Nanoimprinting of micro-optical components fabricated using stamps made with Proton Beam Writing

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Aim of the project

The contractor shall investigate the process of nanoimprinting in combination with proton beam writing (P-beam writing) with Ni electroplating for the replication of optical components in polymer substrates through nanoimprinting.

Scientific achievements

Three papers have been submitted to the 2nd international workshop on P-beam writing [1-3] (July 2006, Singapore) which require extensive use of the UV exposure machine bought through this project. The first two projects are focused on the fabrication of Ni stamps for optical applications for micro-lenses and waveguides with integrated gratings in multilevel Ni stamps. The last part is focused on general improvement of the p-beam writing process. Here we present an optimized way to fabricate superior resolution standards for P-beam writing, greatly reducing the time to fabricate these standards. Next a brief description of these three projects will be given

I Polymer microlens replication by Nano Imprint Lithography using proton beam fabricated Ni stamps

It is essential to have a simplified and a rapid method for fabricating micro/nano structures in different kinds of polymeric materials. Though it is possible to fabricate arrays of microlenses directly by P-beam writing [4], it is restricted to only a few types of resist materials. Therefore, we have fabricated a Ni electroplated metallic stamp comprising arrays of inverse/negative features of microlenses, spherical as well as cylindrical in shape, for rapid prototyping of arrays of microlenses. The metallic stamp is made on a silicon wafer coated with 8μm thick PMGI resist and the desired structures are written by P-beam writing followed by thermal reflow and Ni electroplating. A Ni stamp featuring a set of inverse/negative microlenses (100μm diameter) is shown in Figure 1a. An array of microlenses is imprinted in a polycarbonate (PC) substrate by the Nano-Imprint-Lithography (NIL) technique and the replicated microlenses featuring various numerical apertures, diameters and pitches are characterized. Note that with p-beam writing it is not possible to fabricate these lenses in PC. In figures 1b and 1c replicated microlenses are shown, they are of similar quality compared to direct p-beam written microlenses in either PMGI of PMMA. We can see that the light can be nicely focused (1b) using these imprinted microlenses in an optical microscope.

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14. ABSTRACT
Investigation of the process of nanoimprinting in combination with proton beam writing with Ni electroplating for the replication of optical components in polymer substrates through nanoimprinting.

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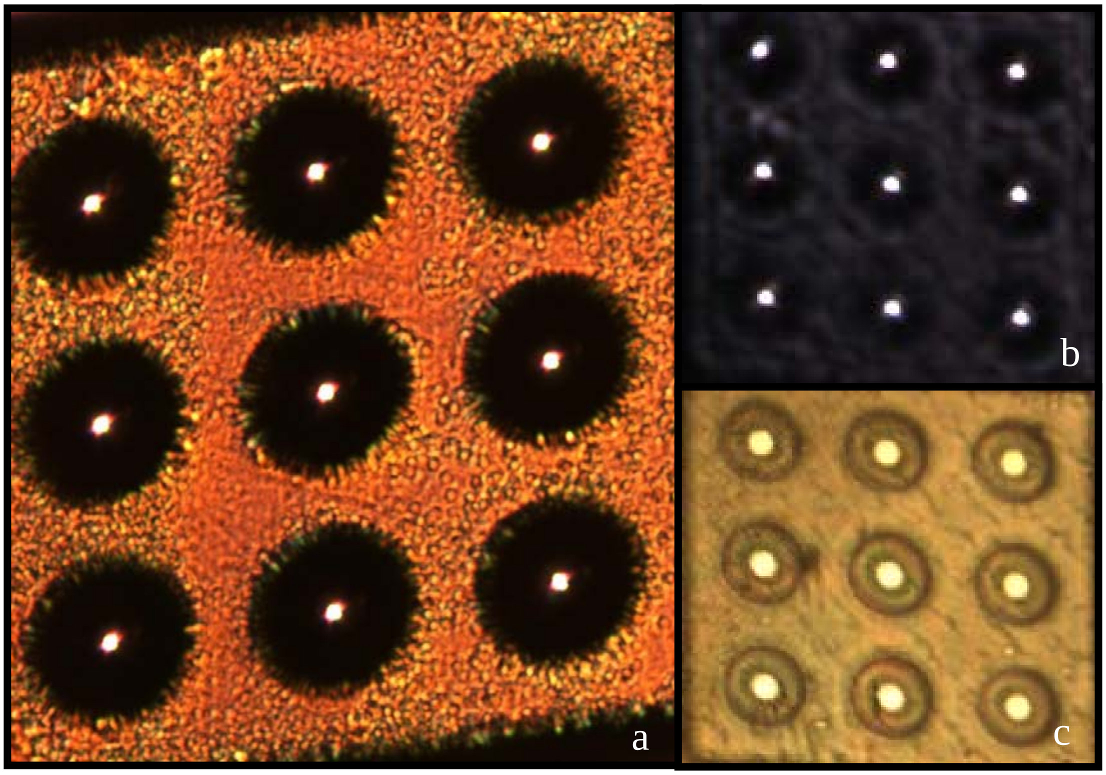

Figure 1a Ni stamp produced using P-beam writing in PMGI and electroplating for microlens replication through nanoimprining. Imprinted microlens arays (1b,1c) in Poly carbonate (PC) featuring 100 μm diameter microlenses.

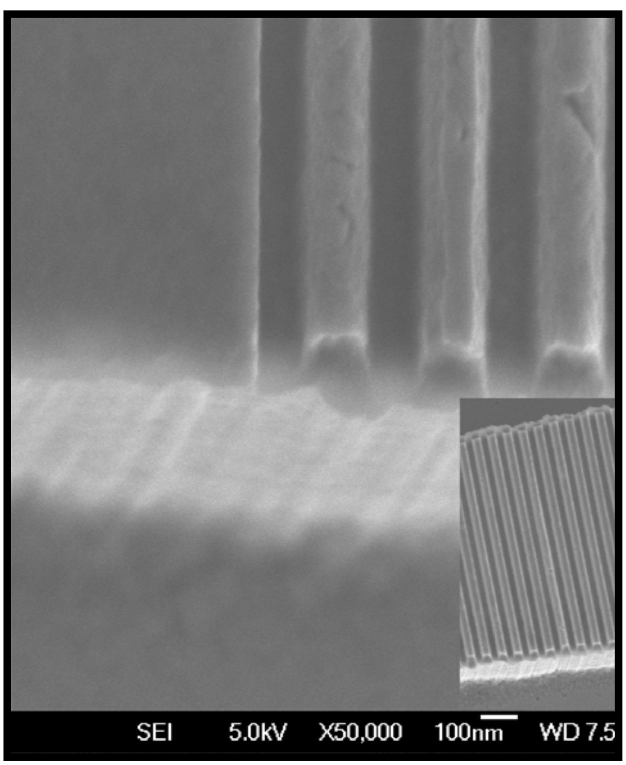

Figure 2 P-beam written multilevel Ni stamp for grated wave guides.

II Fabrication of multilevel Ni stamps featuring waveguide gratings

Fast prototyping of nanostructures on various types of substrates for optical, mechanical and electrical devices is feasible by Nano Imprint Lithography, which demands a metallic stamp with desired features. For the modulation of signals in a waveguide, grated waveguides can be used. Here, we show the fabrication of a multilevel metallic Ni stamp for replication through nano imprinting. The gratings of uniform repeating pitch (100 nm deep and 300 nm repeat) are patterned on a suitable resist on a silicon wafer by P-beam writing. In a next step the waveguides, perpendicular to the gratings, are written in 4 μm thick PMMA resist. A metallic stamp of this multilevel structure is made by Ni Sulfamate electroplating.

III Fabrication of free standing resolution standards using proton beam writing

The need for a smaller beam size has been driven by the goals of producing nano structures using P-beam writing, and also increasing the spatial resolution for ion beam applications (e.g. PIXE, RBS, IBIC, etc) to nano-dimesnsions. Thus, it is vital to have a resolution standard which has a high degree of sidewall straightness. Potentially P-beam writing, as a true direct-write 3D micromachining process, is an ideal way to produce free standing resolution standards with precise edges and straight sidewalls [5].

The main focus of this work is to show a process for fabricating free standing Ni resolution standards with a thickness of 2 µm. A 3-4 µm thick PMMA layer was spin coated on to a Si wafer which was previously coated with a thin layer of Cr, Au and Cu. The Cr, Au layers were added to enhance the adhesion of the Cu layer to the Si substrate which was not the case in earlier experiments [6]. The large area support structure for the grid was patterned using 248nm UV exposure through a patterned Ti layer on a UV transparent quartz slide. In the centre of the support structure we used proton beam writing to fabricate a grid with features down to 400nm, see figure 3a. Ni Sulfamate electroplating was performed to fabricate the 2 µm thick Ni grid from this pattern, see figures 3b and 3c. The release of the Ni grid from the Si wafer was improved by using a Cu etching solution which does not etch Ni [6]. Fabricating these Ni grids using two exposure methods (DUV and PBW) allow faster production of these resolution standards.

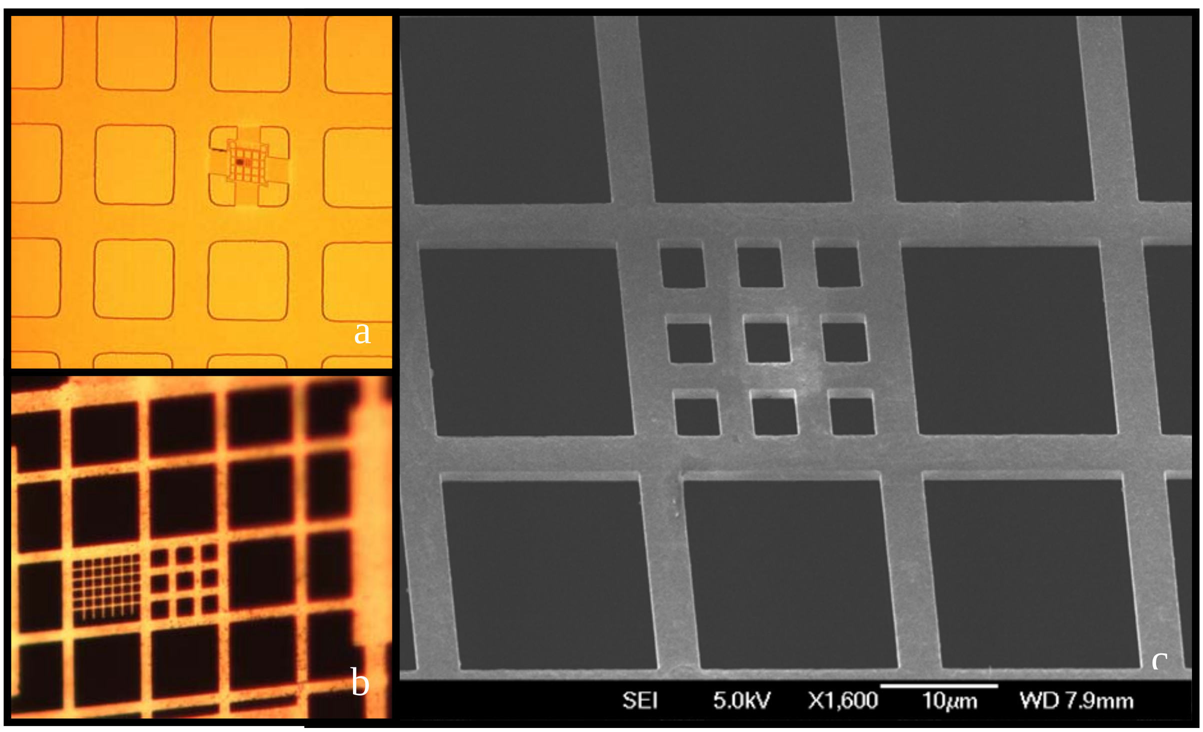

Figure 3a, combination of P-beam writing and deep UV exposure (248 nm) for the fabrication of details in PMMA from 200 µm down to the 400 nm level. In 3b and 3c the electroplated Ni grid after release is shown.

Summary

We have shown two examples of P-beam fabricated Ni stamps; one for microlenses which were imprinted in PC. The imprinted lenses show similar quality compared to direct P-beam written microlenses, demonstratin easy microlens fabrication in different polymers using nano imprinting. In the second example we demonstrated, for the first time the fabrication of Ni moulds for multilevel grated waveguide replication through nanoimprinting. The last example shows the combination of DUV lithography and P-beam writing which allows fast fabrication of high quality resolution standards. These standards allow improved proton beam focusing down to 29 nm [6]. Because of the easy fabrication, these new resolution standards are now routinely used in P-beam writing experiments. In the near future we will supply these standards to other labs around the world.

The results of this work will be presented at the 2006 ICNMTA conference (Singapore), at this conference full length papers will be submitted for publication in refereed journals.

References

1. ***Polymer microlens replication by Nano Imprint Lithography using proton beam fabricated Ni stamps***, R.K. Dutta, J.A. van Kan, A.A. Bettiol, F. Watt, submitted to the 2006 ICNMTA conference, Singapore.
2. ***Fabrication of multilevel Ni stamps featuring waveguide gratings***, R.K. Dutta*, J.A. van Kan, A.A. Bettiol, F. Watt, submitted to the 2006 ICNMTA conference, Singapore.
3. ***Fabrication of free standing resolution standards using proton beam writing***, F. Zhang, J.A. van Kan, F. Watt, submitted to the 2006 ICNMTA conference, Singapore.
4. ***A progress review of proton beam writing applications in microphotonics***, A.A. Bettiol, T.C. Sum, F.C. Cheong, C.H. Sow, S.V. Rao, J.A. van Kan, E.J. Teo, K. Ansari, F. Watt, Nucl. Instr. and Meth. B 231 (2005) 364-371.
5. ***Proton beam micromachined resolution standards for nuclear microprobes***, F. Watt, I. Rajta, J.A. van Kan, A.A. Bettiol and T. Osipowicz, Nucl. Instr. And Meth. B. 190 (2002) 306.
6. ***Fabrication of a new free standing resolution standard for focusing MeV ion beams to sub 30 nm dimensions,*** J.A. van Kan, P.G. Shao, P. Molter, M. Saumer, A.A. Bettiol, T. Osipowicz and F. Watt, Nucl. Instr. And Meth. B. 231 (2005) 170.

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