

## Cause of Pinholes

Pinholes, sometimes referred to as pin-windows, are best seen by illuminating the metallized film from behind. When viewed from the front the metallized film will have attenuated the light except for a scattering of pinpricks of bright light. The pinpricks of light are each where there is an area of unmetallized film frequently nearly circular in shape. These unmetallized areas are primarily caused by dust or debris on the surface being metallized as the film passes through the deposition zone but sometimes after the debris being moved so that what is left is an unmetallized area that corresponds to the shadow shape of the debris. Occasionally the debris does not roll away but slides away and so the pinhole may also have a scratch track leading away from the unmetallized area.

The metal coating thickness is usually very thin, much less than a micron and so it is very easy for the debris to be very much larger in diameter than the coating thickness. This means that the metal coating will not weld or stick the debris to the surface and it could be moved on any occasion that the film has some front surface contact such as from rollers or when the film is re-wound up.

If you consider that much of the debris will be invisible to the eye it can be hard to know if any film is particularly dirty or if any cleaning process has been effective. Many believe that a vacuum plasma treatment will clean off this debris. The assumption being that the debris is held on the surface by electrostatic attraction and the plasma would neutralise any charge and the debris would then fall away because of gravity. This is not true. The major force holding debris onto the surface is Van der Waals force and this is unaffected by the plasma and so it is only debris of the order 100 microns in diameter, where electrostatic charge is the major force, that this mechanism might work. There are other factors that also need consideration. Debris can be pressed into the surface by rollers, in particular nip rolls, and whilst wound up in a roll. Debris can also have a higher moisture level present where the debris contacts the film that may act as glue holding the debris to the surface. The vacuum plasma will have little or not effect on debris pressed into the surface. The plasma may help remove the moisture but the residuals left may still stick the debris to the surface.

Thus a vacuum plasma treatment may chemically clean the film surface but is not effective in removing debris.

Techniques for removing debris tend to be done outside the vacuum system. Many of the traditional techniques used on glass substrates are inappropriate for polymer webs as the polymers are so much softer. The brushing techniques can end up by scratching the film and creating more damage than the pinholes they are trying to prevent. The only contact method that has shown to be effective is the tacky roll method. This is where a tacky roll contacts the surface of the film and the debris sticks to the tacky roll in preference to the film and so is transferred off the film. The tacky roll can quickly lose the tack as the quantity of debris transferred to it increases. Thus it is common to have a second high tack roll to take the debris off the tacky roll. This high tack roll can be refreshed periodically as it too becomes clogged up with debris. This technique can remove debris down to 0.3 microns where below this size the Van der Waals forces are too great for the debris to be pulled away from the

surface. This tacky roll technique does have the advantage that it can be used in the vacuum system thus minimising the risk of re-contaminating the surface before metallization. A non-contact method of cleaning that is as effective as the tacky roll is to use an ultrasonically pulsed neutralised clean air directed at the film with a vacuum extract to collect the debris off the surface. The ultrasonically pulsed gas has the effect of shaking the debris off the surface allowing the debris to be vacuumed away. As this technique requires air it cannot be used in vacuum.

If the pinholes are not caused by debris then the next most common cause is through 'pick-off'. Pick-off is where the metal is uniformly coated but whilst it is in the re-wound roll some of the metal is transferred across from the front surface to the back surface. Hence the name 'pick-off' that refers to the coating being picked off the surface. There are two aspects to this process of which the first is a limitation in the adhesion of the metal to the polymer web and the second is a high pressure point between successive layers on the rewind roll. Metal adhesion is affected by many factors including the polymer type, any fillers or additives in the polymer that might migrate to the surface and also any surface treatment to the polymer web surface. Thus for some polymers any unpolymerised monomer may be present on the surface, for others slip additives may be present on the surface. These tend to be low molecular weight or low surface energy components that limit the adhesion. Where the metal coats these materials the adhesion is likely to be lower than where it is deposited onto the bulk polymer. To improve the handling characteristics of the polymer webs many have fillers included in the polymer. These fillers protrude from the surface to keep the surfaces apart thus reducing the contact surface area and reducing the coefficient of friction. In reducing this contact area the load between the successive layers is all transmitted primarily through the highest of the protruding filler peaks. These high loads will press the peaks into the freshly metallized coating and in some cases the metal ends up by being better stuck to the peaks than the original surface and is thus transferred and picked off as the roll is next unwound.

The solution to this is to increase the metal adhesion to the surface it is initially deposited onto by optimising the surface energy. It may also require rewinding with lower tensions or considering refining the size and quantity of the filler in the polymer.

Another cause of pinholes that on occasions are not just small, uncoated areas of film but can be holes that penetrate through, not only the coating, but the substrate film too. These are caused by spitting of the metal from the resistance heated deposition sources. The metal or metal oxide can be thrown out of the source as a large quantity and may be hot enough to be incandescent. These sparks or spits may contain enough energy to melt a hole through the polymer web and thus produce a pinhole that is much more damaging than the more common loss of coating type. Where there is less energy the material from the spit just lands on the surface and acts the same as any other debris on the surface. If the material being deposited is aluminium the aluminium oxide that the spit will contain is quite hard and often causes scratches too.