Surfaces and Interfaces Studies in X-ray Mirrors

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Institutes, Year: RRCAT/ Devi Ahilya Uni. Indore (**2005**)

The first Indian synchrotron source Indus-1 (450 MeV electron storage ring) was commissioned in 1999 and has opened up soft x-ray region for Indian researcher. To design new beamlines and meet new experimental requirements a demand of x-ray optical elements were realized.

Design and fabrication of optical devices require an accurate knowledge of refractive indices of the materials. Though a comprehensive tabulation of optical data for different materials (Z=1 to 92) are given by Henke *et al.*, but in the vicinity of the absorption edges those data are not accurate. Beside that, the tabulation does not cover different compound materials. The new studies are required to generate a more reliable datasets.

New generation of x-ray optics are based on nanotechnology where the structure of the surfaces and interfaces play an important role. Stability of the interfaces, specially when these optics are exposed to high thermal load at high brilliance synchrotron beamline, is a technological challenge. The most common problems are due to interdiffusion of constituent elements at the interfaces. This leads to a change in roughnesses and periodicity of multilayer structure. Such changes are due to crystallization of metal layers and expansion of spacer layers. The non-equilibrium thermo dynamical conditions prevailed during deposition is also responsible for structural instability. The knowledge of surface and interface behaviors is required to design a stable and good quality optics.

To address these issues a study of optical constants of surfaces of float glass, silicon, and silicon dioxide are initiated as these are important substrate materials for making x-ray mirrors. Interfacial properties of W/C and Mo/Si multilayers are also investigated in detail.

One side of float glass contains significant amount of diffused tin arising from manufacturing process. The diffused tin leads to a change in surface density. Optical constants δ & β are measured on both non tin side and tin side surfaces in 80-200Å wavelength range. For non-tin side surface, the experimental results suggest that the optical constants follow a trend of Henke's tabulated data of SiO_2 with an upward shift in δ values. Away from the silicon L-edge (124Å) the upward shift lies in the range of 5-15% and near the edge this increased to 30-80% value. The δ value measured for tin side surface is high in comparison to those of non tin side surface. A shift in delta value of 10-50% with respect to non tin side data is measured. This difference is attributed to change in surface density due to presence of diffused tin. Likewise two other materials, silicon and silicon dioxide are also investigated. For silicon, the values of δ and β are in good agreement with the Henke's tabulated values in the wavelength range of 130 to 160Å. Here the variation in δ is within $\pm$ 3% and in β it is $\pm$5%. In 80 to 120 Å region, the variation in δ is within $\pm$7% and in β it is $\pm$9%.

As a part of multilayer study, annealing experiments are carried out on sputtered deposited W/C multilayer $(70Å\ C/\ 40Å\ W)_{10}$ in 200-850°C temperature range. It is found that the period of the multilayer expands by 8% upon annealing. The interface roughness increases gradually from bottom to top layer indicating roughness accumulating effect in W/C system. The roughness replication constant for tungsten layer is high in comparison to that of carbon layer. Details of the interface modification and period evolution are given in the thesis. A study on Mo/Si multilayer $(30Å\ Mo/\ 59Å\ Si)_5$ is carried out to understand asymmetric interface behavior in Mo/Si combination. Kinetic energy and thermal conductivity model is used to explain the formation of asymmetric Si-on-Mo interface and Mo-on-Si interface due to intermixing of molybdenum and silicon.

The thesis is comprised of three major activities i) development of reflectometer station on reflectivity beamline on Indus-1 synchrotron source ii) optical study of the surfaces of float glass, silicon and SiO_2 materials and iii) structural analysis of W/C, Mo/Si multilayers. This was the first PhD work carried out using Indus-1 synchrotron source.