



Ion-Assisted Deposition (IAD)

Film Formation Methods [1]

The formation of films on a glass surface can generally occur in a subtractive or additive way by chemical or physical processes. In the former, the multi-component glass loses some of its constituents on or in the regions near the surface through chemical or physical action. Films obtained using this method is less common as compared to additive methods. The common methods used in deposition of films using the additive method are:

- (a) deposition through using chemical solutions
- (b) immersion or dip-coating
- (c) spraying
- (d) ink-jet coating
- (e) spin-coating
- (f) chemical vapor deposition (CVD)
- (g) physical vapor deposition (PVD)

Film deposition using chemical solution can be an inorganic or organic process. The electroplating process can also be classified under this category and this inorganic process can deposit films from a fraction of a micron¹ to few hundred microns. Coatings are uniform and usually made up of one type of coating material.

One example of an inorganic deposition process is bio-mineralization. This is a self-organizing process where under the presence of certain enzymes, the dissolved minerals begin to assemble themselves in well-organized structures. One such example found in nature is the forming of sea shells in the ocean. This method of film formation is still an active research area.

Immersion and spraying are widely used in depositing films. It is an inexpensive method but the control of the thickness and uniformity of the coating is difficult. Spin-coat and ink-jet printing give a better control over the thickness and uniformity of the coating. Ink-jet printing technique is used in the manufacture of Organic Light Emitting Diodes (OLED).

Chemical Vapor Deposition (CVD) is a well established process and there are various configurations of the process ranging from deposition under atmospheric pressure to vacuum deposition. In CVD, the material to be deposited on the glass surface is in the form of gases. The gases react on the surface of the

glass forming a film. CVD process is commonly used in the fabrication of wafers.

In PVD, coatings are produced on solid surfaces by condensation of elements and compounds from the vapor phase. This is done in a vacuum and some of the common methods are:

- (a) sputtering
- (b) coating by evaporation
- (c) ion-assisted deposition (IAD)

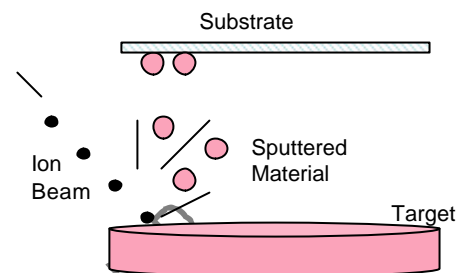


Figure 1: Sputtering Process

Without going too much into the details, in sputtering, a target (e.g. Aluminium if you wish to deposit Aluminium onto the substrate) is bombarded with high-energy ions in a vacuum chamber. The ions will dislodge the material from the surface of the target. The sputtered material then floats towards and get deposited onto the substrate surface. In some cases, the sputtering process is a reactive process i.e. chemical reaction occurs during sputtering. For example, Aluminium Oxide can be deposited on the substrate by sputtering an Aluminium target and at the same time introducing Oxygen into the process.

Evaporation deposition is different from sputtering. In this case, the actual material, that needs to be deposited onto the substrate, is evaporated using an electron beam. For example, if Aluminium Oxide need to be deposited, the Aluminium Oxide material is evaporated in a crucible using an electron beam and the evaporated material will then deposit onto the surface of the substrate.

In IAD, the process is similar to evaporative coating but the evaporated material are further bombarded with high energy ions such as Argon ions. The Argon ions (see Figure 1 for Leybold² Advance Plasma Source Coater) are generated using a plasma source. During collision between the Argon ions and the evaporated material, some momentum is transferred from the Argon ions to the

¹ As a comparison, the diameter of a human hair is 80 microns

² Leybold is one of the suppliers of IAD systems



evaporated material. When the evaporated material condenses on the substrate surface, it forms a dense layer of coating. Any Argon ions that hit the coating will also help to compact the material deposited.

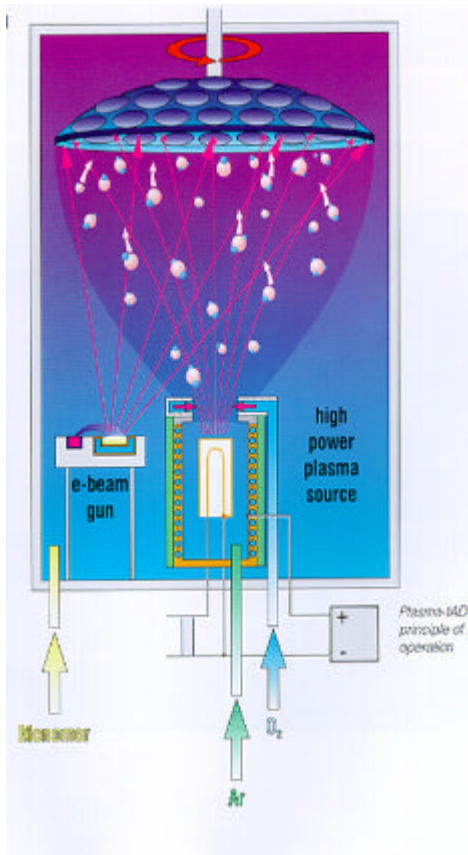


Figure 2: Leybold APS

In the Leybold system, the substrates are held in a substrate holder above the plasma source and the crucible holding the coating material. There are two types of substrate holder. One is the calotte or dome shaped substrate holder. The substrates are mounted onto the calotte with the underside of the substrate facing the coating material. When the coating material is evaporated, it will take the line-of-sight and travels towards the substrate. The shape of the calotte is optimized so as to capture most of the materials evaporated. The calotte also rotates at a certain speed to ensure that the coating is uniform for all the parts on the calotte.

Another type of substrate holder is the planetary system. In the planetary system, the substrate holder consists of four circular discs in an assembly, hung above the coating materials and plasma source. The circular discs themselves can rotate on their axis and at the same time the whole assembly of discs rotates on another axis; like the planets orbiting round the sun. The planetary system is good

for very uniform coatings and suitable for producing high-end filters.

The thickness of the coatings is monitored on-line using precise optical monitoring systems, which can control the thickness of the coatings to fraction of a nanometer.

Which Process Is Suitable For Optical Thin Film Coatings?

The materials used in optical coatings are usually compounds such as oxides (SiO_2 , TiO_2 , Al_2O_3 , Ta_2O_5), fluorides (MgF_2 , BaF_2) or sulphides (ZnS). For multi-layer coatings, alternate layers of different materials, e.g. SiO_2 and TiO_2 , are used to give the desired optical properties. The thickness of each layer has to be in the order of quarter of a wavelength of light (about 100nm to 200 nm thick) and must be very uniform to achieve the desired optical properties or functions [2,3].

From the processes described, it is very clear that not all the processes can be used for optical coatings. For products that require coatings for cosmetic appearance e.g. metallic finish, methods such as electro-plating, immersion coating and spin-coating can be used. If the optical functional requirement is not so stringent such as anti-reflection (AR) coating on architecture glass, dip-coating can be used. For other optical functional coatings, it has to be done using vacuum deposition process.

In the deposition of optical thin films, the common vacuum deposition methods are sputtering, evaporative deposition or IAD. Sputtering is widely used in creating reflective metallic surfaces such as mirrors. It is a fast process and it is almost a 'cold' process. This means that plastic can also be sputtered and it is used in creating the reflective surface on compact discs.

For creating other optical functional coatings [3], such as filters, sputtering is less suitable because the coating materials such as SiO_2 cannot be sputtered directly. Instead, a Silicon target is sputtered and oxygen is introduced into the process to cause a chemical reaction to form SiO_2 . Controlling the reactive sputtering process to form SiO_2 to the desired thickness is also not easy. Sputtering is also not suitable if the substrate has a complex geometrical shape. So, for higher requirement optical functional coatings, evaporative deposition has to be used.

Between the two evaporative methods, IAD gives a superior coating. IAD had been proven to give:



- (a) extremely good adhesion between film and substrate
- (b) high density of film (often the same density as the bulk material)
- (c) relatively uniform coating of substrate of complex shape
- (d) a high coating rate
- (e) able to coat plastic substrates
- (f) good thermal stability of coatings resulting in stable optical spectrum over different operating temperatures [4].

The last point is important because the coating should not deteriorate over time or change when the temperature changes. If it does, the optical performance will change and this will be disastrous for narrow-band filters.

References:

- [1] "Coatings on Glass", H.K. Pulker, *Elsevier Science*.
- [2] "Optical thin film coatings", *Opto-Precision Application Note A001*.
- [3] "Optical thin film applications", *Opto-Precision Application Note A003*.
- [4] "Characterisation of a hardened ultrastable UV linear variable filter and recent results on the radiometric stability of narrow band interference filters subject to temperature/ humidity, thermal/ vacuum and ionization radiation environment", Donald F. Heath, Ernest Hilsenrath and Scott Janz, *Optical Remote Sensing of the Atmosphere and Clouds*.

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