Nano Pattern Transfer into Si and ITO using masks made by Electron Beam Induced Deposition

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Resist-based electron beam lithography does not routinely provide sub-10nm resolution. The project Single Nanometer Manufacturing for beyond CMOS devices (SNM)[1] aims at achieving that, using Nano Imprint Lithography (NIL). NIL stamps can be fabricated using Electron Beam Induced Deposition (EBID), by transferring a lithographically defined pattern into the stamp material. To gain some experience in the pattern transfer of sub-10 nm features, we study the pattern transfer into Silicon of masks made by EBID. We have used different plasma etching recipes based on hydrogen bromide, chlorine and fluorine chemistries, that are known to etch Silicon. Etching was carried out using an Oxford Instruments Plasma Technology Plasmalab133 ICP380. The EBID masks were fabricated using the Platinum precursor ($MeCpPtMe_3$) in a FEI Nova Nano Lab 650 Scanning Electron Microscope, at 20 kV and 25 pA. A typical mask, shown in Fig.1a, consists of arrays of dots and sets of lines with width down to 8 nm and height of 0.5 nm. These patterns were successfully transferred into Si using SF_6/C_4F_8 chemistry, as shown in Fig.1b. The smallest lines had a width of 14.3 nm and height of 2.5 nm, approximately, resulting in a selectivity of 5. However, Step and Flash Nano Imprint Lithography (SFIL) requires UV transparent stamps[2], for which glass substrates can be used. To define mask patterns on glass wafers, using EBID a conductive and transparent top layer is needed to prevent charging effects. We used ITO as a conductive layer and the EBID masks, using the same Platinum precursor, consist of a set of 10 lines, as depicted in Fig.2a. The pattern transfer was carried out using CH_4/H_2 chemistry, that is known to etch ITO[3]. Argon is added to this gas mixture to prevent polymer film formation during the etching process. Fig.2b shows a SEM micrograph of the etched mask. The resulting selectivity was measured to be 1.5. Etching with BCl_3/Cl_2 chemistry provided a somewhat larger selectivity of about 2, where the EBID etch rate was measured to be 10nm/min and ITO etch rate 20 nm/min. An issue that still needs to be addressed is the surface roughness of the ITO, which is enhanced after etching, as seen in Fig. 2b. We will present more detailed results on the various processes we used.

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[1] We acknowledge support from the European Union under Grant Agreement No. 318804 - SNM

[2] L.J. Guo, Adv. Mater.19 (2007) 495-513

[3] D.Y. Kim, J.H. Ko, M.S. Park, N.-E. Lee, Thin Solid Films 516 (2008) 3512-3516

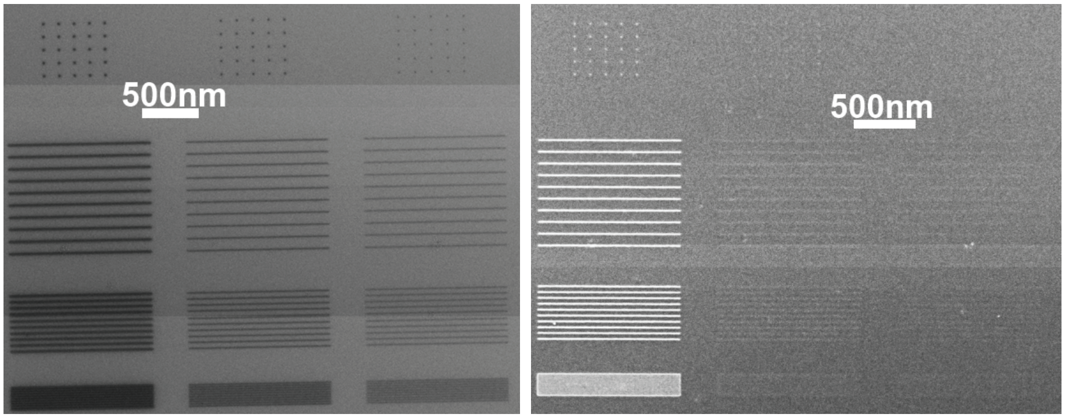

Figure 1: Left (a): SEM image of an EBID mask on Silicon, before etching, consisting of 3 array of dots (diameter of 20 nm, 13 nm and 7 nm) and 9 sets of lines (widths of 17 nm, 10 nm and 6 nm with 100 nm, 50 nm and 20 nm spacing). *Right (b):* SEM image of the mask after etching (SF_6/C_4F_8 recipe).

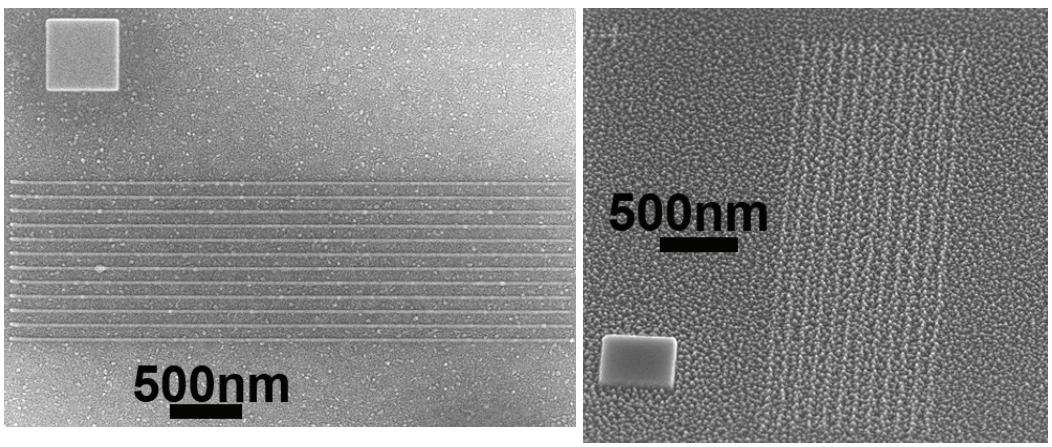

Figure 2: Left (a): SEM image of an EBID mask on ITO, before etching, consisting of a set of 12 lines, with width of 18 nm at 100 nm spacing. *Right (b):* 45° tilted SEM image of the mask after etching ($CH_4/H_2/Ar$ recipe). Notice the surface roughness.