was started with the aim to install the experimental system on reflectometry beamline in Indus-1. In view of that, before Indus-1 commissioning, the reflectometry station was set on a CAT developed rotating anode x-ray generator (RAX). It was aimed to rebuild the same after commissioning the beamline on Indus-1 via purchasing the new hardware. The system was successfully commissioned on RAX and later moved to Indus-1 beamline. Presently the new XRR system is under commissioning and soon will be available in new shape. Here we describe our experience with grazing incidence reflectivity setup installed on RAX. Significant effort had been made to use the hardware developed indigenously or available in the local market.

In CAT XRR system, for carrying out the θ-2θ rotary motion of sample and detector, a goniometer had been fabricated using the two rotary stages. Stepping motors had been used to drive the stages in micro stepping mode. For accurate positioning of rotation axes relative to each other the stages were mechanically pre-aligned on a co-ordinate measuring machine. For moving the sample in and out of the beam a linear translation stage is mounted on sample rotation stage.

For an initial experiment, due to geometrical constraints, the reflectometer system was set on a point source window of RAX. The whole goniometer system was geometrically aligned in 8° configurations by adjusting the height corresponding to x-ray take off angle. Fig. A.5.1 shows the schematic of x-ray reflectivity setup with a grazing incidence monochromator. A beam of 0.05 degree angular divergence was generated using a 150μm slit before the sample. Sample holder with the spring loading mechanism was used to maintain the sample surface at the axis of the goniometer. An exit arm monochromator using a graphite crystal was set to record the reflected Cu K_α(λ=1.54Å) radiation. A large rocking- curve- width graphite crystal (0.24°), allowed using a low precision manual rotary mount. The graphite crystal was set to diffract 1.54Å (Cu K_α) and a GM counter was employed to detect the radiation. The small count rate-handling capacity (3000c/s) of GM detector forced us to measure large dynamic range of reflectivity pattern in different power settings of RAX.

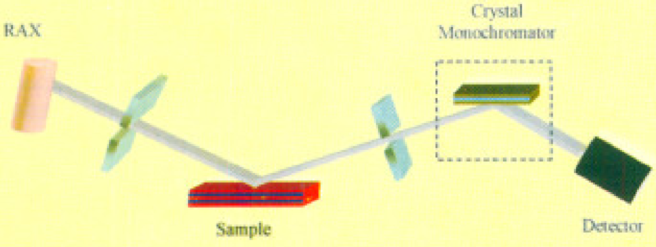

Fig. A.5.1 Schematic of x-ray reflectivity setup using exit arm monochromater

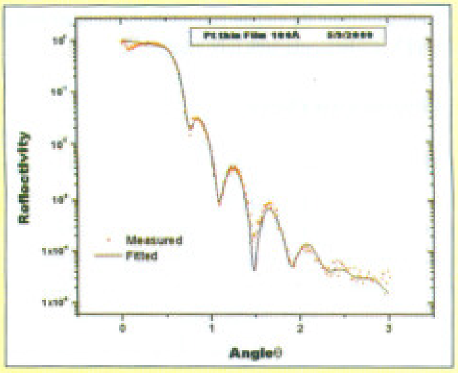

Fig. A.5.2 XRR spectra of Pt thin film (100Å) deposited on float glass. Continuous curve represents the fitted spectra. Reflectivity is measured at λ=1.54Å

The test experiments of x-ray reflectivity were carried out on thin film and multilayer samples. Representative reflectivity measurement of 100Å Pt thin films is shown in fig. A.5.2. In this samples the interference fringes corresponding to 100Å film thickness were recorded. This measurement was performed with tube parameters of 30kV, 30mA. Due to footprint effect at extreme grazing angle on finite size sample, a dip in reflectivity pattern near the zero degree was observed. The reflected intensity was normalized to incident intensity, for obtaining the absolute reflectivity.

Presently efforts are underway to commission a new XRR system in CAT. The hardware required has already been procured. The required mechanical attachments are fabricated. This new system is being commissioned on a new sealed tube x-ray source.

(Reported by: G. S. Lodha; lodha@cat.ernet.in)

A.6 Total reflection x-ray fluorescence spectrometer

Total reflection x-ray fluorescence (TXRF) spectrometry is a modern technique for the determination of ultra-trace amounts of elements in various kinds of samples. This technique is a variant of the well-established energy dispersive x-ray fluorescence (EDXRF) technique. The versatility of TXRF stems from: (i) the amount of sample needed is very small, (ii) detection sensitivities at sub-ppm level in relative terms and in picograms in absolute mass levels, and (iii) ability to do surface characterization of thin films and surfaces. In TXRF, the primary x-ray beam excites the specimen at a glancing angle less than the critical angle thereby exploiting the effect of total reflection of x-rays. This mode of x-ray fluorescence excitation eliminates the large Compton scattering of the primary x-ray beam from the sample bulk, which is the major limiting factor for achieving good detection sensitivity in the conventional EDXRF. The critical angle for x-rays, below which total reflection occurs, is typically in milliradian range and such small angles are quite difficult to adjust and maintain properly. In addition to the precise control of the grazing angles, all optical components of the spectrometer require good mechanical stability.

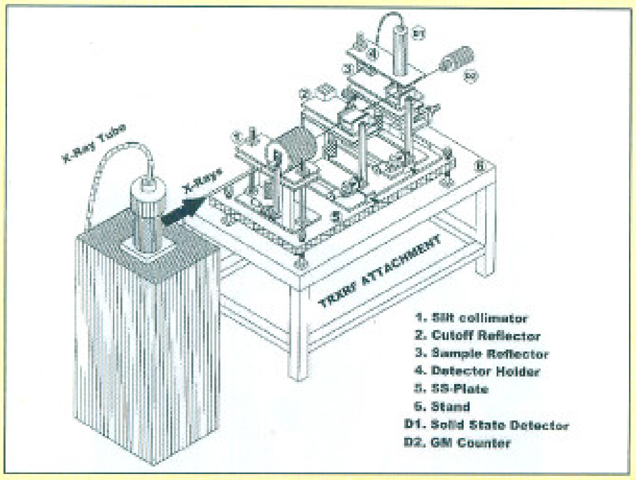

Fig. A.6.1 An isometric view of the TXRF attachment

A simple and fairly inexpensive TRXF spectrometer has been designed, constructed and realized in CAT. The TXRF setup comprises of an x-ray generator, a slit collimator arrangement, a monochromator / cutoff-stage, a sample reflector stage and an x-ray detection system.

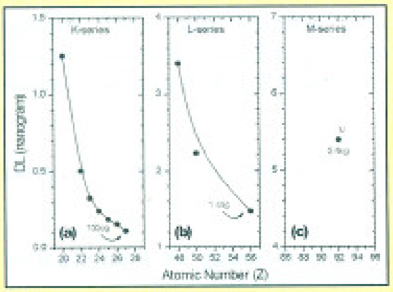

Fig. A.6.2 Detection limits of the TXRF spectrometer

The glancing angle of incidence on the two reflectors is implemented using a sine-bar mechanism that enables precise angle adjustments. An energy dispersive detector and a GM counter are employed for measuring the fluorescence intensities and the direct x-ray beam intensity respectively. A Cu-target x-ray generator with its line focus window is used as an excitation source. The spectrometer is quite compact in design and employs a peltier cooled solid-state detector for energy dispersive detection. Alignment and characterization of the TXRF system has been performed and the detection limits for various elements have been determined to be in the range of 100pg to 5ng even at low x-ray generator powers of 150 W. The capability of the TXRF system for thin film characterization is also demonstrated. Isometric view of the TRXF spectrometer and the detection limits achieved are shown in figs. A.6.1 and A.6.2. The spectrometer is being adopted for use with 4kW x-ray generator that will further improve the detection sensitivities of the spectrometer.

(Reported by: K.J.S. Sawhney; sawhney@cat.ernet.in)

A.7 Linac and Undulator Development

For a terahertz free-electron laser (FEL), lasing between 50–100μm, a 5cm period, 2.5μm long undulator has been designed in two equal sections each of length 1.25m. At present one of these sections has already been assembled (fig. A.7.1) and field-mapped. The quality of the undulator is within specification. For example, we had calculated a requirement of a field quality of better than 1% in $\Delta B/B$ – we obtained 0.7%. This can be improved further by using magnetic shims. The second section has been assembled, and field mapping is presently on. This undulator has established our ability to master undulator technology for IR/FEL applications.

Another major challenge has been the development of the linear accelerator structure. Rather than buy the structure outright, we chose to build it ourselves, motivated by the desire to develop linac technology in the country. With this view, we also chose to build a rather unconventional structure – the Plane Wave Transformer (PWT) linac. This is a much more open structure, with strong coupling between the cells – and consequently with relaxed fabrication tolerances. The only PWT linac working in the world is at UCLA, and once operational ours would be the second in the world. After building a number of prototypes and ascending a steep technology curve, we now have a structure (fig. A.7.2) that has been fabricated to the required tolerances (30μm) and surface finish (0.2μm CLA), which can hold UHV (1×10^{-8} Torr), resonates at the desired frequency of 2856MHz, and has a loaded Q of 8,000. High power conditioning will commence shortly.

A 69kV, 330A, 25MW, 10μs, line-type pulse modulator, has been developed for powering the 10MW, 10μs, 2856MHz klystron that we have bought from TOIRY, Russia. We have successfully extracted up to 6MW of power from the klystron, and are only limited from going to higher power by the fact that our wave guides are presently pressurized with N_2. We plan to switch later to SF_6, which has a higher breakdown threshold, after which we expect to be able to extract the full 10MW from the klystron.