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Microfabrication of X-Ray grating for Talbot Interferometry

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Introduction

X-Ray Talbot Interferometry (XTI) for phase contrast imaging was first demonstrated in the early 2000s by Momose et al. [1]. It has since gained interest due to its ability to work with restricted brilliance laboratory X-Ray sources, as opposed to highly coherent beam synchrotron facilities [2]. The technique requires the use of gratings placed along the beam path as illustrated in Figure 1. While the period and duty cycle of the gratings depend on the geometry of the setup, the quality of the final image and its contrast, depend on the height and the homogeneity of the phase-shift grating (G1) and the analyzer grating (G2). The analyzer grating G2, poses the most severe fabrication challenges. It is often fabricated using electrodeposition of gold in a prefabricated silicon mold. Although expensive, gold is an ideal absorber for X-Ray and can easily be electroplated. However, to achieve a complete absorber grating with this conventional method, several steps must be achieved hence, increasing the complexity of the fabrication process [3] [4].

X-Ray fabrication of grating using dry etch

Our general research goal is to obtain a good quality grating while focusing on the following points:

- Reproducibility of the fabrication process for industrial fabrication
- Reducing the fabrication complexity by reducing the number of process steps
- Evaluating the possibilities to pattern cheaper absorbing material (i.e. Tungsten)

In this project, we investigate the feasibility to structure an X-Ray grating using deep reactive ion etching (DRIE) of silicon. In our first approach to reduce complexity of the fabrication, we used a photoresist layer pattern of 3 µm lines with a duty cycle of 0.5 using standard UV photolithography. The resist was spun directly onto the silicon substrate. The optimized DRIE Bosch process creates a fluorocarbon (FC) layer deposited homogeneously along the sidewall of the trench. While the depth of the trench increases with the dry etch cycles, an FC layer is accumulating at the top of the trench as illustrated in the fabrication process in Figure 2. This protrusion allows for shadow masking the side-walls during thermal evaporation of gold in order to deposit a seed layer at the bottom of the trench allowing for later metallization by electroplating. SEM investigation confirmed the presence of a seed layer at the bottom of the trench and side-walls free of metal (see Figure *3*). The FC layer together with the resist and the metal are removed in acetone followed by oxygen plasma ashing, thus leaving a seed layer at the bottom of the groove for subsequent electroplating.

Results

In this work we are developing an absorbing grating using a method based on DRIE and using the FC layer naturally forming during the Bosch process. We demonstrate that FC can be used as a lift-off polymer after metal evaporation. The grating will be electroplated with highly X-ray absorbing material such as gold and tested in an X-Ray Talbot Interferometer.

Future tests in the development of absorbing gratings will involve the use of a similar Bosch process in order to pattern gratings with aspect ratio 1:10 into bulk tungsten, hence reducing the complexity of the fabrication.

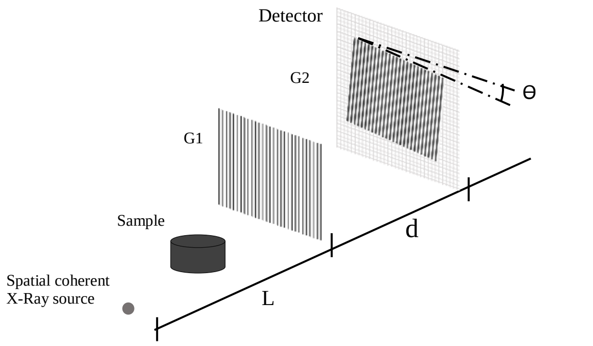

Figure 1. - Schematic of a laboratory setup of an X-Ray Talbot Interferometer. Grating G2 is tilted to an angle Θ to create Moiré fringes used for image analysis.

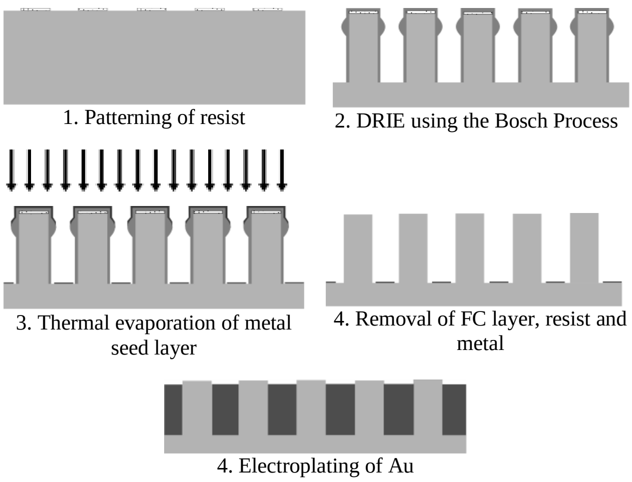

Figure 2. - Fabrication process to create analyzer grating using a FC layer from DRIE Bosch process. Aspect ratio 1:10.

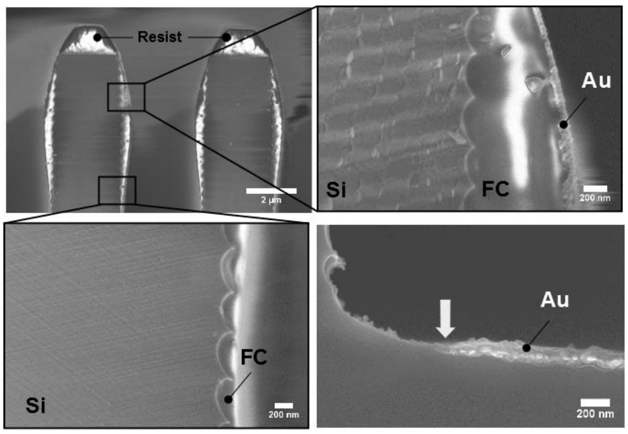

Figure 3. - Illustration of metal deposition on the FC layer. Bottom right image shows the limit (see arrow) of the metal deposition at the bottom of the trench.

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