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PVD Processes: Fixtures & Tooling

Although there is no general definition for physical vapor deposition (PVD) fixtures and tooling, the following description applies. Fixtures can be defined as the removable and reusable structures that hold the substrates, and tooling as the structure that moves the fixtures (and generally remains in the system).

Fixtures are very important components of the PVD system. The number of substrates the fixture will hold and the cycle-time of the deposition system determine the product throughput, or number of substrates that can be processed in one hr. Compact discs (CDs) for the music industry, for example, were initially coated in batches of several hundred in a large vacuum deposition chamber. Today they are coated one-at-a-time in a small chamber, which is integrated into a plastic molding machine with a cycle time of 2.8 sec. To achieve the same throughput in a large batch-type system holding 500 CDs would require a cycle time of about 25 min, and integration into the plastic molding operation would be difficult.

The fixtures may be either in a stationary position during the deposition, or may be moved around in the system so that all substrates receive the same deposition conditions. This procedure ensures that all the deposited films have the same properties (*i.e.*, position equivalency).

Fixture Configurations

Fixtures often have a very open structure, and there are several common fixture configurations, as can be seen in the accompanying figure (examples *a–f*).

Pallet Fixtures

Example *a* of the figure depicts a pallet fixture on which the substrate lies and is passed over the deposition source. The planar magnetron sputter deposition source provides a dual-track linear vaporization pattern of any desired length. By making the linear source longer than the substrate's width, a uniform film can be deposited. This type of fixture is used to deposit films on 4-in. diameter silicon wafers and 10-ft wide architectural glass panels. It has the advantage that the substrates are held in place by gravity.

Example *b* shows a multiple-pallet fixture, which can be used to deposit multilayer films on several substrates by passing them over different sources that are turned on sequentially. It can also be used to deposit alloy or mixture films by having the sources turned on simultaneously.

Drum Fixtures

Substrates are mounted on the exterior or interior surface of the drum fixture (example *c*), then rotated in front of the vaporization source(s) located on the interior or exterior of the drum. The drum can be mounted horizontally or vertically. Horizontal mounting is preferred when the vaporization source is a linear array of evaporation sources, such as in the evaporation of aluminum for reflectors.

Vertical mounting is often used when the vaporization comes from a magnetron sputtering source. The drum fixture design allows the substrates to cool during rotation. Temperature-sensitive substrates, therefore, can be coated without a significant temperature rise.

The two-axis drum source in example *d* (mounted horizontally or vertically) is used to coat three-dimensional substrates, such as metal drills, or to coat complex-curvature surfaces, such as auto headlight reflectors. The fixture's open structure allows deposition on the part, even when it is not facing the vaporization source.

Calotte Fixtures

Example *e* shows a hemispherical calotte fixture where the substrates are mounted on a rotating fixture that is attached to a section of a rotating hemisphere. When using a small diameter vaporization source, such as an evaporation filament mounted at the center of the sphere, all points on the sphere are equi-distant from the source, which aids in depositing a uniformly thick film. Uniform coatings on the interior surface of the calotte can be achieved using an S-gun magnetron source, which has a broad vaporization plume. This type of fixture is often used to coat optical components.

Barrel or Cage Fixtures

A barrel or cage fixture (example *f*) has a grid structure that contains the substrates. By rotating the cage, the substrates are tumbled, thereby exposing all surfaces to the deposition. This type of fixture is used to coat small substrates, such as aluminum-coated titanium fasteners for the aerospace industry.

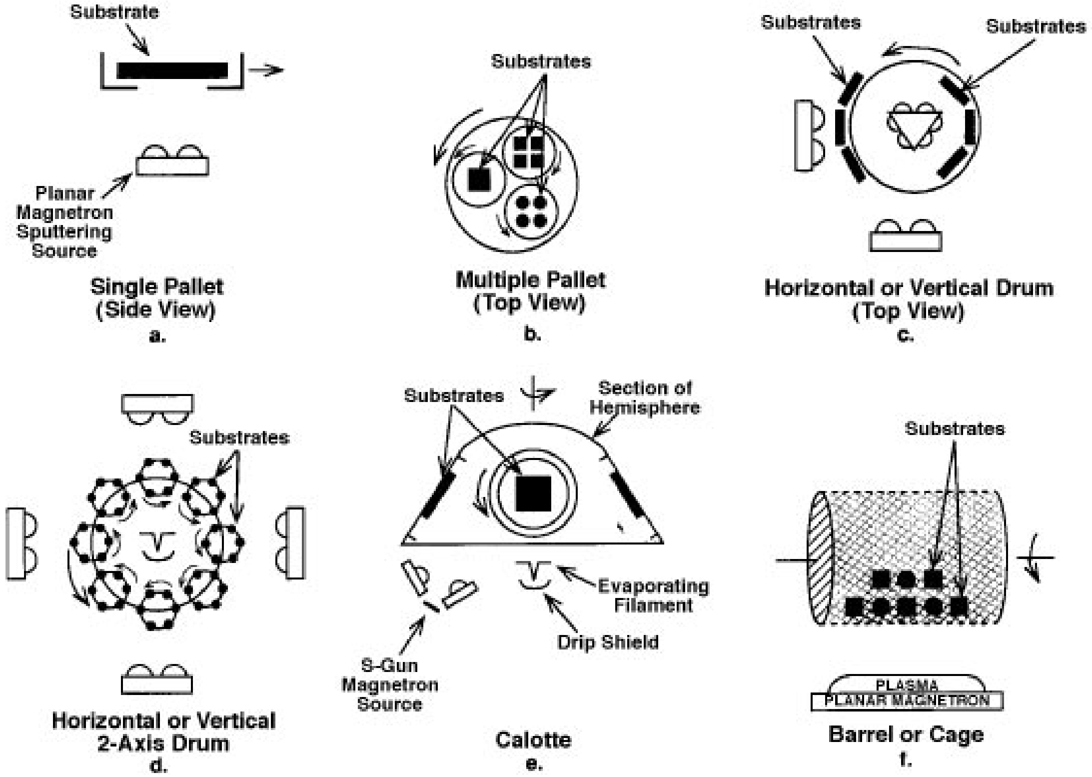
Design Considerations

When using fixtures where gravity will not hold the substrates on the fixture, some type of mechanical clamping must be used. The clamping points are not coated, however, so the substrates and film structure should be designed appropriately. If 100-percent coverage is necessary, a cage fixture should be used. As an option, the clamping points on the substrate can be moved during the deposition to allow full coverage. In some cases, however, the substrate must be coated a second time for full coverage.

In addition, some fixtures must be designed so that they can be passed from one tooling arrangement to another, such as in load-lock systems.

In ion plating applications, a high voltage must be applied to the fixture.

Common Fixture Configurations



If the fixture is rotating or translating, electrical contact for DC power must be made through a sliding contact. Often this is through the bearings used on the rotating shaft. Wear, galling and seizure of the contacts can be minimized by:

- Using hard materials in contact,
- Using an electrically conducting anti-seize lubricant (selenide), or
- Using non-sticking contacting materials, such as osmium-to-gold.

If high currents are used, the contacting areas should be large. For rf power to be applied to the fixture, the surfaces do not need to be in contact, because the non-contacting surfaces can be capacitively coupled.

Moving surfaces in contact can generate particulates in the deposition system. If these particles fall on substrate surfaces, they will cause pinholes in the deposited film. Proper design of the fixturing can minimize this problem.

Linear and rotational motion can be introduced into the chamber by mechanical or magnetic feedthroughs. Examples include:

- Metal bellows, which allow no leak path;
- O-ring seals, which should be lubricated and differentially pumped to reduce leakage; or
- Ferrofluidic seals.

Moving fixtures are heated by radiant heating from quartz lamps, by electron bombardment, or, as in the case of sputter-cleaning and ion-plating, by ion bombardment. Stationary fixtures are cooled with liquids or gases. Helium, which has a high thermal conductivity, is often used. Because cooling moving fixtures is difficult, it is best accomplished with a cold, infrared absorbing surface near the fixture—radiant cooling is most effective. In some cases, rotating gas or liquid feedthroughs can be used to cool solid, moving fixtures, such as drum fixtures. These types of feedthroughs often present problems, however, and should be avoided.

The deposition chamber should be designed around the type of fixture to be used. Often the fixture represents a major capital investment, so careful consideration should be given to its design. When the fixture has a large surface area, it should be cleaned and handled carefully to prevent introducing contamination into the system. Because several fixtures are usually available during an operation, one fixture can be used while the others are in the process of being stripped, cleaned and loaded with substrates.

Design considerations also apply to tooling, as well as to fixtures. Tooling can be used to move masks and shutters, and also to move the vaporization source. The latter is useful when coating a large part in a relatively small chamber. ❑