Imaging onto Resist Film of Intensity Modulated Coherent Hard X-rays by Two Periodic Structures in Near Field Regime: Sectioned Multilayer Mask and Au Film Grating

Suyong Lee, In Hwa Cho, Jae Myung Kim, Hyon Chol Kang, and Do Young Noh

Department of Materials Science and Engineering, Gwangju Institute of Science and Technology, Gwangju, Korea

In near field regime, coherent light shows well-defined intensity distribution in space on account of diffraction by periodic structures with sub-micron pitch. For imaging them, spatial resolution of nanometer scale is needed so the current widely used 2-dimensional CCD detector is not appropriate due to its poor spatial resolution. Regardless of low photon sensitivity, photoresist is a good candidate as an imaging detector with its ~10nm spatial resolution. In this research, we have taken images of intensity modulated coherent x-rays propagating after periodic structures. Two different periodic structures, 'sectioned multilayer mask' in transmission geometry and 'Au grating film' in reflection geometry were tested.

Resist films were prepared by spin-coating ZEP520A-7 (Nippon Zeon Co., Ltd.) on Si(100) substrates. The average film thickness was 250nm. Subsequently, the prebake was carried out on a hot plate at 180 ℃ for 3 min. After x-ray exposure, samples were dipped in the developer (ZED-N50) for 75 s and then rinsed with IPA. To align and fine gap adjustment of the mask and the sample, our new apparatus was used, which consisted of sub-micron stages, several linear stages, fine angle adjustment stages and JJ ESRF slit with resolution of sub-micron. In this experiment, selected x-ray energy was 7.5 keV. The resulting nano-scale patterns were measured by FE-SEM (JEOL, JSM-7500F).

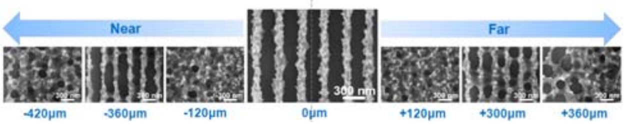

Fig. 1: SEM images of patterned resist films by modulated coherent x-rays passing through sectioned multilayer mask. Varying gaps between the mask and the resist film, talbot effect can be observed. Distance in the figure is from talbot distance(0μm) and beam propagates to the right.

As shown in Fig. 1, intensity modulations were recorded on the resist as coherent x-rays propagate after passing through a periodic structure, 'sectioned multilayer(WSi2/α-Si) mask'. The period (d) and the ratio of the thickness of the WSi2 layer were 300nm and 200nm, respectively. Talbot effect shown in the result is well-known diffraction phenomenon of periodic structure under illumination of coherent light. The noticeable fact is that the intensity profile at the exit of the mask repeats at the special distance called 'Talbot distance'. Experiments were done varying gaps by 60um from -420um to +360um relative to the Talbot distance. Thanks to the high flux monochromatic x-rays fine scanning varying both expose times and the gaps was available. Set the exit of the mask as z=0 um, the replicated image was observed at 1089 um coincided with the calculated Talbot distance. In addition to that, intensity modulations were observed with the beam propagation that is well fit to the simulated intensity profile. These results indicates high coherency of the x-rays used in this experiments. We expect that it can be exploited for fabricating under 50nm features with wider gap(for 100nm period, gap ~100 um) in the next experiments, which is under preparation to test using the 100nm period mask.

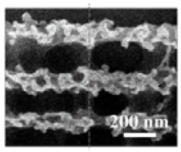

Fig. 2: SEM image of patterned resist film fabricated by exploiting x-ray total external reflection. Its average period is 280nm.

Figure 2 shows patterned resist film on which modulated intensity from Au grating film was printed when x-rays were incident on the film at near Au critical angle. The Au grating film was Au line (20um width) patterns with 40um pitch on Si substrate. The reflectivity from the substrate is about 10 times lower than that from the Au pattern when the incident angle is close to the Au critical angle (αc, Au ~ 0.52 deg. at 7.5keV). As we expected, projected lines on the resist surface perpendicular to that of grating film were observed and its average pitch was ~ 280nm (calculated value 279nm) at incident angle of 0.4deg. However, in the grazing-incidence setup there are prominent 1D line patterns under coherent x-ray illumination, which is caused by long range roughness in vertical direction to the film surface. These lines are considered as the main reason to deteriorate the uniformity of the pattern. Moreover, in near field regime, different paths of each Au lines play a significant role in analyzing intensity modulations. To be easy observation of the modulations, Au pattern is designed based on obtained pattern from the expecting simple and uniform intensity modulations.