Gratings with Extreme Aspect Ratios for X-ray Phase Contrast Tomography at High Energies

J. Mohr[1)], V. Altapova[2)], T. Baumbach[2)], T. Grund[1)], J. Kenntner[1)], I. Zanette[3)], T. Weitkamp[4)],
[1,2)]Karlsruhe Institute of Technology, [1)]Institute of Microstructure Technology, [2)]Institute of Synchrotron Radiation, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany
[3)]European Synchrotron Radiation Facility, Grenoble, France
[4)]Synchrotron Soleil, Gif-sur-Yvette, France
Corresponding E-mail: juergen.mohr@kit.edu, Phone: +49 721 608 24433, FAX: +49 721 608 24331

X-ray phase contrast imaging based on grating interferometry has gained a lot of interest in the last years due to impressive contrast enhancement for low absorbing materials. Among the different phase contrast methods, the recently developed interferometric method based on the Talbot effect does not need a coherent source as long as a grating is used which generates an array of small sources with a size which fits to the geometry of the Talbot interferometer. This opens up the possibility to use grating interferometry for application with conventional X-ray tubes, which makes it interesting for medical applications and in materials X-ray analysis also on an industrial level. With the grating interferometer, three images are generated in parallel: absorption contrast image, phase contrast image and dark field (small angle scattering) image. The last two images give additional information to the conventional absorption radiography. Combining the information of the three images can even give more detailed information.

The grating interferometer set-up at conventional X-ray sources consists of three gratings: source grating, phase grating and absorption grating. The qualities of these gratings have strong influence on the performance of a grating interferometer. Especially the absorption grating which is used to evaluate the interferogram requires high aspect ratio structures with grating periods in the range of a few micrometers only. In case of high energies the structures should have heights of more than 100 µm to achieve an acceptable visibility.

To fabricate these challenging structures we used Deep X-ray lithography to pattern a special adopted epoxy based resist for generating a polymer template, which is filled subsequently with gold by electroforming. It is obvious that resist structures with, e.g. 1.2 µm width and heights of 100 µm are not mechanically stable enough in the developer and electroforming bath. Therefore additional support structures had to be included into the design (see Fig. 1). Different variations of support structures were tested. Reinforcing column structures exposed at an angle of 45° with respect to the first exposure direction which generates the lamella structures tend to be the most successful solution. In this case grating structures with 2.4 µm period and heights of more than 100 µm could be easily achieved (see Fig. 2). The quality of the different gratings has been analyzed using synchrotron light for different energies. Whereas for small energies the grating quality dominates the resulting visibility, the height is more relevant in case of high energies as in this case the visibility is still limited. Nevertheless, for a photon energy of 52 keV we could demonstrate visibilitiy of up to 20%. Higher values can be expected by further process improvements.

In the talk we will describe the fabrication process and show the results on the visibility measurements, which qualify the gratings to be used also for high energy applications.

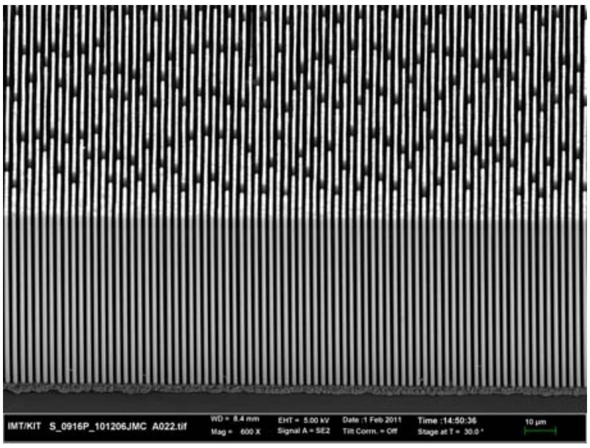

Fig. 1: Side view of an X-ray grating structure in metal with a height of 125 µm and a period of 2.4 µm. The spaces along the lamellas (dark spots) are the result of stabilizing bridges between the polymer lamellas acting as a template for electroforming.

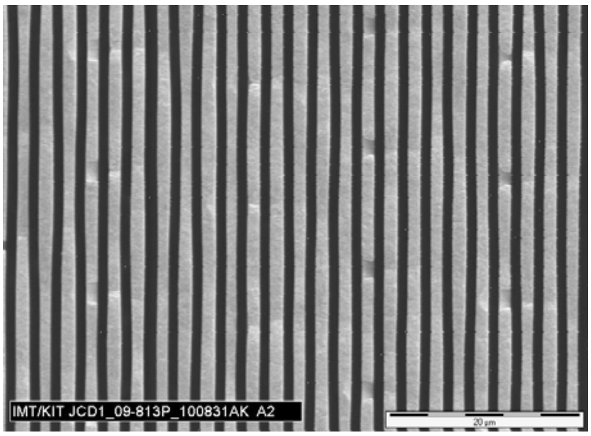

Fig. 2: Top view of an X-ray grating structure in metal which has been fabricated by electroforming using a polymer template with reinforced column structures (dots seen on top are starting points of the 45° columns in the polymer template).