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Synchrotron Radiation Lithography and MEMS Technique at NSRL

LIU Gang, TIAN Yang-chao

(National Synchrotron Radiation Laboratory, University of Science and Technology of China, Hefei, 230029, China)

Abstract: Two beamlines and stations for soft X-ray lithography and hard X-ray lithography at NSRL are presented. Synchrotron radiation lithography (SRL) and mask techniques are developed, and the micro-electro-mechanical systems (MEMS) techniques are also investigated at NSRL. In this paper, some results based on SRL and MEMS techniques are reported, and sub-micron and high aspect ratio microstructures are given. Some micro-devices, such as microreactors are fabricated at NSRL.

Key words: synchrotron radiation lithography(SRL); MEMS; microreactors
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1 Introduction

The SRL includes soft X-ray lithography and deep X-ray lithography. The soft X-ray lithography is aimed at fabricating the sub-micron microstructure for the fabrication of quantum devices and the replication of deep lithography mask. The deep lithography is used to fabricate high aspect ratio micro-structure with sub-micron tolerance.

LIGA[1-2] (lithography, electroforming, molding) technology, in connection with deep X-ray lithography, plays an important role in micro-fabricating technologies. X-ray LIGA can offer a large, non-silicon choice of materials and better inherent precision, which has been already used for micro-mechanics, micro-optics and micro-hydrodynamics.

In this paper, the facilities for SRL at NSRL are presented. Some sub-micron and high aspect ratio microstructures and some micro-devices based on the SRL and MEMS techniques are reported.

2 Facilities for SRL at NSRL

There are two beamlines and experimental stations for soft X-ray lithography and deep X-ray lithography at NSRL. The soft X-ray lithography beamline with the wavelength range from 0.5 to 2nm was designed originally for sub-micron lithography. It is also used to replicate the deep X-ray lithography mask. The exposure area is 30×30mm^2.

The deep X-ray lithography beamline is under construction and will be operating in 2002. It is from an insertion device- 6T superconducting wiggler. The wavelength range is from 0.2 to 0.7nm after two beryllium windows, and the spectrum can be modified by different absorber films. The multiply exposure and complex microstructure can be developed at NSRL because the beamline has been installed a tiltable mask/resist carrier and an offline alignment with ±0.2μm accuracy. The exposure is operating in the 100mbar helium to reduce the thermal stress of mask.

3 Results of SRL and MEMS technique

3.1 Soft X-ray lithography

The mask technique for sub-micron lithography is developed at NSRL. The sidewall process[3] is employed in manufacturing SRL mask with a line

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-width of 50nm. The result of the soft X - ray lithography is shown in figure 1.

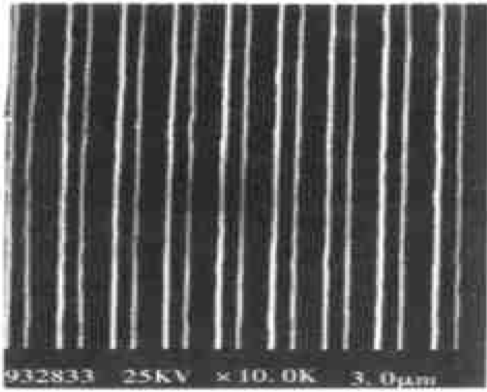


Fig. 1 SEM picture of 50nm lines

We have also carried out the soft X - ray lithography to fabricate T-type gate source of HEMT device. The pattern with width of 150nm was obtained on the positive photo-resist using multiply film technique. The microstructure is shown in figure 2.

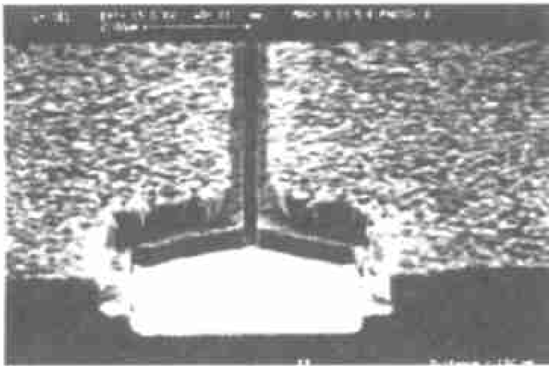
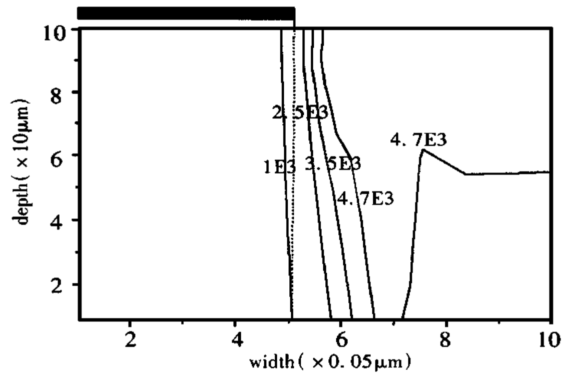


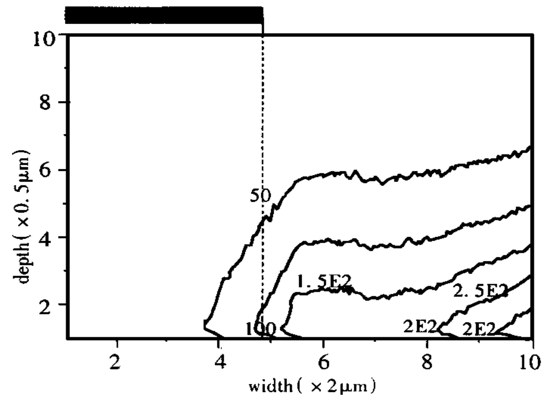
Fig. 2 SEM picture of type HEMT

3.2 Simulation and results of DXRL

Gauss function is constructed to simulate Fresnel diffraction effect on the accuracy in DXRL. When the exposure depth is 100μm, the change is less than 0.1μm. Along with the increase of the exposure depth, the change becomes large, but still under sub-micron. Monte Carlo model is constructed to simulate the photoelectronic effect. The result shows that the photoelectron's effect distance is no more than 5μm, and the exposure dose contributed by electrons is not large enough to effect the accuracy when the Si wafer is used. The result of simulation is shown in figure 3.



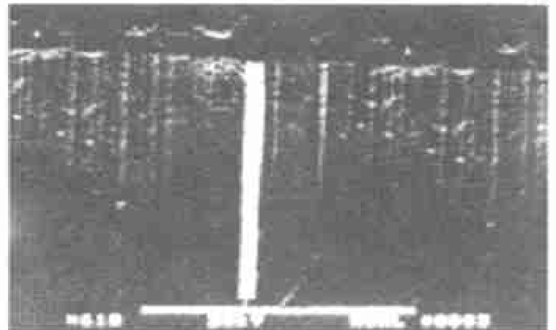
(a) Effect of Fresnel diffraction



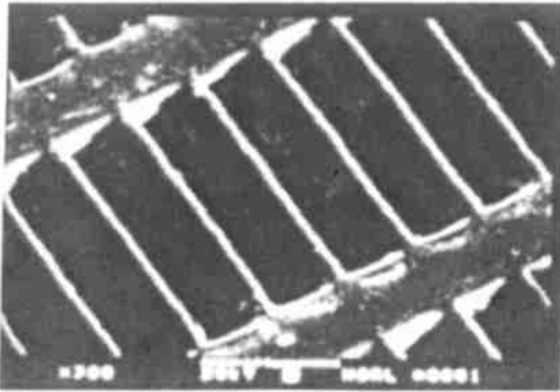
(b) Effect of photoelectron

Fig. 3 Simulation of DXRL at NSRL

The first DXRL results are shown in figure 4. The complex microstructures are fabricated by tilted and rotated lithography. The technique parameters of DXRL will be studied later.



(a) Line width: 5μm
Height: 150μm



(b) Tilted structure(45°)

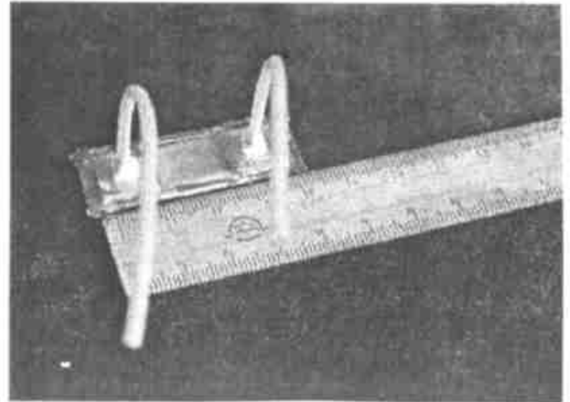
Fig. 4 SEM picture of DXRL

The results of simulation and DXRL show that the complex and high precision microstructure can be manufactured at NSRL.

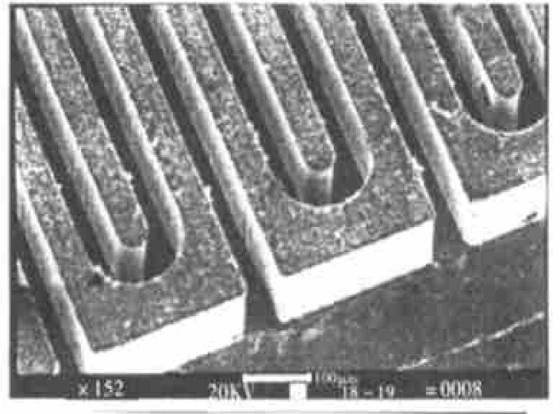
4 Study of MEMS techniques

The LIGA technique and relative MEMS techniques are developed at NSRL. The movable microstructures are fabricated by assembling technique and sacrificial layer technique. The tribology of microsystems is studied. A method[4] for improving the tribological properties of microsystems is developed.

Some micro- devices are fabricated at NSRL, such as acceleration sensors, fiber- clip couplers, Frensel zone plates, micro- flowmeters, microreactors[5], etc. The microreactor is shown in figure 5. The reaction acetaldehyde synthesized from ethanol with Ag as catalyst was demonstrated. Catalytic reaction works at 300℃. The result shows that the high flammable gas can be oxidized safely in the microreactor.



(a) Packaged microreactor



(b) Local part (microchannel)

Fig. 5 Picture of the microreactor

5 Conclusion

The SRL techniques are developed at NSRL. The sub- micron and high aspect ratio microstructures can be fabricated at NSRL. Some micro- devices are manufactured by the SRL and MEMS techniques.

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