A.8: Ion assisted growth study on Molybdenum thin film at RRCAT

Electron beam physical vapor deposition process is used to deposit high purity thin films. But, due to the low energy (~ 1eV) of atoms being added, the films grown by e-beam are not so much dense and smooth as films grown by the other sputtering techniques. To improve the quality (density and roughness) of the films, we added an ion source (Kaufman type) in our existing electron beam deposition facility. High density and smooth coatings are needed for development of x-ray multilayers mirrors. Optimum performance of x-ray multilayer strongly depends on the density contrast at interface and interface imperfection such as interface roughness and interdiffusion. Therefore, study of film growth to improve structural parameters such as densification and surface morphology is important and interesting for both basic and applied physics. The structural parameters such as density and surface morphology of evaporated films are related to the size, mass, distribution and energy of ad atoms in the vapour stream. Thus for a particular materials, it is required to optimize ion flux, energy and deposition rate to achieve optimum growth condition.

After installations (75^0 with respect to normal of sample surface) and commissioning of ion source in deposition system, Mo films (~26 nm thick) are deposited on ultrasonically clean Si substrate using Ion assisted electron beam evaporation system. The current density is varied between 0.4 mA/cm^2 to 2.05 mA/cm^2 and deposition rate is varied from 5 Å to 8 Å per minute. The optimized ion beam voltage is fixed at 90 Volts. The ion-to-atom ratio (r) is varied (0.06 to 0.4) by independently adjusting the ion current density and the deposition rate. Here we present results of improving structural parameters (film density and roughness) in ion-assisted evaporation Mo film by optimizing ion-to-atom ratios and deposition rate. Micro structural parameters of the deposited samples are obtained using hard X-ray reflectivity (XRR) using Cu-K_α (λ= 0.154 nm) radiation. Figure A.8.1 shows the measured hard XRR profile of different Mo films fabricated with varying ion-to-atom ratios (r) along with the fitted curve. The measured reflectivity profile clearly reveal that the critical angle ($\theta_c = \sqrt{(2\delta)}$) increases (marked by vertical line) as r increases systematically with respect to without ion assisted film (r=0.0). Furthermore, as r increases the surface roughness of the film decreases as observed from the measured profile. The measured profiles are fitted using parratt formalism. The best fit results are shown in Table A.7.1. It is observed that with increasing ion-to-atom ratio in ion beam assisted process, film became smoother as well as denser. As the ion-to-atom ratio increases, the roughness of the film decreases from 20.17 Å to 8.4 Å. Densification of the film occurs as the ion-to-atom ratio increases. Mass density of the film increases from 85% to 98 % with respect to bulk value.

Table A.9.1: Structural parameters (thickness t, relative film mass density ρ_f, surface roughness σ) obtained from Best-fit XRR results (Fig. A.8.1) for Mo films deposited at different ion-to-atom ratios.

Sample No.	Ion flux ($cm^{-2}s^{-1}$)	Ion-to-atom-ratio (r)	t (Å)	ρ_f with respect to bulk	σ (Å)
Mo-1	0	0.0	285.8	85%	20.1
Mo-2	400 μA	0.06	276.1	85%	15.1
Mo-3	450 μA	0.08	255.6	87%	14.0
Mo-4	780 μA	0.12	243.9	89%	13.2
Mo-5	1.21 mA	0.21	274.9	90%	12.8
Mo-6	1.45 mA	0.29	245.1	93%	12.7
Mo-7	2.05 mA	0.40	220.4	98%	08.4

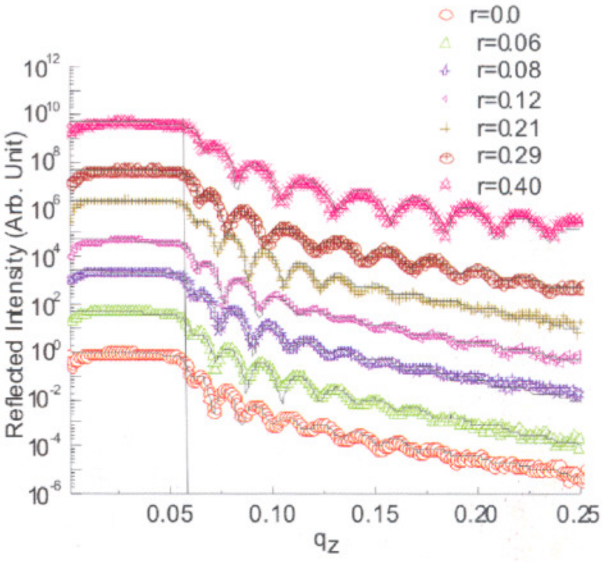

Fig. A.8.1: Measured and fitted XRR spectra at Cu K_α energy for different Mo films deposited with varying ion-to-atom ratios. The vertical line indicates the guideline for shifting of critical angle to higher side.

Here we have demonstrated that with ion assisted growth it is possible to deposit low roughness and high-density films. This is a very useful development for our x-ray multilayer program.

Reported by:
P. K. Yadav (praveenyadav@rrcat.gov.in),
M. Nayak, G. S. Lodha and S.K Rai