A.13: Refurbishing of x-ray mirror by capacitively coupled RF plasma

Under the influence of soft x-ray/vacuum ultra violet (VUV) radiation growth of carbon contamination on optical elements in a synchrotron beam line is a known problem. The carbon contamination layer causes severe absorption near the carbon K-edge and also increases scattered background, consequently the efficiency of reflection and monochromotization decreases particularly in the soft x-ray/ vacuum ultra violet region. The carbon layer causes destructive interference and affects photon beam intensity in high energy region as well. The photon flux loss due to carbon contaminations has forced to search suitable technique to remove contamination layer and restore the optical surfaces. Synchrotron optics require extremely precise coatings on premium quality substrates, these substrates and coatings can be very expensive, so it is desirable to refurbish the contaminated optics by suitable carbon removal technique. In present work we refurbished carbon contaminated gold coated toroidal pre-mirror of reflectivity beam line (BL-04 at Indus-1) by an in-house developed capacitively coupled RF plasma cleaning setup developed at Laser Plasma Section. Photograph of the mirror before and after RF plasma cleaning is shown in Figure A.13.1. Before cleaning the actual mirror in the system, RF power, exposure time and process gas pressure of the system was optimized using test samples(Si-substrate/Pt (450Å)/C (300 Å)) and it is observed that10 W (33.3 mW/cm^2) power is suitable for removing 30 nm carbon film in 30 min without affecting roughness of the surface. The samples to be cleaned were kept at the bottom electrode keeping the contaminated surface in vertical plane in order to avoid ion sputtering from the reflecting surface. The contaminated mirror was exposed to RF plasma at 10 W powers for one hour. During the exposure experiment, the emission lines of CO and $CO_2$was continuously recorded by a fiber based optical spectrometer.

Measured and fitted SXR patterns, before and after cleaning the mirror are shown in Figure A.13.2. A clear dip before the critical momentum of gold in reflectivity patterns of contaminated mirror indicates the presence of carbon contaminated layer. The layer density and optical constants are obtained by fitting of measured data. During the SXR fitting, thicknesses and interface roughnesses of C, Au and Cr layer and optical constants of C layer kept as free parameters whereas optical constants of Au and Cr layer are kept constant. The energy dependent optical constants values are taken from Henke data base. The contamination layer thickness, roughness and density was found to be 400 Å, 60 Å and 75% of graphitic carbon density, respectively. The disappearance of a dip in the reflection patterns just before the gold critical momentum indicates that the carbon layer is removed after the exposure of the mirror in the RF plasma.

Fig. A.13.1: (a) Synchrotron radiation induced carbon contaminated mirror (size 340mm x 60mm x 40mm) (b) After carbon removal by RF plasma at 10 watt power for 1 hour.

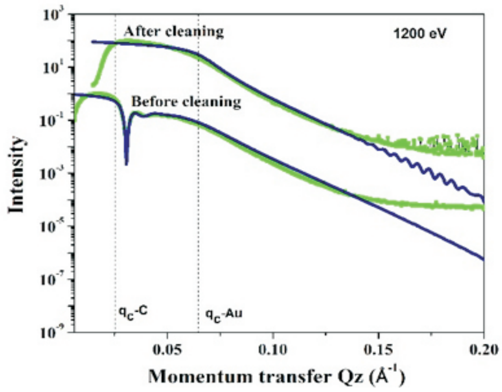

Fig. A.13.2: Soft x-ray reflectivity patterns before and after cleaning the contaminated mirror are shown.

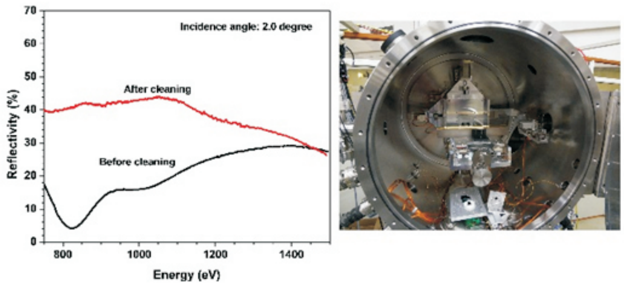

Fig. A.13.3: (a) Soft x-ray reflectivity performance in 750 to 1500 eV energy region measured before and after RF plasma cleaning at 2 degree incidence angle (b) View of reflectometer (at BL-3, Indus-2) with mirror mounted for soft x-ray reflectivity test.

Energy dependent reflectivity pattern of contaminated mirror measured in 750 to 1500 eV photon energy region is shown in Figure A.13.3 alongwith inside view of the reflectometer with the mirror mounted for the test. It is found that the reflectivity performance is regained after the carbon layer removal using the RF plama technique. In summary we successfully refurbished a synchrotron mirror using capacitively coupled RF plasma.

Reported by:
P. K. Yadav (praveenyadav@rrcat.gov.in) and M. Kumar