

Exercise 3

Physical Vapour Deposition

Physical Vapour Deposition (PVD) technology consist of the techniques of arc deposition, ion plating, resistance evaporation, electron beam evaporation, sputtering and many others. It is used to deposit films and coatings or self-supported shapes such as sheet, foil, tubing, etc. The thickness of the deposits can vary from angstroms to millimetres. The application of these techniques ranges over a wide variety of applications from decorative to utilitarian over significant segments of the engineering, chemical, nuclear, microelectronics and related industries. Their use has been increasing at a very rapid rate since modern technology demands multiple and often conflicting sets of properties from engineering materials, e.g. combination of two or more of the following – high temperature strength, impact strength, specific optical, electrical or magnetic properties, wear resistance, fabric ability into complex shapes, biocompatibility, cost, etc. A single or monolithic material cannot meet such demand in high technology applications. The resultant solution is therefore a composite material, i.e., a core material and a coating each having the requisite properties to fulfil the specifications.

PVD technology is a very versatile, enabling one to deposit virtually every type of inorganic materials – metals, alloys, compounds and mixtures thereof, as well as some organic materials. The deposition rates can be varied from 10 to 750 000Å (10Å=1nm) per minute, the higher rates having come about in the last 25 years with the advent of electron beam heated sources.

The thickness limits for thin thick films are somewhat arbitrary. A thickness of 10 000Å (1µm) is often accepted as the boundary between thin and thick film. A recent viewpoint is that a film can be considered thin or thick depending on whether it exhibits surface-like or bulk-like properties.

The objective of deposition processes is to controllably transfer atoms from a source to a substrate where film formation and growth proceed atomistically. In evaporation, atoms are removed from the source by thermal means. Two methods of PVD are used in our laboratory:

- a) resistance (thermal) evaporation
- b) electron beam evaporation

The aim of the exercise is to look at electron beam gun (post is under construction) and to perform complete process of thermal evaporation using the wafer from Exercise 2. It includes

carrying out process of pumping high vacuum, heating up tungsten boat with Al as a source, evaporating, switching off system and checking the silicon wafer with Al layer.

The physical vapour deposition processes take place in vacuum. The vacuum environment is a complex one and is neither a void nor inert. To be successful, thin film deposition must be done with awareness of the effect of the environment upon the vapour flux and growing film. The three most important aspects of the vacuum environment to thin film deposition are: the pressure, expressed as the mean free path, the partial pressure of reactive gasses and in inert working gasses and the film vapour arrival to reactive gas impingement rate ratio. In our laboratory system shown in Fig. 1. is employed for vacuum evaporation of metals. The basic pumping system consists of oil-diffusion pump backed by rotary mechanical pump. The upper chamber must be vented to air in order to load substrates. A dual vacuum-pumping circuit consisting of three valves, in addition to vent valve, is required to accomplish these ends.

A) Resistance evaporator

Deposition of thin films from resistance heated evaporation sources was the first practical thin film deposition technique. The resistance refractory metal source is the heart of the evaporation system (Fig.1). Selection of a suitable source (Fig.2) is the critical decision in designing a resistance evaporation process. A source is selected to meet the following process requirements: evaporant compatibility (many important evaporants dissolve all refractory metals to some extent), capacity and power availability. In general, sources are made of refractory metal (Mo, Ta, W) of three design classes: coils, boats and special purpose designs.

B) Electron beam gun

The electron beam heated evaporation source is a thermal evaporator as is a resistance heated source. It differs from resistance heated source in two ways: the heating energy is supplied to the top of the evaporant by the kinetic energy of a high current electron beam, and the evaporant is contained in a water cooled cavity or hearth. Heating by electron beam allows attainment of temperatures limited only by radiation and conduction to the hearth. Evaporants contained in a water cooled hearth do not significantly react with the hearth, thus providing a nearly universal evaporant container.

The electron beam heated source is made up of a power supply and evaporation source. Power supply (Fig.3) consist of three interconnected but independent power supplies, high voltage, filament and magnet. Evaporation source (Fig.4), as used for high technology thin films fabrications has 3 basic sections: the electron gun, the beam deflection magnetic lens and the evaporant-containing hearth. The beam is formed in the gun, passes through the magnetic lens and is focused upon the evaporant.

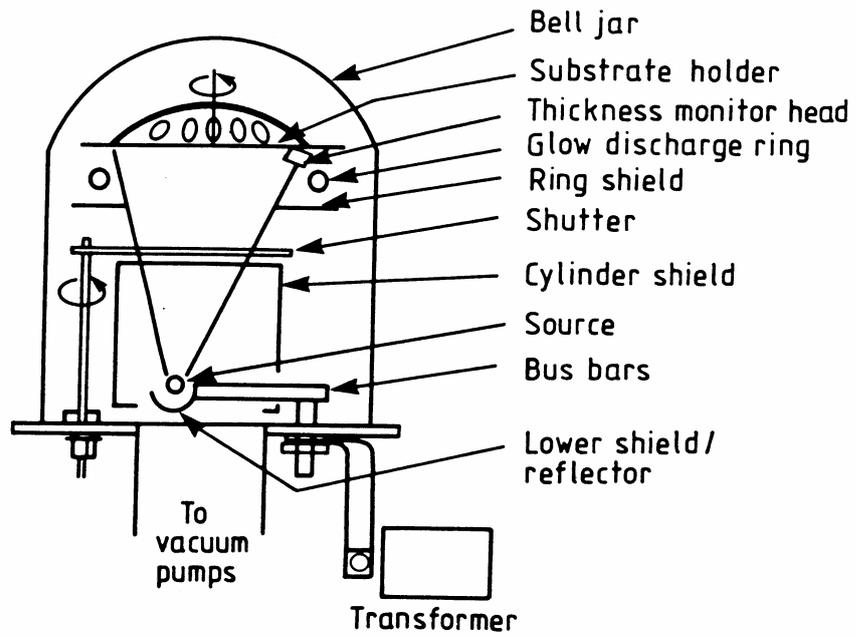


Fig.1

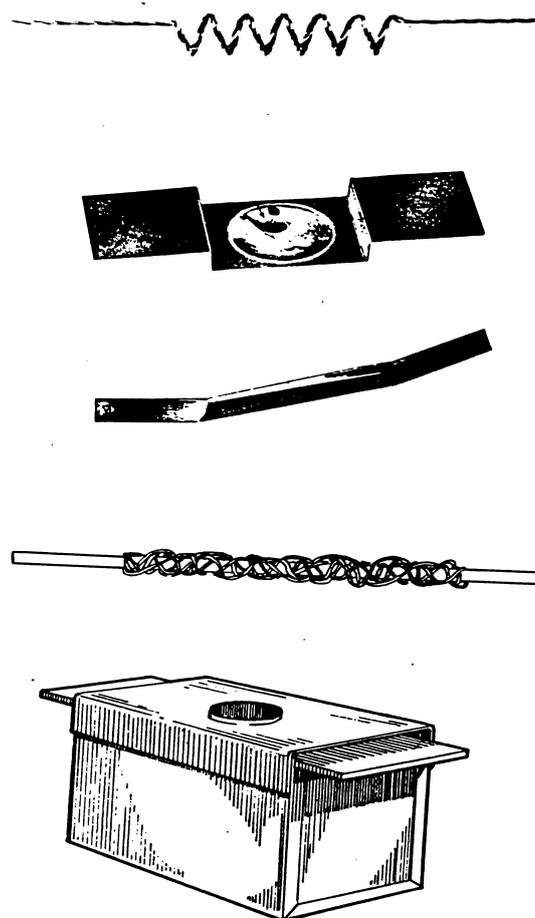


Fig.2

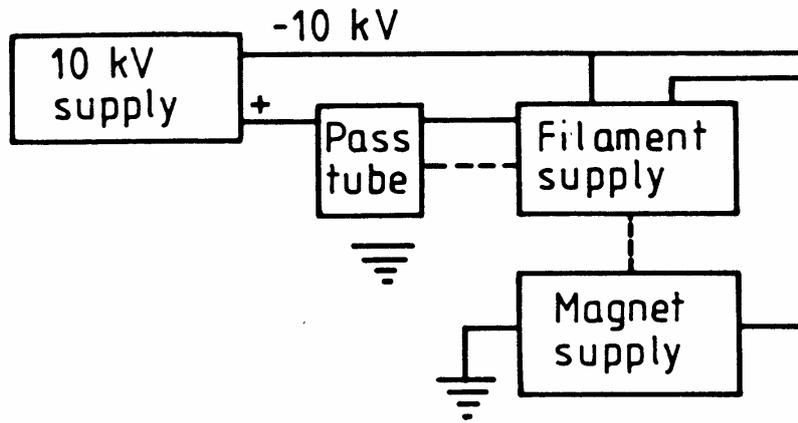


Fig.3

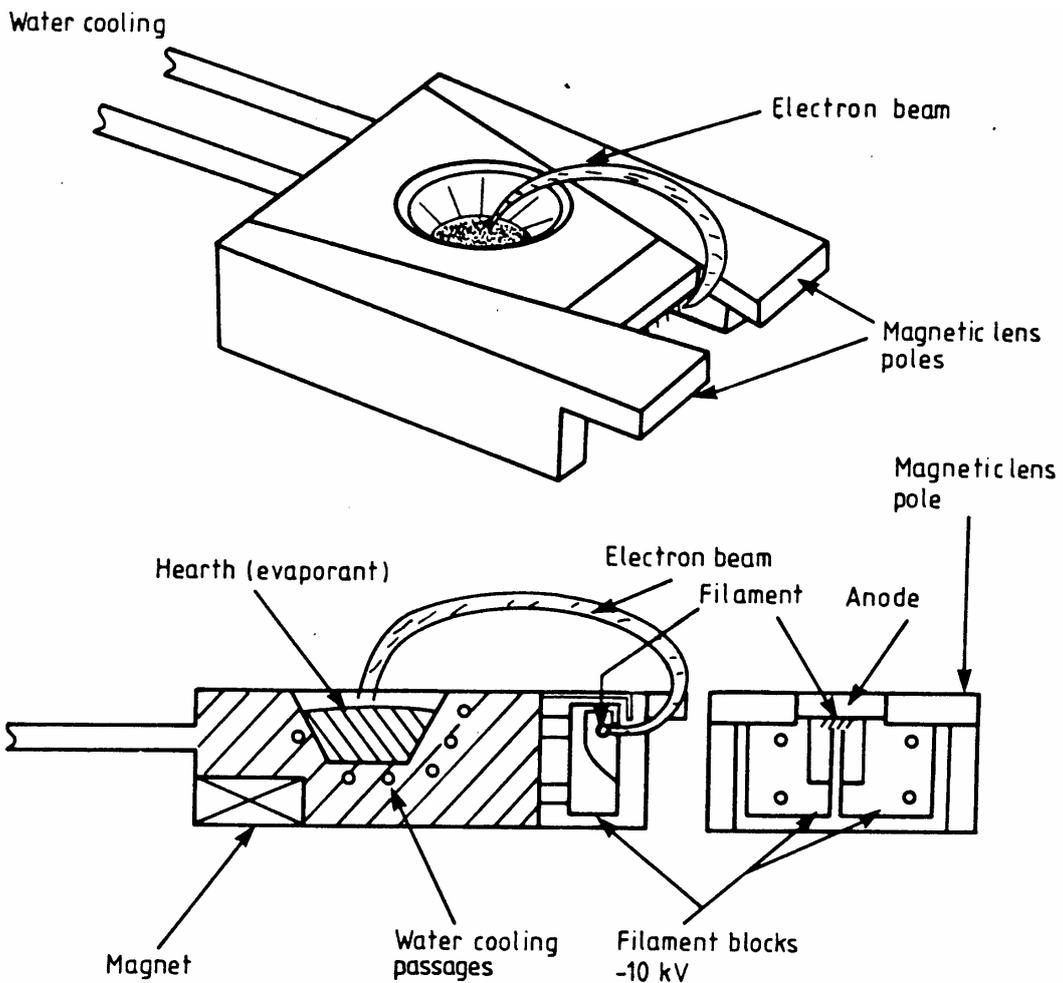


Fig.4

To perform the evaporation one should:

1. Switch on the cooling water – taps are behind vacuum plant, next to the wall
2. Switch on vacuum plant
3. Open the chamber (button UP) and place wafer in Al holder above evaporator No2 or No3 and close the chamber (button DOWN)
4. Pump high vacuum:
 - a) Switch on rotary pump, open valve P(3) and pump prevacuum in chamber – 10^{-2} hPa
 - b) Close P(3), open P(2) and pump prevacuum in diffusion pump
 - c) Open P(1), switch on diffusion pump and pump high vacuum in the chamber - more than 10^{-3} hPa (it takes 30 minutes)
5. Evaporating:
 - a) Select proper evaporator and switch it on
 - b) Increase power slowly
 - c) After melting Al maintain power till the end of evaporating Al
 - d) Decrease power to zero and switch it off
6. Wait 7 minutes, close P(1) and vent chamber – valve P(4)
7. Open the chamber, take wafer out and close the chamber
8. Pump prevacuum in the chamber
9. Close P(3), open P(2) and switch diffusion pump off
10. After 15 minutes close P(2) and switch rotary pump off
11. Examine the process quality under the microscope. Consider smoothness and continuity and possible contamination.

WARNING:

Any of your actions must not be performed without the supervision of the lab staff. This is for your safety only!