Optimum dose distribution for Argon ion multi-beam sputtering of microlens array templates

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The ion multi-beam tool, developed as part of the European project CHARPAN (Charged Particle Nanotech[1]) performs beam sputtering with thousands of focused beams in parallel. Among other tasks the tool is intended for 3D patterning. In case of ion beam etching the main difficulty of the nontrivial 3D problem is the dependence of the etching rate on the inclination angle. The report is devoted to the description and implementation of a new approach to solve the ion beam inverse etching problem based on a model of isotropic local etching which was first developed and exploited for *liquid etching*. An algorithm of inverse 3D etching with ion multi-beams was developed. As practical task the fabrication of 10 x 10 arrays of *square* microlenses using about 250-thousand 10 keV Argon ion beams of different size was chosen for verification of the isotropic local etching approach. Fig.1 shows calculation of optimal ion dose for lens array.

Fig. 2 shows the difference between ideal lens profile and simulated profile. Calculations were performed with dose distribution from Fig.1 using rigorous Ionshaper® simulator[2], which considers ion re-deposition neglected in the isotropic local etching model. For 85% of the microlens area the optimum ion beam dose distribution coincides with the target profile to 5nm accuracy.

To compare the isotropic local etching model with experimental results, 10x10 arrays of square convex and concave microlenses (Fig. 3a-c) were designed with 2.2 µm lens edge and height up to 0.57 µm. For these configurations the optimum ion beam dose distribution D_{il} (Fig.1) was calculated using the isotropic local etching model. SEM and AFM images of 10x10 microlens arrays fabricated with the CHARPAN tool are shown in Figs. 3a-c. There is good agreement with the target profile confirming the usefulness of the isotropic local etching model to fabricate predefined "shallow" 3D structures.

In spite of the fact that the isotropic local etching model has been developed for *liquid* etching it can be successfully applied to ion beam *dry* etching, opening a way to solve the inverse problem of 3D ion beam patterning

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[1] www.charpan.com

[2] www.ims.co.at

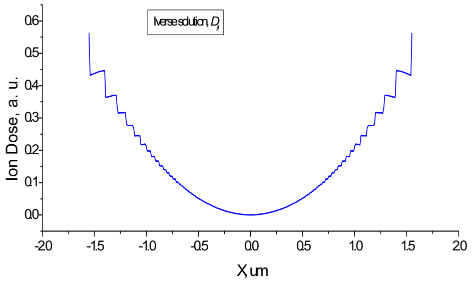

Fig. 1: The optimum ion beam dose distribution D_{il} calculated with the model of isotropic local etching. The sharp steps are inherent features of the inverse etching problem.

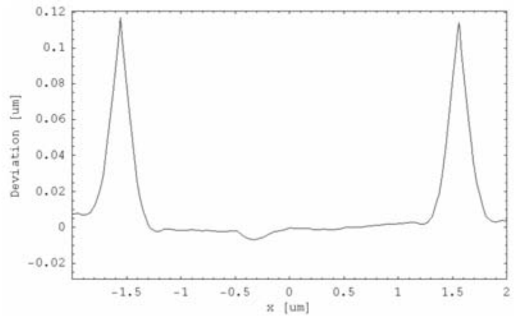

Fig. 2: Difference of designed and Ionshaper® calculated profiles. The difference is less than 5nm for 85% of the microlens area.

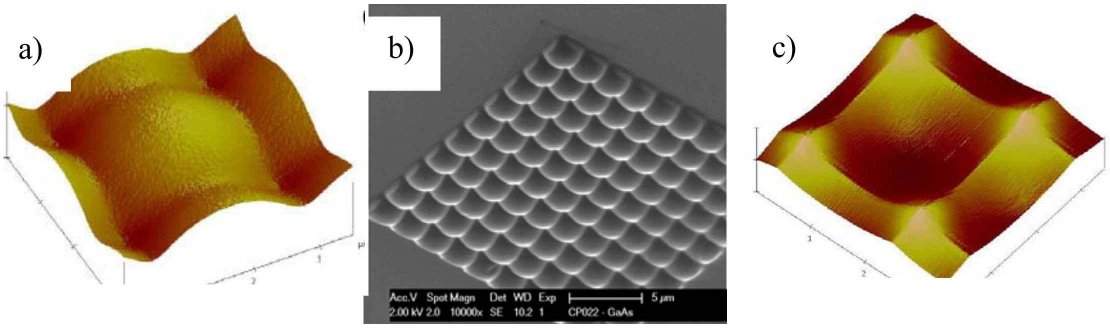

Fig. 3: 10x10 array of square microlenses fabricated by CHARPAN tool patterning with ~ 250,000 Argon ion beams (of different size) in parallel of 10 keV energy: a) concave microlenses on Si surface, b) and c) convex microlenses on GaAs surface.

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