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Activities of LIGA and Nano LIGA Technologies at BSRF

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Abstract. Beijing Synchrotron Radiation Facility (BSRF) is a partly dedicated synchrotron radiation (SR) source operated in either parasitic or dedicated mode. LIGA research at BSRF started from 1993 and focused in the first two steps of deep X-ray lithography and electroplating. Scanning exposure chamber of deep X-ray lithography was first built in 1996 on a 3W1 wiggler beamline with very hard X-ray and high X-ray density. We used the system for the research of LIGA deep X-ray lithography for many years, and found that the wiggler beamline does not meet the LIGA deep X-ray lithography for its disadvantages of small and bad uniform X-ray spot of 30mm on the wafer in horizontal and the very high X-ray power density on the wafer which causes the distortion of resist structures by the large heat load on the resist. In 2001 we used a bending magnet beamline (3B1) as deep X-ray lithography instead of wiggler beamline. The 3B1 beamline is divided to be 3B1B as LIGA deep X-ray lithography and 3B1A as nano X-ray lithography. The electroplating is used to make the mechanical parts and mold insert with nickel and copper materials for different applications.

1. Introduction

LIGA research at BSRF focuses in the first two steps of deep X-ray lithography and electroplating. In the early days, a scanning exposure chamber of deep X-ray lithography was built in a 3W1 wiggler beamline of 5 period numbers with very hard X-ray and high X-ray density [1,2]. The wiggler beamline is not suitable for the deep X-ray lithography with the small and bad uniform X-ray spot of 30mm in horizontal. And especially the X-ray power density on the wafer is very high and produces very large heat load on the resist which will cause the distortion of resist structures. After 2001 we started to use a bending magnet beamline as deep X-ray lithography instead of wiggler beamline [3]. The bending magnet beamline can provide very large spot in horizontal with several hundred millimeters needed in large scale production for application. X-ray from bending magnet, which is softer in X-ray and lower in power than that from wiggler, can not meet the ultra deep X-ray lithography for structures of above 0.5mm thickness with normal cross link PMMA resist used in wiggler source. For the deep X-ray lithography above 0.5 mm thickness with bending magnet

beamline, the compositions of PMMA resist have been adjusted to reduce the molecular weight and improve sensitivities to X-ray. The PMMA structures with 1mm height and $10\mu\text{m}$ fine width are fabricated on the bending magnet beamline. Nickel and copper in electroplating process is used as metal structures and molding insert tools. The beamline for Nano X-ray lithography is originally designed and run for IC process, now it is changed for the need of NEMS activities such as Fresnel zoom.

2. LIGA activities at BSRF

2.1 Layout and properties of the beamline for deep and nano X-ray lithography

The 3B1 beamline, extracted from the first bending magnet in the third part of storage ring, is divided to be 3B1B as LIGA deep X-ray lithography and 3B1A as nano X-ray lithography [3]. Figure 1 shows the optic layout of 3B1 beamline for deep X-ray lithography of LIGA process and nano X-ray lithography of nano LIGA process. The X-ray of 3b1 source is reflected by a mirror with a grating angle of 1.6 degree and goes through a Be film of $18\mu\text{m}$ thickness into nano X-ray exposure chamber at the end of 3B1A beamline for nano LIGA process. The mirror with external size of 110mm width and 240mm length, which accepts SR with 6mrad in horizontal direction and 0.4mrad in the vertical direction, rotates to scan X-ray to form a uniform X-ray spot on the wafer in exposure chamber for nano X-ray lithography [3]. For deep X-ray lithography, the mirror moves up out of the beamline and X-ray travels directly into a scanning chamber of deep X-ray lithography through a beryllium window with $250\mu\text{m}$ thickness at the end of 3B1B beamline. Deep X-ray lithography exposure chamber is located in a lead shield hutch and filled with helium to reduce the heat load on mask and wafer when exposure. The scanning table, driven by a linear motor, moves in vertical direct to form a uniform X-ray spot of 50mm in horizontal direction on the sample with the distance of 20-100mm.

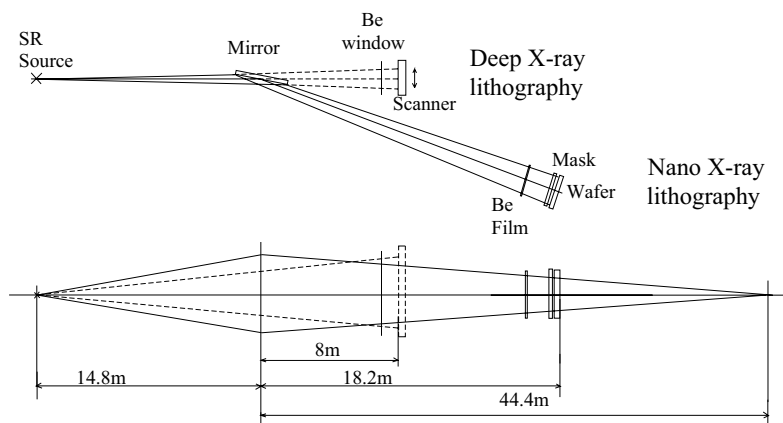


Figure 1, The optical layout of 3B1 beamline for deep and nano X-ray lithography.

Figure 2 shows the spectra of bending magnet and wiggler source at $E=2.2\text{GeV}$ and $I=100\text{mA}$ of storage ring and 1mrad of accepting angle in horizontal direction through a Be window of $250\mu\text{m}$ thickness for 3W1 and 3B1B, and reflected by the mirror coated by chromium with glazing angle of 1.6 degree and through a Be film of $18\mu\text{m}$ thickness for 3B1A. The total powers with above

parameters of storing ring after Be window are 25.8W with peak $E=4.8\text{KeV}$ for 3W1 and 0.95W with peak $E=3.9\text{KeV}$ for 3B1B.

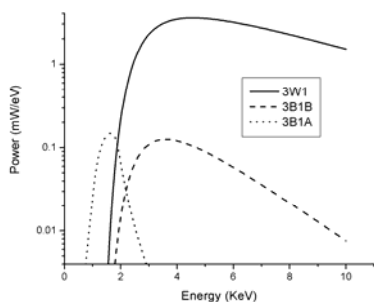


Figure 2, The X-ray spectra of bending magnet and wiggler source.

2.2 The mask fabrication for deep X-ray lithography

In the first several years of LIGA research, we had to use soft X-ray of 3B1A to copy X-ray mask with the gold absorbed structure of $1\mu\text{m}$ height to LIGA mask with gold absorbed structures above $10\mu\text{m}$ height. This process is very complicated and will take much more time to be done. After the SU8 resist is available in commerce, the resist is used to make the original template structure for gold electroplating of absorbed structure of LIGA mask. Polyimide with $20\mu\text{m}$ thickness is chosen to be the membrane of LIGA mask, and shows good stability for long time use and high X-ray radiation. This process for fabrication of LIGA mask with SU8 and polyimide has been developed to be a standard one in our Lab.. For deep X-ray lithography with 3B1B beamline, above $12\mu\text{m}$ height of the gold absorbed structure is enough to avoid PMMA resist after it to be exposed, and for 3W1 beamline the thickness of gold absorbed structure has to be finished above $15\mu\text{m}$. Fig. 3 shows a gold absorbed structure of SEM photon with the height of $20\mu\text{m}$.

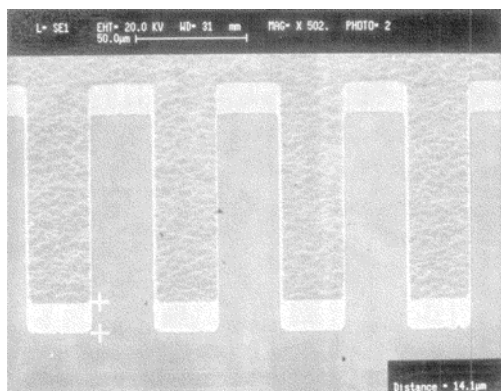


Figure 3, The gold absorbed structure of SEM photon with the height of $20\mu\text{m}$.

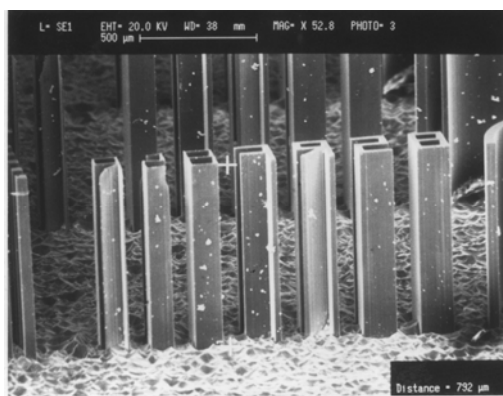


Figure 4, The SEM photon of the PMMA structures

2.3 LIGA deep X-ray lithography

Scanning exposure chamber of LIGA deep X-ray lithography was first built in a 3W1 wiggler

beamline with very hard and high X-ray density. The X-ray spot of 30mm in horizontal is too small for 3 inch or large wafer, and its uniformity is not good enough to meet the deep X-ray exposure. Especially the X-ray power density on the wafer is very high and produces very large heat load on the resist which will cause the distortion of resist structures [2]. After 2001, we started to use bending magnet beamline as deep X-ray lithography instead of wiggler beamline. The bending magnet beamline can provide very large spot in horizontal with several hundred millimeters needed in large scale production for application. SR source from bending magnet, which is softer in X-ray and lower in power than that from wiggler, can not meet the ultra deep X-ray lithography for above 0.5mm thickness structures with huge cross link PMMA resist used in wiggler source. For the deep X-ray lithography above 0.5 mm thickness with bending magnet beamline, the compositions of PMMA resist have been adjusted to reduce the molecular weight and improve sensitivities to X-ray. The PMMA structures with 1mm height and 10 μ m fine width are fabricated on the bending magnet beamline. Figure 4 shows SEM photon of the PMMA structures with aspect ratio of 100 (Grains on the side wall of PMMA structures are silver crystals produced in chemical deposition of silver film for the SEM requirement.).

2.4 The LIGA electroplating and some applications

Nickel and copper in electroplating process is used as metal structures and molding tools for different applications. The pin holes and large stress of nickel growth existed during the electroplating cause much trouble for the electroplating step of LIGA process. We have taken much more time to resolve the problems and get very good results. The nickel structure is showed in figure 5 with 10 μ m width and 400 μ m height.

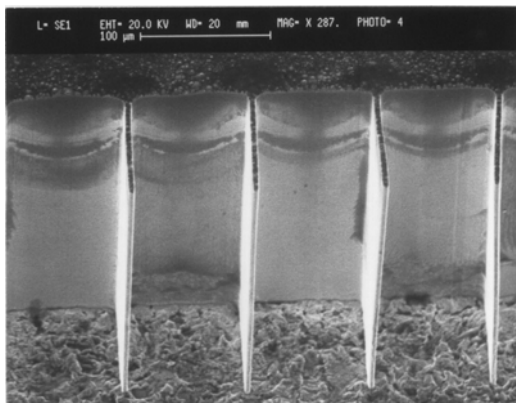


Figure 5, Nickel structure of SEM with aspect ratio of 40

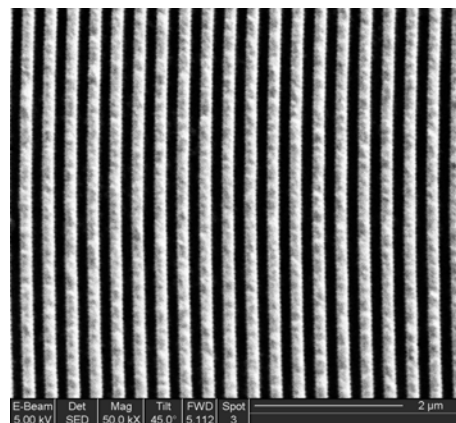


Figure 6, A SEM photon of gold structures for X-ray Fresnel zoom plate

3. Nano X-ray lithography

3B1A beamline and station are originally designed for fabrication of electronic device of IC, but now changed to NEMS research because it is not possible to make it to be the process of mass production of IC devices. Nano X-ray lithography for nano LIGA process, cooperated with Institute of Micro

Electrons, just starts in structures fabrication of Fresnel zoom and other elements. The X-ray spectrum for nano X-ray lithography, showed in Fig.2 with curve line of 3B1A, is about 1-2.5KeV at peak energy of 1.5KeV. Figure 6 shows a SEM photon of Fresnel zoom plate for X-ray focus with the gold fine line of 0.15 μ m width.

4. Conclusion

LIGA technology is a very powerful method especially to fabricate the structure with very high aspect ratio, its ability to make the structure with height to centimeters and aspect ratio above 100 can not be replaced by any other technologies. But its need of synchrotron radiation largely limits its widely application in MEMS. For users, they want to get the one step service for their all requirements. a manufacture center with different fabricating methods, such as LIGA, UV-LIGA, deep RIE, EDM, Laser, etc, should be established to meet the whole needs of users.

At BSRF, a standard process of LIGA technique with the first steps of deep X-ray lithography and electroplating has been established to supply for different users, and many mechanical parts and devices have been finished to users, such as nickel filters, copper heat exchanger with internal channels, copper structure for EDM, prototype of micro stepping motor, and so on [4]. For requirements of special structures, some new methods have been developed to meet the special needs, such as surface sacrificial layer technology to be used to fabricate the movable parts [4], the method of exposure from rear of mask for SU8 structures [5]. The need for LIGA technique will become strong following the market growth of MEMS.

Acknowledgments:

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