EXPERIMENTAL REPORT ON MI542
Dec. 14-17 2001

Beam time application: Large area, Zone Plates, with Improved Diffraction Efficiency for 2.5-4 KeV operation.

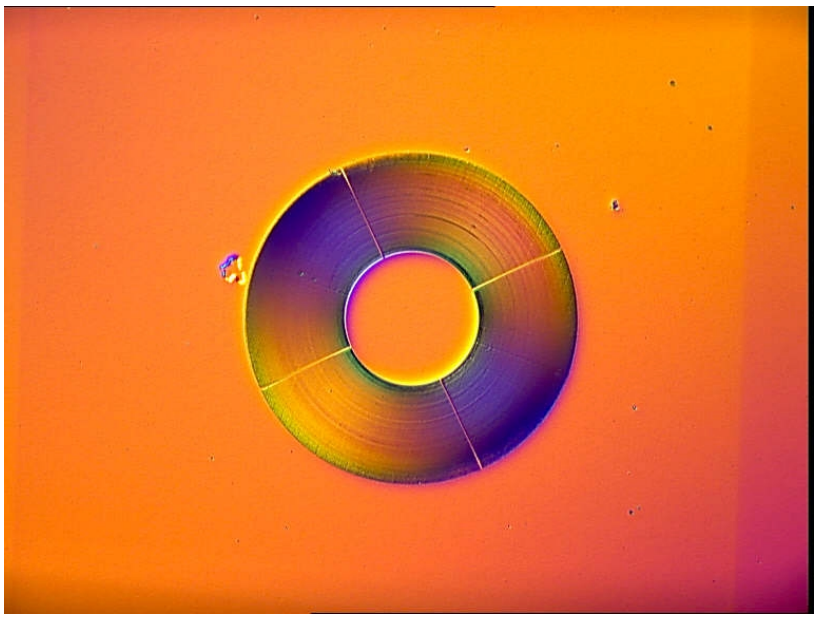
The experiment is an essential part of on-going work in all aspects of nanofabrication, in this instance specifically applied to the manufacturing of high resolution /good diffraction efficiency Fresnel diffraction Zone Plates for X-ray (spectro)microscopy. An ideal Zone Plate would have two essential characteristics; High diffraction efficiency, combined with high resolution, which in practical terms would translate into as large a fraction of the incident flux (on the ZP) as possible reaching the first order diffraction focal spot, which should be as small as possible. The diffraction limited 1st order focal spot of a ZP is ~1.22 X the outermost zone width (dr_n).

There are many factors affecting the choice of parameters for Zone Plate design; the choice of zone material should be tailored to the intended operating energy range. The dimensions of the optic should be such that the resulting focal spot does not degrade (from diffraction limited dimensions) because of the optical arrangement of the host beam line. Finally, technological limitations in fabrication, impose limits on the ***aspect ratio*** of zones, with implications on the diffraction efficiency that can be achieved for any given resolution.

For MI542 we tested a number of tungsten ZPs which were designed to be ***useful*** working optics on ID21, the host beam line at the ESRF. Over the years, we have been steadily improving the quality of our Zone Plates, and the ZPs tested in MI542 carry on this trend. In order to be able to chart the performance of new ZPs and compare them with existing ones, a very simple formula has been devised, which gives a measure of both the transmitted flux and the smallness of the focal spot (resolution) into a single figure of merit, the ***Gain Factor*** in the table below. The comparison is with a reference high resolution ZP, with parameters which would be envied by many X-ray microscopists world wide. The gain factor is proportional to the area ratio of the real and reference ZPs, and inversely proportional to the area of their respective focal spots.

The table below shows the best three of the ZPs tested, in terms of the measured 1st order diffraction efficiency and ZP outermost zone width (dr_n) which ultimately determines the resolution. The improvement over the "reference" Zone Plate is very obvious. All tests were carried out at 3.3 keV. The thickness of the tungsten zones was ~300 nm. The diffraction efficiency figures in parenthesis are for the 2nd order diffraction, at potentially double the resolution of 1st order. Zone Plate KCL-W1 needed more etching and it is hoped that it will be re-tested at a later beam time, but still offers a significant gain over the reference ZP.

ZP	Diameter (μm)	Efficiency(%)	dr_n (nm)	Gain factor(%)
REFERENCE	100	10	100	100
KCL-W3	250	6(0.9)	80	586
KCL-W2	250	4.2(1.1)	60	694
KCL-W1	250	1.4	40	547



Micrograph of KCL-W2, Dia. = 250 μm, dr_n = 60 nm, Efficiency = 4.2 %

Following characterisation, the above Zone Plate was set up in a proper imaging configuration in the STXM at ID21, and was used to image a test specimen, in order to confirm its imaging qualities. The test object was also manufactured in our laboratory, and it consists of a few letters of text and a scale bar of exactly 6 μm. The letters are composed of ~1 μm tall cones of DLC (Diamond Like Carbon), overcoated with ~50 nm of gold. This sample contains features < 50 nm which are not visible with the present resolution capabilities of the X-ray microscope at ID21 irrespective of the Zone plate used. This is imposed by the present optical arrangement and the geometry of the line as well as beam source fluctuations, especially in the horizontal direction.

The micrographs below show an SEM image of the test object (left), and an X-ray image (right) recorded using the above ZP. The lettering “6 μm” as well as the scale bar are clearly visible. The image was recorded at 3.3 keV.