various techniques. We have carried out the synthesis of CuO and FeO nanorods by annealing a commercial grade Cu and Fe foil in oxygen atmosphere at high temperature. Our detailed investigations reveal that *(a)* the aspect ratio (the ratio of length to diameter of the nanorod) and density (number of nanorods per unit area) critically depends on the growth conditions, like the oxygen flow rate, annealing temperature, annealing time, *etc.* and *(b)* the growth of nanorods proceeds in three steps. During the initial stages of annealing of foil under the optimized growth condition results in the formation of hills and valley structure, which is due to the anisotropic surface diffusion of oxygen atoms. The CuO nanorods grow only in the valleys while on the hills only sparse growth of very small nanorods is observed. In the second step, a porous structure is formed in the oxide film. The pores have pyramid structure and act as the nucleation sites for the growth of the nanorods. The nanorods grow from these pyramids due to the relaxation of stress accumulated in them during the process of annealing.

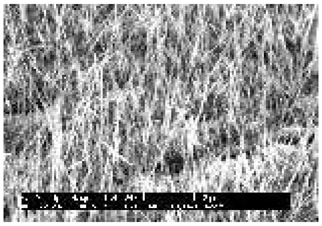

Fig. A.2.1 *CuO nanorods grown on Cu foil*

Fig. A.2.2 *FeO nanorods grown on Fe foil*

The CuO nanorods produced by this method are almost unidirectional with high aspect ratio as is evident from the scanning electron micrograph shown in fig. A.2.1; the average length and diameter of these nanorods are ~7mm and ~110nm, respectively. Further, the growth of these nanorods is perpendicular to the substrate (foil) and they almost uniformly cover the complete area of the substrate. FeO nanorods also grows perpendicular to the foil (fig. A.2.2). The aspect ratio of these nanorods with respect to annealing temperature, time and oxygen flow is yet to be optimized.

(Contributed by: R.V. Nandedkar
A.K.Srivastava (sarvind@cat.ernet.in))

A.3 Development of front-end components for Indus-2 beam lines

A font-end is a device, which is placed in between a beam line and a dipole chamber from where synchrotron radiation (SR) is tapped. It is basically a set of ultra high vacuum components with associated controls and interlocks. The main functions of front-end are:

Protection of storage ring vacuum from any vacuum leaks from a beam line.

Absorption of heat load and radiation when a beam line is not in operation.

Defining the maximum excursion of the X-ray beam, so that the beam does not strike any uncooled surface along beamline

Establishing the photon beam position including its average take-off angle.

Filter out soft X-rays and isolate beamline vacuum from the vacuum of front-end using a beryllium window.

The following components of the front-end are designed and fabricated:

1. Collimator (CM)

Collimator is the first active component to interact with beam in the front end. The collimator is a beam-defining aperture made of OFE copper solid block with rectangular tapered hole along its central axis coinciding with the beam axis. Collimator will receive around 24mrad of beam out of which only 7mrad beam will pass through it resulting in heating the collimator block by a heat load of around 420 watts. Water cooling channels of diameter 6.3 mm are drilled along and across the aperture to avoid direct vacuum – water joints. Copper block is vacuum brazed with two S.S. conflat flanges at the ends by means of brazing alloy BVAG8 foils.

2. Photon beam absorber (BA)

The photon beam shutter completely intercepts the SR beam in the closed position. It is designed to absorb the full thermal power of the beam to isolate downstream components from the thermal load of X-ray source. The time necessary to close this shutter is few seconds. A Cu tube is brazed over the plate and taken out through a conflat flange such that there is no direct vacuum to water joint. The shutter block can be moved up and down inside a vacuum chamber by means of a pneumatic cylinder through a solenoid valve.

Fig. A.3.1 *Prototype front end*

3. Photon beam position monitors (BPM)

BPM measures the average position of the X-ray beam. The first monitor is located just after the beam collimator and the second monitor approximately 5-10m downstream. The BPMs provide real time position and profile information. If the position of the photon beam is known at two places along the beamline, then the average position and angle of the electron beam in the X- ray source can be determined.

4. Fixed mask (FM)

A fixed mask is a water-cooled copper plate with a rectangular hole in the center. The purpose of FM is to provide the required beam size for a particular beam line. Typical thermal load on fixed mask is about 150 –200 watts depending upon the opening.

5. Safety shutter

The purpose of safety shutter is to absorb bremsstrahlung gamma radiation generated from electron beam scattering. The safety shutter essentially comprises of a vacuum chamber, inside of which is placed a radiation absorber head made of steel clad lead or densimate a tungsten alloy. A water cooled copper plate is placed at 45^0 before the head to protect it from the heat load. Typical size of the absorber head made of densimate are 200 x 100 x $60mm^3$ which is very massive. It is moved by a pneumatic cylinder through a welded bellow.

(Contributed by: V.K.Raghuvanshi **(**vkraghu@cat.ernet.in) and R.V.Nandedkar)

A.4 Large area ionization chamber for intensity monitoring in hard X-ray beam lines in Indus- 2

Ionization chamber (IC) is commonly used in hard X-ray beam lines to measure intensity. ICs are gas (in this case argon) filled detectors, which can be used for various purposes in a beam line. They are kept just before the experimental station to monitor the incident intensity (I_0) of X-ray beam. They can also be kept immediately after a double crystal monochromater (DCM) to align for DCM crystals and used in detuning the second crystal to suppress higher order harmonics [CAT 2004–19].

A large area IC has been fabricated and tested on 3kW, CuKa X-ray source. Fig. A.4.1 shows the photograph of the set up. The IC consists of a cylindrical chamber of 450mm length and 150mm diameter. This has two 203mm diameter flanges at the ends with rectangular cross section holes for the passage of X-rays. 50mm thick Kapton windows are stuck on these rectangular holes with the help of an adhesive. Six ports, welded on the circumference of the main pipe, contain flanges of 70mm diameter each. Both the electrodes are electrically isolated from the body of the IC. In one of the flanges high voltage feed-through is attached. Voltage up to 3kV is applied through this port. The IC is then filled at desired argon pressure and sealed. For this set of measurements, pure argon gas was filled at pressures between 1.0 and 1.8bar. The IC is first evacuated to a pressure of ~ 10^{-2}mbar, using a rotary pump. The IC current is measured using a Keithly electrometer.

Fig. A.4.1 *Ionization Chamber along with the high voltage power supply and ammeter*

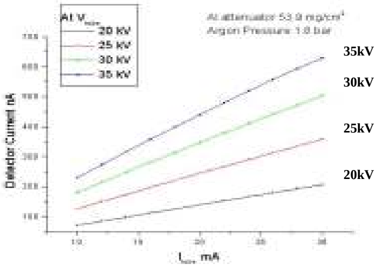

Fig. A.4.2 *I_{det} plotted as a function of I_{tube} for various values of V_{tube}*

The IC was tested on X-ray source. We find that the ionization region for the IC is between 500volts and 1000volts depending upon incident intensity. For a given accelerating tube voltage, IC current is approximately linear with the X-ray tube current for lower values of IC current (fig. A.4.2). Non-linearity sets in when the incident X-ray intensities are high.

(Contributed by : A.K.Sinha (anil@cat.ernt.in) and R.V.Nandedkar)

A.5 Development of ECR proton source

50keV, 30mA Electron cyclotron resonance (ECR) proton source (fig. A.5.1) for use as an ion source for a proton linac is designed and fabricated. The source is excited with 350watts of microwave power at 2450MHz frequency to produce hydrogen plasma. Two-electrode extraction geometry is designed for extraction of the proton beam. The extraction aperture of the plasma electrode is 8mm and ground electrode is 10mm. The proton beam current 5mA (peak) at 15keV with a pulse width of 5msec., and repetition rate 100Hz is obtained. The beam current is measured 100mm down the