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Thin Film Deposition and Measurement – *DRAFT* Phy 462

Introduction:

The ability to deposit thin films of various materials is important for the fabrication of modern microelectronic devices and for enabling a variety of investigations of fundamental physical principles. There are many techniques for controllably depositing thin films onto a substrate with thicknesses as small as a few nm. In this project, you will focus on one deposition technique – thermal evaporation – and produce thin metal films. You will produce patterns in the thin films using a shadow mask which is configured for subsequent electrical measurements of the resistance of the film.

Objectives

- Learn about techniques for producing a high vacuum.
- Learn about techniques for measuring pressure.
- Perform the thermal evaporation of thin metal films.
- Study the operation of quartz crystal thickness monitors.
- Learn how to use a lock-in amplifier to detect small signals.
- Study the relationship between measured resistance to parameters of thin film structure.

Suggested Reading: There are informative manuals on vacuum techniques and thin film deposition available on the website of the Cornell Nanoscale Facility (CNF). There is a discussion of diffusion pumps and lock-in amplifiers in R.A. Dunlap *Experimental Physics*, Oxford University Press, 1988. Also, read the treatment of lock-in amplifiers in Horowitz and Hill *The Art of Electronics*.

Suggested Apparatus:

1. Physics Department thermal evaporator in B?, managed by Sam Sampere.
2. Thermal evaporation supplies: tungsten boats, metals, glass slides.
3. Stanford Research Systems lock-in amplifier model 830.

Caution:

- Carefully follow all instructions for the evaporator from Sam Sampere for safety and avoiding damage.
- Wear gloves when handling indium.

Getting acquainted with the thermal evaporator
The introduction to the thermal evaporator should be undertaken with Sam Sampere and either the TA or instructor. Safety is important!

Important features to study include:

- Vacuum seals, vacuum pumps – mechanical roughing/backing pump, diffusion pump
- Evaporation power supply, electrodes, boats
- Thickness monitor
- Metals, substrates, shadow masks.

Depositing films

1. Load glass slide with shadow mask.
2. Load tungsten coil boat with aluminum for evaporation.
3. Operate valves appropriately to evacuate chamber. Record pressure at one-minute intervals – after completing deposition process, plot pressure *vs.* time.
4. When pressure reaches the system base pressure, evaporate aluminum by slowly ramping power to the boat. Aim for a target deposition rate of $\sim 5\mathring{A}/s$ and record the corresponding power, as percentage of full scale.

5. After depositing 150$\mathring{A}$ of aluminum, ramp down power. Allow system to cool, close valves appropriately and vent chamber to remove sample.
6. Repeat procedure, but deposit 300$\mathring{A}$ of aluminum on a different glass slide.
7. If time permits, evaporate 150$\mathring{A}$ of chrome using Cr-coated tungsten rod.

Measuring resistances

1. Discuss the operation of the lock-in amplifier with the instructor or TA.
2. Choose an appropriate load resistor and perform a test measurement of the resistance of a 1Ω resistor.
3. Remove shadow mask and substrate from holder and mount substrate in wiring jig.
4. Discuss technique for attaching wires between thin-film strips and wiring jig using indium pads. Choose one of the three strips on the slide and wire current leads to the ends of the strip. Attach leads for voltage pairs
5. Measure the resistance of various lengths of the strip, as defined by the locations of the voltage probes.
6. Repeat the previous two steps for the other strips on the same slide.
7. Repeat the previous three steps for the other slide with the different film thickness.

Memoranda

- Plot the variation of resistance with strip width and length.
- Based on your measurements, compute the resistivity for the film and compare with the appropriate bulk value.
- Compare your measurements for the films with the two different thicknesses. Do they vary as you would expect? Do they correspond to the same resistivity of the film?