Water in vacuum

Water in vacuum is probably the biggest uncontrolled variable in the vacuum deposition process. The surface area of the vacuum chamber will vary as the quantity of stray coating varies between cleaning operations. The amount of moisture that this changing surface area will absorb will depend upon the humidity and the surface temperature. Thus bringing the vacuum system up to atmospheric pressure using dry warm air is much better than simply allowing the ambient air to be used.

Polymer films can contain moisture both within the entrained air and also absorbed in the film. Thus when winding starts the system pressure is often seen to rise from the release of the entrained air. The moisture contained within the polymer film loses the surface moisture quite quickly and then the rest is removed at a speed related than the speed of diffusion through the film. This can be demonstrated by winding the film through a vacuum system. The system pressure will be seen to rise as a result of the water from the surface. If the film is rewound again there will be seen to be an almost identical pressure rise. This is as a result of the water in the bulk of the polymer migrating to the surface whilst the film was in the re-wound roll so that on the second pass there was a similar amount of water available to be removed from the surface the second time as there was available in the first pass. This can be repeated several times with the same effect.

The amount of water contained within the polymer and in the entrained air can be dependent upon the manufacturing conditions, any further processing conditions as well as the storage conditions such as temperature, time and humidity. Thus seasonal changes can have a large effect on the water content of polymer films unless the factory has some form of air conditioning to control the temperature and humidity.

The water content of polymer films is not all bad. The water can improve the heat transfer coefficient between the film and the deposition drum. This effect led to the deliberate introduction of gas between the web and drum to both control and raise the heat transfer coefficient.

Water can be pumped away but the volume of water can slow down the evacuation process and also the volume of water can contaminate the roughing pump oil requiring almost continuous ballasting to raise the pump temperature to flush out the water. Thus it is a better solution to use a pump that specifically pumps water well. This pump is commonly known as a ‘Polycold’ simply because this company has dominated the market for so long. This type of pump works in the same way as a refrigerator by compressing a gas and allowing it to expand again. Where the gas expands it requires energy and takes it by reducing the temperature thus the gas cools a tube, usually of copper, that will condense and freeze any water that collides with the cold surface. This cold tube is usually a coil or serpentine is shape and often sited near to the area where the film surface becomes first exposed after unwinding so that the water has a high chance of hitting the cold surface. This cryocoils can pump water more than ten times faster than diffusion pumps but it can only pump water vapour. As it collects and accumulates all the water on the coils the efficiency can fall as the ice layer increases and after each deposition run the coil needs to be heated and the water collected and disposed of. This pumping system is well developed and makes metallizing paper easily possible even though paper can have anywhere up to a quarter of the weight being the water content.

The water content needs to be controlled if at all possible as it can be a source of problems to the coating quality and not just a productivity issue due to slower pumping speeds. Water is a source of oxygen and so a high water vapour content in the vacuum system can give a higher contamination rate to the aluminium. As the aluminium oxide is transparent it can simply mean that, to achieve a particular optical density where there is a high water vapour background pressure, a greater thickness of metal needs to be deposited to allow for a higher proportion to be converted to aluminium oxide. In the worst cases the water vapour can cause some loss of reflectivity. As the coatings increase in thickness the preferential growth patterns emerge from the different nucleated crystal orientations and this is seen as a surface roughening. Thus it is better to deposit the thinnest possible films the give the highest reflectivity. If the roughness is gross the surface roughness can cause enough scattering that the surface can appear 'milky' or white and even matt rather than reflective. If the oxide thickness is thick the silver metal reflecting surface can also become tinted, most commonly yellow making the metal appear a light golden colour.