Chemical Vapor Deposition vs. Physical Vapor Deposition

APPLICATION NOTE

To discuss the differences between the chemical and physical vapor deposition processes, we need to describe them.

Chemical Vapor Deposition (CVD) – A precursor is introduced into a reaction chamber and is controlled by balanced flow regulators and control valves. Precursor molecules pass by the substrate, are drawn into the boundary layer, and are deposited on the surface of the substrate.

Physical Vapor Deposition (PVD) consists of different methods, such as evaporation, sputtering, and molecular beam epitaxy (MBE).

- **Evaporation:** Material is heated to a gas phase, where it then diffuses through a vacuum to the substrate.
- **Sputtering:** Plasma is generated first; this plasma contains argon ions and electrons. Next, atoms from the target are ejected after being struck by argon ions. The atoms from the target then travel through the plasma and form a layer on the substrate.
- **Molecular beam epitaxy:** The substrate is cleaned and loaded into a chamber that is evacuated and heated to drive off surface contaminants and to roughen the surface of the substrate. The molecular beams emit a small amount of source material through a shutter, which then collects on the substrate.

Advantages and Disadvantages

Depending on the application, there are sound arguments for the use of either process (PVD or CVD).

One reason to use a physical vapor deposition process (such as sputtering) instead of chemical vapor deposition is the temperature requirement. CVD processes run at much higher temperatures than PVD processes, usually between 300°C and 900°C. This heat is supplied by a furnace, RF coil, or laser, but it always heats the substrate. Substrates that cannot tolerate this temperature must have thin films deposited by the physical form of vapor deposition instead. The benefit of the substrate temperature in some CVD processes is that there is less waste deposition, especially in cold-wall reactors, because only the heated surfaces are coated. With the use of a laser heating system, the chemical vapor deposition process becomes selective to the path of the laser; this is a distinct advantage over physical vapor deposition methods such as sputtering.

Molecular beam epitaxy (PVD process) has a distinct advantage of atomic level control of chemical composition, film thickness, and transition sharpness. This process is relatively more expensive, but is worth the added cost for applications that demand higher precision.

Sputtering (PVD process) does not require the use of specialized precursor materials as used in CVD. Sputtering has a wider range of materials readily available for deposition.

Another advantage of physical vapor deposition over chemical vapor deposition is the safety issue of the materials that are used for chemical vapor deposition. It is known that some precursors and some by-products are toxic, pyrophoric, or corrosive. This can cause issues with material handling and storage.

There are applications that could use either deposition method successfully. However, an experienced engineer could easily recommend chemical or physical vapor deposition for a job based on criteria such as cost, film thickness, source material availability, and compositional control.

Form No. 98752 (A4) R0

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