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The Phototron[tm] and UV Enhanced Deposition: Part 1

Patent No. 4660297

by Phil Danielson

As physical vapor deposition processes and film requirements become more stringent, it becomes more and more important to consider process parameters in more and more detail. Low process pressures and attention to residual gas makeup have brought about an increased awareness of the problems of hydrocarbon contamination and the effects of water vapor. This is evidenced by the shift to oil-free pumping and the steady increase in the use of Phototron UV treatment to reduce water vapor concentrations. Additionally, a great deal of attention is presently being focused on both the effects of solid particles and the formation of water vapor aerosols during roughing. The effects of the interaction of residual water vapor with the substrate surfaces before deposition and with the growing film during deposition can also be crucial to film properties.

WATER SORBED ON THE SUBSTRATE

Any and all water vapor that is sorbed on the surface of a substrate is likely to cause problems to at least some extent when a thin film is deposited, and any substrate that is either placed within a batch system or introduced through a loadlock is likely to be heavily coated with sorbed water vapor. The most obvious problem is the difficulty in obtaining good adherence over a thick film of sorbed water as is shown schematically in Figure 1.

The routine use of a Phototron to reduce the desorption rate of water from a chamber's inner surfaces will result in the desorption of a portion of the water sorbed on a substrate within the chamber, but complete desorption will require a higher watt density on the substrate. This is usually accomplished with a dedicated Phototron source called a "Substrate Desorber," which is fitted with a variable reflector to concentrate the UV power onto the substrate's surface, shown schematically in Figure 2. Watt densities required for complete desorption of water from a substrate are shown in Figure 3.

Although partial or complete desorption will have a varying effect upon the adherence of the thin film, the presence of water on the substrate surface can have other effects upon the film. Water molecules will have an effect upon the presence of nucleation sites for the film as the evaporant or sputterant arrives. The effect will vary greatly depending on the process, materials, etc., but a good example is the detrimental generation of bright spots in optical films over sorbed water sites. The resultant variations in film structure around these sorbed water sites will often result in variations in film structure and integrity, which in turn result in variations in the film's application behavior in terms of variations in reflectivity and transmission in optical films and variations in electronic performance in electrical films. In general, this effect can be likened to sweeping ball bearings under a rug.

Surface Cleanliness

The desorption of water vapor from the surface of the substrate has several advantages beyond the mere removal of water. When a substrate is introduced into a vacuum chamber, it is coated with a matrix of sorbed water that is many hundreds of monolayers thick. Within that matrix, contaminants are often trapped.

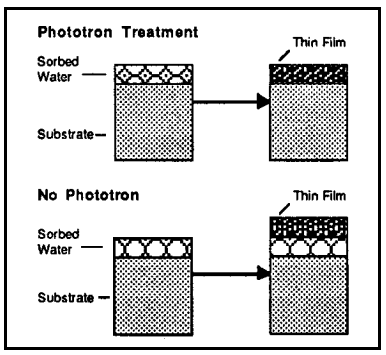

Figure 1. Effect of substrate surface conditions on deposited film.

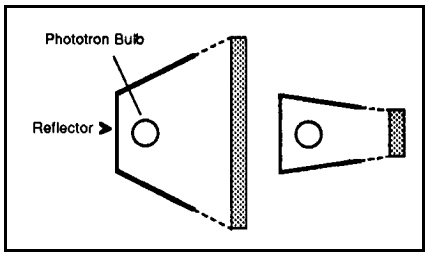

Figure 2. Examples of reflector position on power density.

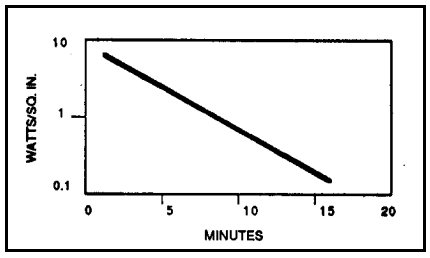

Figure 3. Effect of UHV power density on time required for complete desorption.

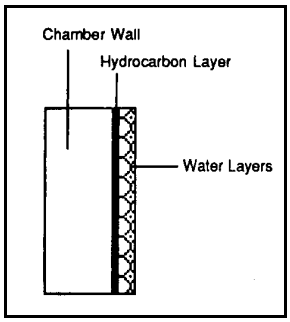

Figure 4. Hydrocarbon contamination covered by sorbed water.

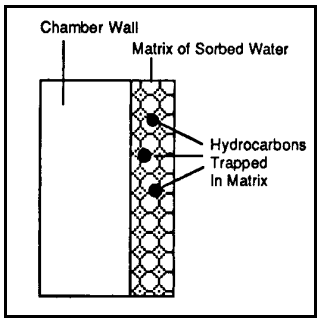

Figure 5. Hydrocarbons trapped in matrix of sorbed water.

Layers of hydrocarbons picked up during handling prior to introduction into the chamber often coat the substrate below the water matrix as shown in Figure 4. Additional hydrocarbons are often found trapped within the matrix as shown in Figure 5. Since some water desorption is likely to occur during deposition due to localized heating caused by ion energy transfer or heat of condensation, it becomes probable that a percentage of the trapped hydrocarbons will be freed from the water matrix to become available to be trapped either physically or chemically within the depositing film.

In fact, any gases that are trapped within the water bed's matrix will be released during desorption erosion of the water bed matrix. Chemically active air gases such as N_2, O_2, etc., are often trapped within the water matrix as the water bed forms while the chamber is up to air, as is shown in Figure 6. Subsequent desorption during deposition processes frees these gases for interaction with the forming film. Although these active gases or hydrocarbons as discussed previously are so few in number that they wouldn't cause a significant pressure rise within a chamber if released, it must be considered that they are released directly into the volume around the growing film and would easily have as much contaminant contribution to the film as would a chamber many orders in magnitude higher in pressure than the normal pressures specified for successful deposition processes.

Conclusions

The effects of water sorbed on the substrate discussed in the above section would indicate that the quality of most thin films formed by physical vapor deposition would be improved by total or partial desorption of water vapor from the substrate. Use of the Phototron UV desorption technique would easily accomplish the desorp-tion requirements whether a standard open Phototron UV source or a Phototron Substrate Desorber UV source were used. Choice of the specific source would be dependent upon the process, the process system, and the degree of desorption required by the process.

Continued in Part 2

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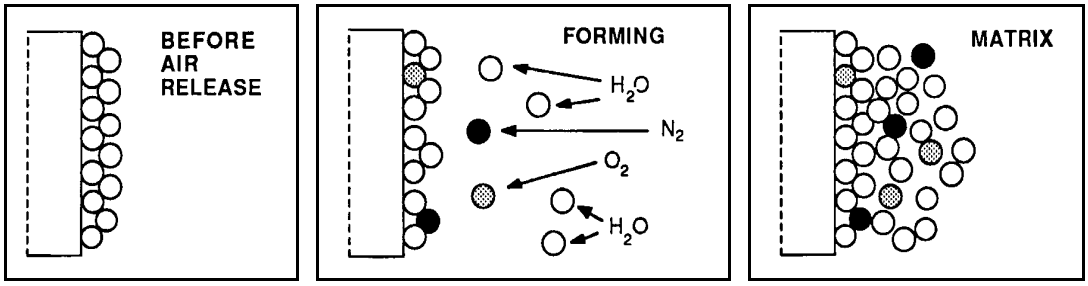

Figure 6. Water matrix trapping gases.

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