

Laboratory Report

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

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Report presented for the
Advanced Physics Laboratory Course (PL 701)



School of Physical Sciences
UM-DAE Centre for Excellence in Basic Sciences
Mumbai, MH, India
November 25, 2024

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 Vacuum (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 Vacuum (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 ± 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.

References

Books by M.Ohring and K.L Chopra

Lab handouts provided at Prof. Rai's lab.