Laboratory Report

Growth of Thin Films by Electron-Beam and Thermal Evaporation System

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Objectives:

Growth and characterization of thin films by electron-beam and thermal evaporation systems.

1. Chromium and copper thin film deposition on cover glass slips using electron-beam and thermal evaporation techniques, respectively.

2. Thickness determination of the deposited thin films using a profilometer.

Theory:

1. **Electron Beam Evaporation and Thermal Evaporation:**
   Electron Beam Evaporation is a form of Physical Vapor Deposition (PVD) in which the target material is bombarded with an electron beam from a charged tungsten filament. From crucible, material evaporates and converts into a gaseous state for deposition of the material to be coated onto the substrate. This is carried out in a high vacuum chamber. Thermal Evaporation is one of the simplest PVD techniques. Basically, target material is heated in a vacuum chamber until its surface atoms have sufficient energy to leave its surface. The atoms will traverse the vacuum chamber, at thermal energy and coat a substrate. The pressure in the chamber must be below the critical point where the mean free path is longer than the distance between the evaporation source and the substrate.

2. **Vacuum system:**
   Turbo Molecular Pump (TMP): It is used to create high vacuum in the chamber. The ultimate vacuum of TMP is in the range of 5×10^{-10} mbar.
   Rotary pump: It is a dry pump used to create fore vacuum in the chamber and to serve as a backing pump for the TMP. It achieves an ultimate vacuum in the range of 5.0×10^{-2} mbar.
   Substrate heater: The heater is used to heat the substrate for better deposition. A 2-inch heater is equipped with this evaporation system which can be used to heat the substrate up to 800°C.
   Quartz Crystal Microbalance (QCM): It is used to measure the thickness of the film deposited on a substrate. This is achieved by tracking the frequency response of a quartz crystal during the coating process. The change in frequency can be directly related to the amount of coating material on the crystal surface.

3. **Thickness Profilometer:**
   A thickness profilometer is an essential instrument used for measuring the thickness of thin films and coatings. It works by scanning the surface of a sample and recording the topographical variations with high precision. The device typically uses a stylus or optical method to trace the surface contours, providing detailed information about the film uniformity and thickness.

Observations:

Electron beam evaporation

Base Vaccum (mBar)	Evaporation beam condition					
	Source Material	Emission Current(mA)	Filament current (A)	DC Output Voltage(kV)	Deposition rate (nm/s)	Thickness by QCM (nm)
$(8.8 \pm 0.1) \times 10^{-7}$	Cr	12 ± 1	14.5 ± 0.1	7.36 ± 0.01	0.40 ± 0.01	5 ± 0.8

Thermal evaporation

Base Vaccum (mBar)	Evaporation beam condition				
	Source Material	Emission current (A)	Voltage (kV)	Deposition rate (nm/s)	Thickness by QCM (nm)
$(1.2 \pm 0.1) \times 10^{-6}$	Cu	112.0 ± 1.5	40.5 ± 1	0.65 ± 0.05	45 ± 1.3

Calibration factor

$$\text{Calibration factor (C.F)} = \frac{\text{Thickness obtained in the Profilometer}}{\text{Thickness expected}}$$

Thickness obtained in the Profilometer $= 54 \pm 1$ nm

$$\text{Calibration factor (C.F)} = \frac{54}{50} = 1.08$$

$$\text{Error in Calibration factor } = \frac{\delta a}{a} + \frac{\delta b + \delta c}{b + c}$$

Where a is measurement relating to profilometer, b is measurement relating to electron beam and c is measurement relating to thermal evaporation.

$$\delta(C.F) = \frac{1}{54} + \frac{0.8 + 1.3}{50}$$
$$\delta(C.F) = 0.06$$

Results

- We have successfully made a film of Chromium-Copper deposition using Electron beam and Thermal evaporation techniques.
- We have used 5 ± 0.8 nm thickness for Chromium and 45 ± 1.3 nm for Copper to give roughly 50 ± 2.1 nm thickness of film.
- The calibration factor that can be used for further studies is 1.08 ± 0.06
- **Note:** The errors for thickness in electron beam was done by measuring the time taken to close the shutter and reaction time, multiplied by the rate of deposition.