Combination of E-Beam Lithography and X-ray Lithography on the Fabrication of Thick Nanostructured Devices

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The XRL is a potential process according to its high resolution, focusing depth and yield production. Thus it is applicable to fabricate structure with high aspect ratio, low surface roughness and vertical side wall, even the micro devices of 2 or 3 dimension. However, the difficulty on the hard mask fabrication still remains in doubt that obstructs its further progress. The XRL is always carried out by the proximity way for exposure rather than the projection to minification. As a result of the patterns are transferred to the resist with 1 to 1 ratio, the fabrication of hard mask has to be concerned carefully, namely the accuracy of origin patterns definition and patterns deformation during exposure. Subsequently the XRL plays an important role on lithography electroforming micro molding (LIGA) instead of high aspect ratio structure fabrication with nano scale.

In spite of the EBL does successfully pattern the very small line width (50nm) of the zone plate outermost zone, the yield is rather low and requires very expensive e-beam writer time. Therefore, the XRL seems to be the applicable process to replace EBL for later mass production of nano scale structures. With our successful definition of zone plate patterns, the well-controlled Au electroplating process does also successfully construct the metal zone wall as absorber of zone plate. Figure 1 shows the 1/4 zone plate patterns with aspect ratio about 4 (50nm outermost zone and 200nm altitude) after electroplating, in which the pattern is in accordance with the origin definition pattern by EBL. The high definition structure is able to be used as the hard mask for later XRL process for pattern transfer.

The XRL was carried out in NSRRC with BL19A beamline, where the applied beam energy is 800 to 2000 eV. Figure 2 is a SEM micrograph of the resist patterned by a XRL process, in which the applied dosage of x-ray is about 300mA·min. In Fig. 2, the 1/4 zone plate pattern can be clearly identified but with low resolution. Owing to the XRL is the proximity way for patterns transfer, therefore, the space exists between mask and resist that will results in the diffraction of incident x-ray according to the following formula:

$$P_{\min} = \alpha\sqrt{\lambda g}$$

where $P_{\min}$ is the minimum period, λ is the wavelength of x-ray, g is the proximity gap and α is a scaling parameter.

Finally the as-developed samples reveal patterns with low resolution comparing to origin mask patterns as shown in Fig. 1 and Fig. 2(b). According to the previous studies on XRL investigation, the demonstrated smallest line width is about 50nm with 150nm thickness resist. In our case, the patterns are able to be with smallest line width about 30nm (Fig. 2(b)), meaning that the line width smaller than 50nm is able to be demonstrated. However, the line period between each line is not in accordance with the origin hard mask that might result from the diffraction effect of x-ray and thick resist (200nm). Although the XRL process is with high definition hard mask, the gap between mask and resist still has to be decreased to reduce the diffraction effect. In addition, it is necessary to decrease the thickness of resist in order to enhance the resolution of transferred patterns. Briefly, we still successfully proof that the XRL is an applicable way on nano structure patterns transfer for later mass production.

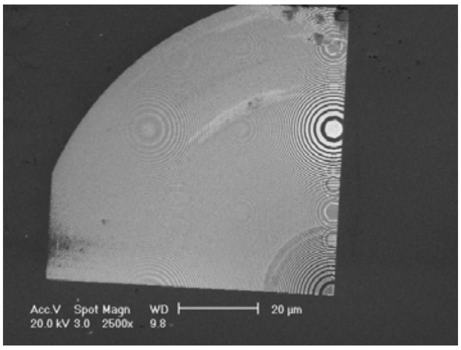

Figure 1. The SEM observation of Au electroplating on etched zone plate pattern.

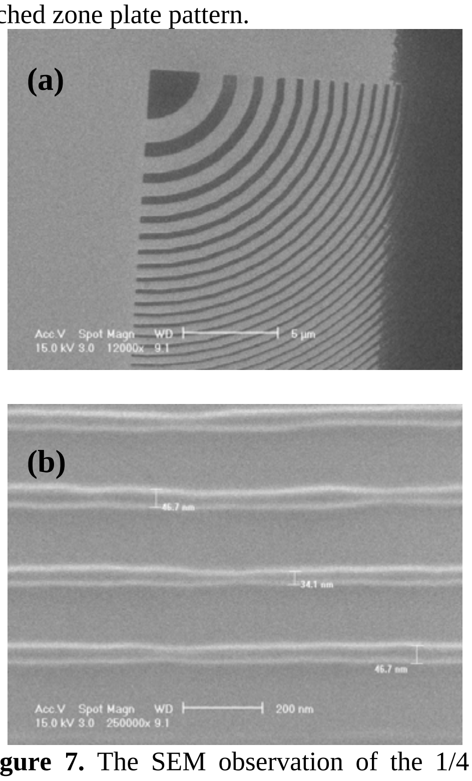

Figure 7. The SEM observation of the 1/4 zone plate pattern after X-ray lithography.