A.5: Development of X-ray lenses at Indus-2 using Soft and Deep X-ray Lithography Beamline (SDXRL), BL-07

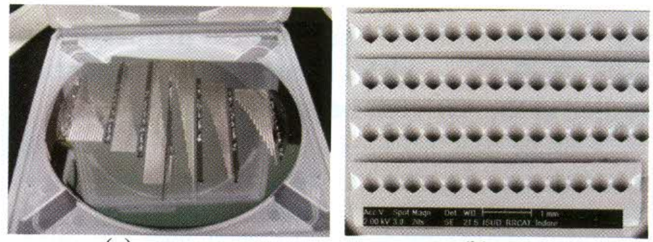
Focusing x-ray beam in the range of few μm to nm size are required at many synchrotron radiation facilities to perform microfocus based experiments using various x-ray techniques. This is however a very challenging task, as the refractive index of materials in the x-ray region is ~1. Thus, typical refractive lenses for x-rays consist of a stack of large number (~ 50-100) lenses of a low Z material with lateral dimensions in the range of tens of microns. Conventional mechanical techniques have to be stressed to their limits for such fabrication. At RRCAT, the synchrotron beamline BL-07, in Indus-2 has been used for the fabrication of x-ray lenses. The major advantage of using x-ray lithography technique for this fabrication is that a large number (~4000) of lenses can be made in a single process and high quality lens profile both in lateral and vertical (depth) directions can be obtained.

Planar parabolic refractive x-ray lenses for energy range 8-20 keV, is designed and fabricated with a minimum feature size of < 10 μm and depth of > 1000 μm. These lenses have been made in SU-8, which is a radiation resistant and high temperature compatible material. The focussing properties of x-ray lenses are studied at Indus-2. Some of the results of x-ray lenses fabricated in PMMA and SU-8 are already reported and details can be found elsewhere [1, 2]. Here, we describe the more recent results obtained using SU-8 lens.

X-ray lenses were designed considering the requirement of hard x-ray (8-20 keV) focusing experiments at Indus-2. The design calculations are carried out for x-ray lenses having planer parabolic shape lenses. Three different radii of curvatures (R = 25, 50 and 100 μm) are selected for design and development of x-ray lenses with focal length f = 0.3-1 m. The design of the lenses is arranged on a 100 mm diameter Si chip to obtain constant focal length for desired energies. Therefore, a lens chip provides the versatility in x-ray microfocussing at different energy range and different focal lengths.

An in-house developed x-ray mask fabrication technology is used to produce x-ray mask for x-ray lens fabrication. X-ray exposure of this mask is carried out at SDXRL beamline. The developed SU-8 x-ray lenses on Si chip and its SEM image are shown in Fig. A.5.1. One Si chip contains nearly 4000 lenses.

The investigation of the focus size of fabricated x-ray lenses was carried out at the Indus-2 BL-16 beamline. For this purpose, a dedicated x-ray lens characterisation facility is built at BL-16.



(a) (b)

Fig. A.5.1: (a) X-ray mask lens chip on 100 mm diameter Si wafer (b) SEM image of fabricated parabolic X-ray lens.

The setup consists of lens mounting platform with 5 degrees of freedom, which can manoeuvre the x-ray lens chip for alignment in the incident x-ray beam. Suitable x-ray energy can be tuned by using double crystal monochromator in the range of 8-20 keV and allowed to impinge on x-ray lens. The distance between the source and the centre of lenses was fixed to 20 m. One trail of x-ray lenses carrying 63 numbers bi-concave parabolic shaped lenses with R = 50 μm, f = 0.3 m and geometrical aperture 300 μm was aligned. For precise measurement of the micro-focused beam size, knife-edge scans using a 100 μm diameter gold wire attached to translation stage (1μm step movement) and a photodiode downstream to record the x-ray intensity was used. Various edge scans were recorded as function of x-ray energy to optimise the focal length. The best focussed spot size of 3.4 μm is obtained at 14 keV and is shown in Fig. A.5.2. The obtained focussed spot size is more than the calculated spot size of 2.7 μm. This may be due to density variation in the deposited sample and errors of approximately 1-2 μm in the fabricated lens profile. The focused spot size is correlated with Indus-2 vertical source, size which is found to be 260 μm. This is in reasonable agreement with the calculated value.

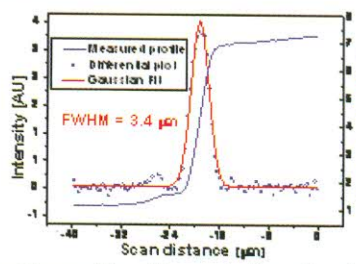


Fig A.5.2: Intensity profile of beam in lens focal plane measured using gold knife edge scan method. The derived derivative of the knife edge scan is also shown with FWHM = 3.4 μm.

For more details please refer to:

[1] V. P. Dhamgaye et. al., Pramana J. Phys., Vol. 83, p. 119 (2014).

[2] V. P. Dhamgaye, et. al., Microsystem Tech. Vol. 10-11, p. 2055 (2014).

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