Nanofabrication by means of selective chemical etching enhanced by irradiation with a focused helium ion beam.

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Ion implantation is a widely used procedure in nanotechnology and microelectronics for material treatment. One of the promising applications of this processing is a defect engineering accompanied by material properties modification [1]. In this field a technique of local ion irradiation with a focused ion beam is of special interest. A helium ion microscope (HIM) with a gas field ion source is still a unique and perspective instrument for these tasks as it possesses a higher spatial resolution than a conventional microscope with a liquid metal ion source can possess, and inert ions do not interact chemically with the sample [2]. We have demonstrated earlier that HIM allows us to change the local chemical etching rate of SiO_2 in a water solution of hydrofluoric acid [3]. This means that patterning by a focused ion beam can be developed as a resistless lithography technique that provides novel opportunities for the fabrication of nanostructures. However ion-matter interactions and scattering events should be considered in this method, since ion-induced defects are distributed not only inside the volume under the irradiated area but also in some vicinity outside it.

In this work we investigate chemical ion beam enhanced etching between irradiated areas occurring due to the ion scattering in the sample bulk. During the experiment we irradiated closely spaced pairs of rectangular areas. The separation distance in pairs, the ion fluence and the area size in transverse direction were varied. Experimental results obtained, numerical calculations based on the Monte-Carlo simulation of ion-matter interaction [4] and our etching model [5] illustrate the possibility of the formation of nanostructure such as a nanostring due to the overlapping of ion-matter interaction volumes from neighboring irradiated regions (figure 1). Besides the nanofabrication, the method described in this work also suggests some consideration of the fundamental problem of secondary electron contrast interpretation in SEM which was raised earlier in [6].

All experimental results were obtained using the equipment of Interdisciplinary Resource Center for Nanotechnology of Research Park of SPbSU.

References

[1] Z.L. Wang et al., Nucl. Instr. Meth. Phys. Res., B 115 (1996) 421–429.
[2] G. Hlawacek et al., Helium Ion Microscopy, NanoScience and Technology (2016).
[3] Yu.V. Petrov et al., Nucl. Instr. Meth. Phys. Res., B 418 (2018) 94-100.
[4] J.F. Ziegler et al., Nucl. Instr. Meth. Phys. Res., B 268 (2010) 1818–1823.
[5] Yu.V. Petrov et al., Nanotechnology, 31 (2020) 215301 (9pp).
[6] M.T. Postek et al., Wiley Periodicals, 33 (2011) 111–125.

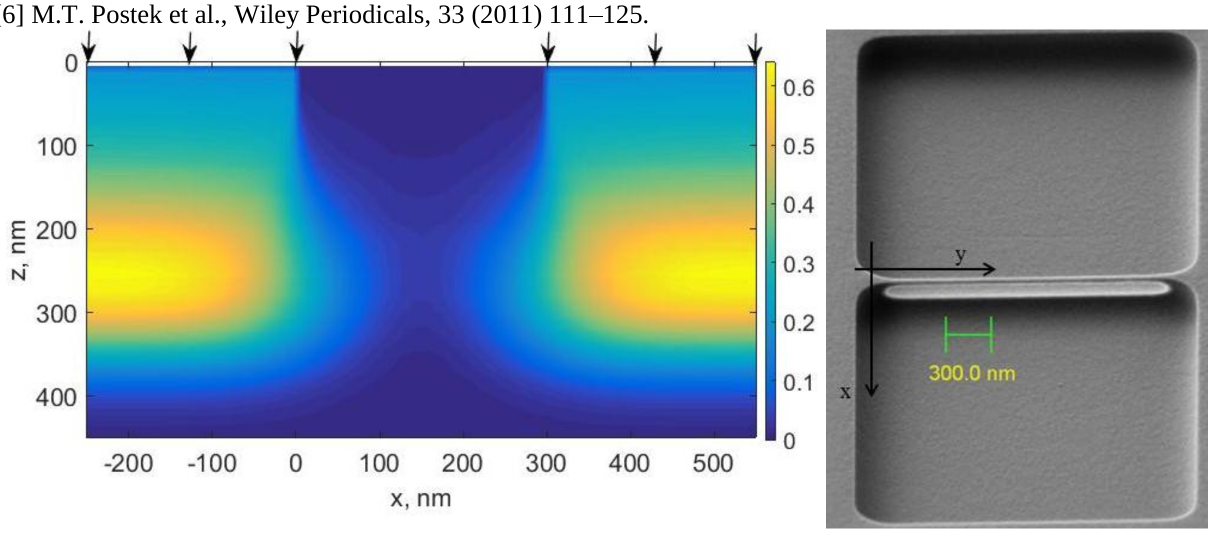

Figure 1. (a) Map of calculated ion-induced defects concentration, there is a slight overlapping between the irradiated areas (arrows on the top show the ion beam); (b) 45-deg tilt SEM images of neighboring areas after under etching through the wall of the volume with overlapping of defects.