by a JEOL6300FS beam-writer at 100 keV with a 7-nm e-beam. The resultant Aztec patterns were carefully characterized by atomic force microscopy (AFM) as well as step profiler, delivered by Bruker. The discrepancies between the designed plateaus and resultant ones, in association with flatness, roughness and height accuracy, were used to modify the dose function for the next exposure. By such an iteration process, well defined multi-steps can be reliably achieved, as shown in both figure 4 and 5. The step height in this particular case is 50 nm. Figure 4 presents the optical image of the Aztec pattern, showing very smooth and flat steps. The uniform color on each step reflects the smooth and flatness achieved. Angle resolved spectra are currently being characterized in our lab. Further results shall be reported in the conference. By summary, we have developed an iteration process of 3D greyscale electron beam lithography, aided by Monte Carlo simulation to replicate well defined multi-step Aztec structures for spectral applications. The iteration procedure developed in this work enables us to achieve well defined multi-steps in PMMA, which is of application prospects in multidisciplinary areas.

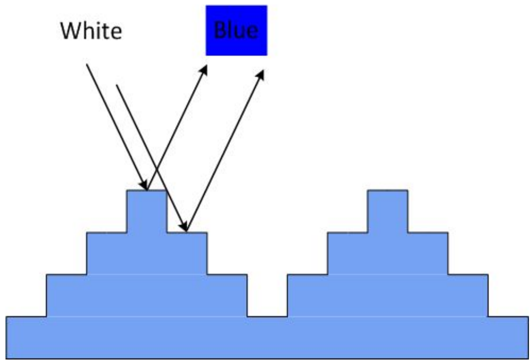

Figure 1: Aztec profile structure as a wavelength selector for micro-spectrometer

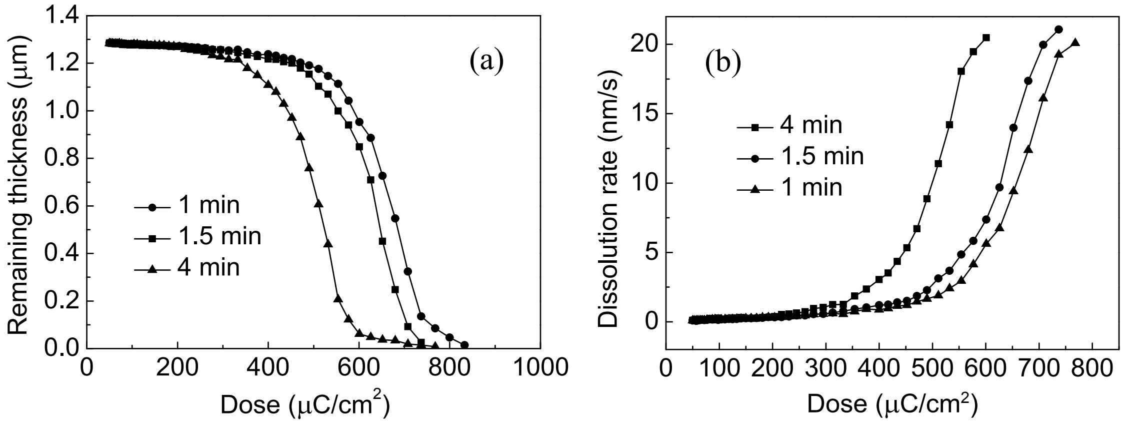

Figure 2: (a) Contrast curves and (b) dissolution rates of 1.3μm-PMMA with different developing time

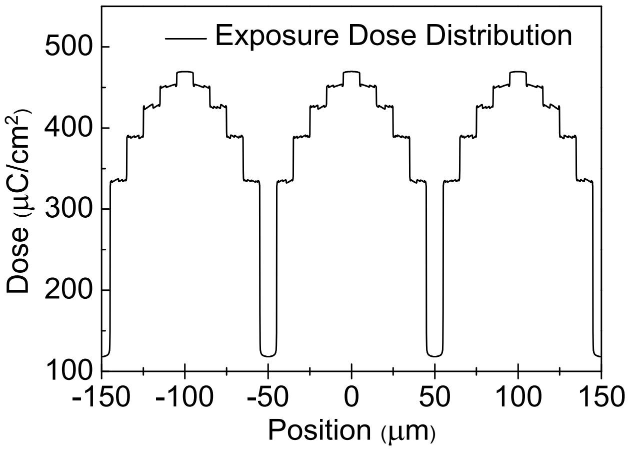

Figure 3: Exposure dose distributions simulated by Monte Carlo simulation

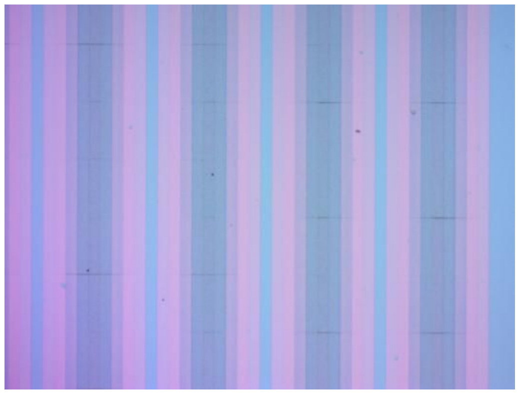

Figure 4: Optical image of the fabricated Aztec pattern

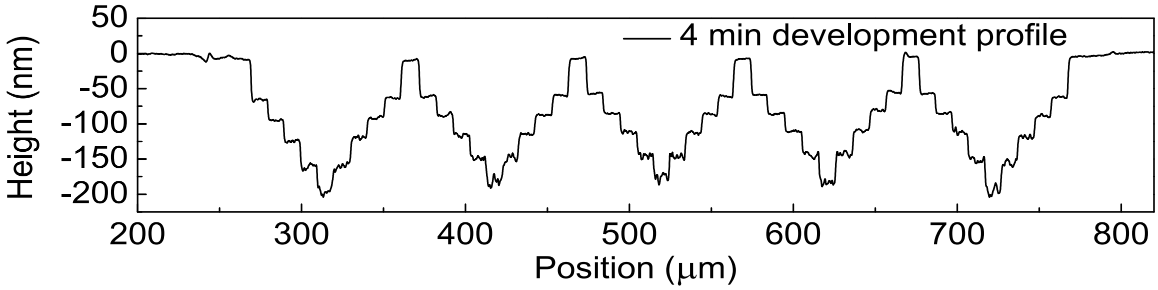

Figure 5: Aztech profile on PMMA resist measured by Bruker step profiler