Fabrication of PDMS micro-lens arrays on a PET film by proton beam writing

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Proton beam writing (PBW) has a potential as a versatile tool for deep micro-fabrication utilizing high-energy (~MeV) protons. Compared with conventional techniques such as electron beam lithography and focused ion beam, the unique features of the PBW include a capability in deep micromachining up to 100 μm and the high reactivity with various materials.

We have previously reported the formation of curved surface on silicon and silica glass substrates using an analog, negative-tone feature of polydimethylsiloxane (PDMS) against proton beam (PB).[1] In this study, we report fabrication of PDMS micro-lens arrays on a flexible film using PBW.

Samples used in this study are 13-μm thick PDMS layer on polyethylene terephthalate (PET) films obtained by spin coating of a base liquid of Sylgard 187 (Dow Corning Corp.). Proton beam writing was performed using a dedicated PB writer installed at the Center for Flexible Integration, Shibaura Inst. Tech. The PB writer is equipped with a doublet quadrupole lens system to focus the PB from a 1.0 MV single-ended accelerator down to submicron dimensions. After the exposure by PBW, development was made using a solution of THF–CH_3CN (8:2) for 2 min. at temperature of 60 °C.

Figure 1 shows contrast curves obtained for PDMS layer with a thickness on PET and ITO-coated PET film. The 13-μm thick PDMS layer on a PET film was insensitive to the PB fluence up to 100 nC/mm^2. Based on the hypothesis that the effective sensitivity of PDMS is affected by the surface conductivity of the PET film as previously discussed,[1] we used instead an indium tin oxide (ITO)-coated PET film. As a result, we were able to observe the remaining PDMS layer on the ITO-coated PET film at fluence of 5.0 nC/mm^2.

Figure 2 shows the arrays of PDMS micro lens with a height of 13 μm and diameter of 40 μm fabricated on an ITO coated PET film by PB exposure with varied fluence. We were able to fabricate the PDMS micro-lens arrays in an area of 1.0 x 1.0 mm^2. Smooth PDMS surfaces were obtained uniformly over the whole area. Application of an imprint lithography technique using a mold made from the PDMS master will be also discussed.

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[1] K. Saito, H. Hayashi, and H. Nishikawa, Nucl. Instr. Meth. Phys. B 306, pp.284-287 (2013)

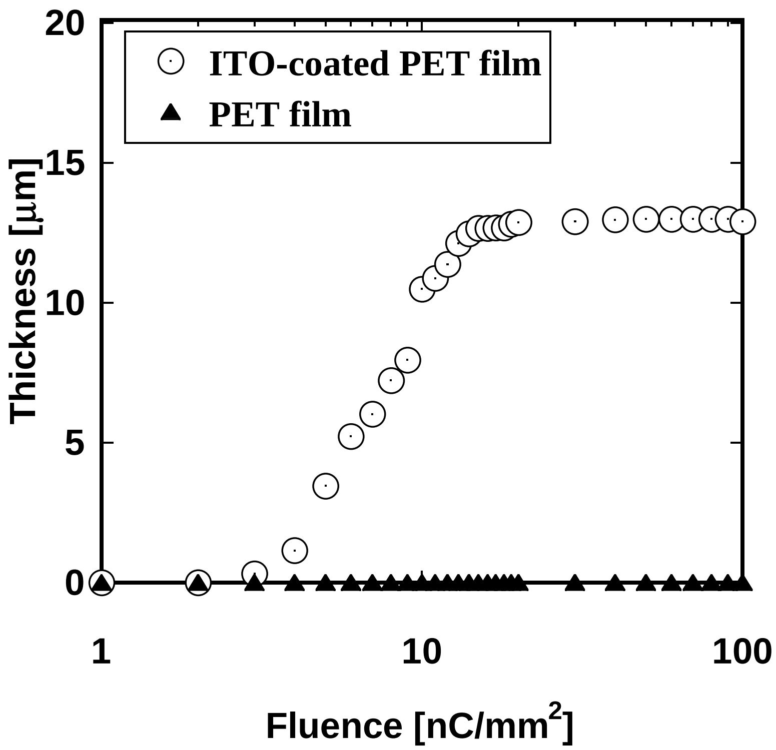
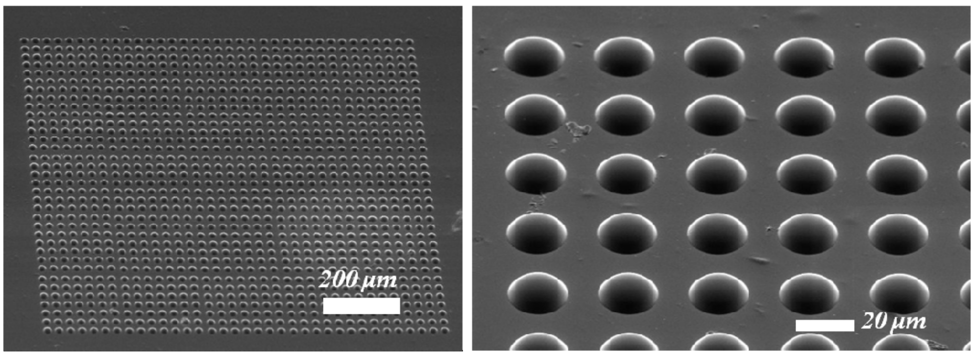


Figure 1: Contrast curves: Remaining PDMS thickness after the development as a function of PB fluece (1.0 MeV). The data for the PDMS layer on a PET film and the one coated with ITO were compared.



(a) Overall image (b) Magnified image

Figure 2: SEM images: PDMS micro-lens arrays fabricated in an area of 1 x 1 mm^2 on the ITO-coated PET film by PBW at 1.0 MeV with varied fluence from 5 to 15 nC/mm^2.