Waste, waste and more waste

One of the key issues for the commercial viability of engineered thin film materials is the amount of waste generated by faulty product, often when a considerable amount of value has been added to the material before it is rejected. A major cause of these rejects is dust or other particlulate contamination so a key step in improving yields is to improve cleanliness throughout the manufacturing process. **Sheila Hamilton of Teknek** discusses new elastomer technologies formulated to address the specific issues of small particle removal

Thin film solar applications have taken an economic hit lately but this has not stopped the research and growth of engineered thin film materials and applications. Of course thin film applications are also driven by Flat Panel Displays (FPD) as well Back Light Units (BLU) are key drivers for engineered thin films providing broader opportunities for research scope and financing.

Engineered thin film devices usemany different layers of coated polymer films in sheet format. These sheets are laminated together, often with glass sheets to form the finished functional unit. Contamination at any stage of the manufacturing process can cause defects, either electrical or optical, which result in the scrapping or rework of these expensive displays.

Some of the demanding requirements of industries in thin film manufacturing are outlined below:

- Thinner films down to 20 microns thick which are particularly difficult to handle and process especially in sheet form.
- The films often have structured rather than flat surfaces. This structure can entrap contaminants within its topography resulting in reduced cleaning effectiveness.
- Many of the coatings used are soft and easily damaged through pressure or scratching.
- Very small particles can cause “killer defects”

To achieve satisfactory yields in these high technology applications exemplary levels of cleanliness in both coating and conversion operations is required. This must however be achieved without impairing the processing of and without damage to the substrates involved.

State of the Art in surface cleanliness is currently the preserve of the semiconductor wafer industry where particles of even a few nanometres must be removed not only from the wafers themselves but also from all the process equipment surfaces. The primary cleaning techniques used in this industry are scrubbing using PVA brushes combined with Ultra and Megasonics, lasers, plasma and blasting with CO_2. While these techniques are ideal for rigid substrates with small surface areas they are not adaptable to processing wide webs or flexible products. Many coatings used are moisture sensitive and any wet technique such as scrubbing or Ultrasonics would damage the coatings. In addition “the adhesion forces of submicron sized particles is sufficiently large that non-contact methods of particle detachment will not remove these particles. The removal energy cannot be transported to the particle sue to the static fluid boundary layer on the surface.” (Kohli, R, 2002)

Clean contacts

Contact Cleaning has been successfully used in the film coating and conversion industries for many years. The currently accepted wisdom regarding the technology is that softer rollers clean more efficiently, ie that cleaning is a function of the Shore Hardness of the elastomer roller. The downside of softer rollers is that they apply a higher adhesion force to the film substrate resulting in tension issues, stretching and scratching in web processing and wrapping of thin films in sheet operation. Currently film processors are in a dilemma namely do they uses harder films to reduce processing issues at the expense of cleaning effectiveness or do they focus on maximum cleaning. Teknek has recognised the need a achieve a balance between optimising cleaning, faster processing and minimising damage

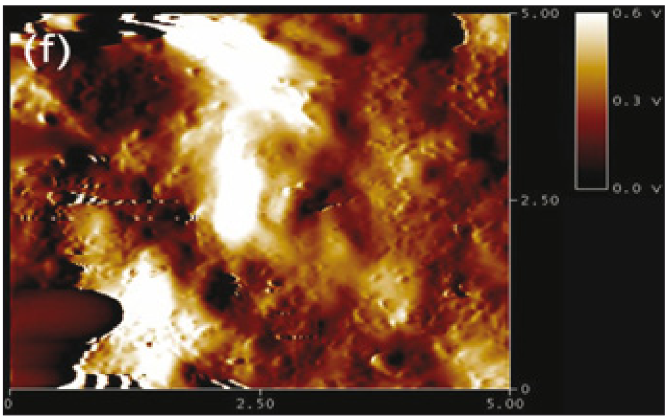

Figure 1. Surface of Teknek F3 Elastomer

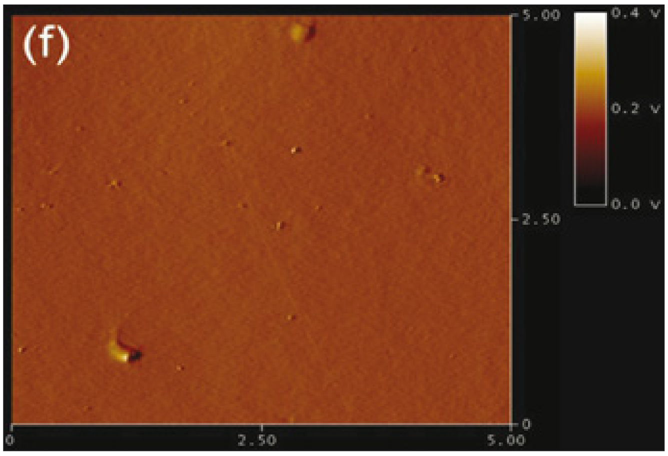

Figure 2. Surface of Teknek Nanocleen Elastomer

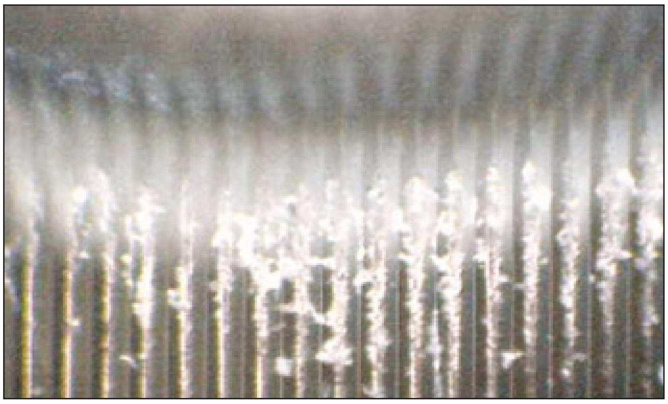

Figure 3. Diecut edge of a structured film with contamination

especially for sheet conversion operations. It has developed a model of its contact cleaning system based on the substantive body of research into the physics of small particles and the forces affecting their adhesion to substrates developed within the semiconductor industry. (Mittal, K, 1995, 1999, 2002, 2006) Small particles are considered to be those under 10 microns as there is a transition away from gravitational forces being dominant at around that particle size.

Research efforts

The aim of this research work was to maximise the removal force on the particle while reducing the adhesion or grab force on the filmic substrate. There are three elements which interact to form the adhesion forces system of the particles on the substrates. These are Particle Transport and Deposition, Particle Adhesion and Particle Detachment. Contact cleaning is concerned with particle detachment but to optimise this element the relative adhesion forces between the particle and the substrate, the elastomer roller and the adhesive roll all have to be taken into account. Initially the adhesion force of deposition onto the elastomer roller must be higher than the adhesion force of the particle to the substrate. Meanwhile the adhesion force of the elastomer to the substrate must be low to avoid processing issues and damage. Finally the adhesion force between the adhesive roll and the particle must be higher than that between the elastomer roll and the particle while the adhesion force between the adhesive roll and the elastomer must be low.

As particle size reduces the surface properties of the particle become more dominant than the bulk properties of the material from which the particle is formed. There are, in addition, many

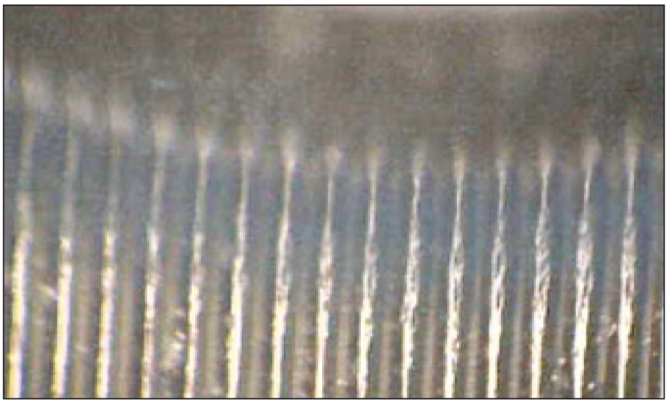

Figure 4. Diecut edge of a structured film after cleaning Autoflex – No Roller

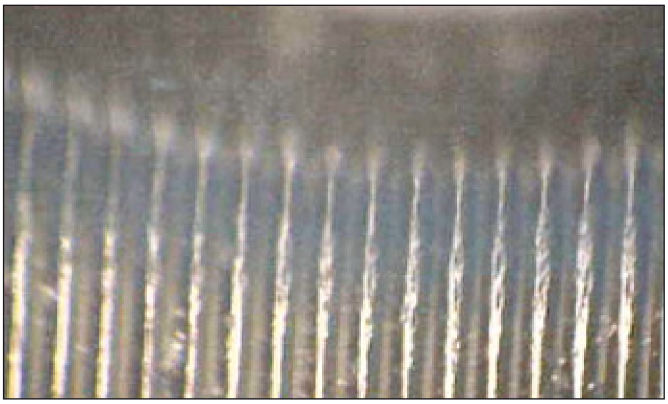

Figure 5. Polyester film before cleaning Autoflex + Nanocleen

types of forces involved in small particle adhesion including van der Waals and its associated forces, Electrostatic forces including coulombic and dielectrophoretic forces and molecular level forces such as hydrogen bonding. The equations defining each of these forces can be readily found in the literature. Each force involves several variables and the resulting model of a contact cleaning system is extremely complex.

In order to reduce the complexity, over the last few years Teknek have carried out a significant amount of empirical research into the key parameters highlighted by the theoretical work. We have developed our own test method to assess the ability of elastomers to detach particles from a surface that we call the Particle Pick Up (PPU) test. There was no industry standard test available to quantify this parameter. This test employs calibrated particles of different sizes, types and morphology and is used to monitor improvements in the cleaning performance of elastomers. This test, in addition to the standard analysis techniques of SEM, EDX and GCMS, is used on different formulations of elastomer to correlate properties both physical and chemical with cleaning performance.

Outcomes

This research has resulted in several improvements to contact cleaning efficiency while at the same time reducing the risk of damage and improving processability particulary in sheet form.

- Increasing the operational window of contact cleaning to remove submicron particles through surface modification. Nanocleen elastomer was designed particles down to 25nm in size from film surfaces during wide web coating. The surface of a standard F_3 roller is shown in Fig 1 while for comparison the surface of Nanocleen is shown in Fig 2
- Cleaning of small particles from Structured film . Contrast enhancement films used in LCD screen often have a grooved surface which can trap particles. Fig 3 shows the edge of a structured film which has been die cut to shape. A significant amount of particles remain both on the surface and within the grooves of the film. Fig 4 is the same section of film having been cleaned using a Teknek special elastomer roller.
- Contact cleaning which does not reduce wettability. History has shown that many contact cleaning rollers reduce the surface energy of a film after cleaning. Teknek's Nanocleen elastomer actually reduces the contact angle and actually increases wettability by removing the small particles. Contact angles for a polyester film before and after cleaning are shown in Figures 5 and 6.
- Highest level of cleaning of 20 micron sheets of gloss /gloss TAC film without damage to or wrapping of films at speeds up to 40 m/min.

By using in depth research into the theory of adhesion forces affecting small particles during deposition, substrate contact and detachment Teknek have been able to construct a model of a contact cleaning system. This model is supported by empirical research into the PPU of elastomers which enables the cleaning system to be tailored to optimise specific performance parameters for specific applications.

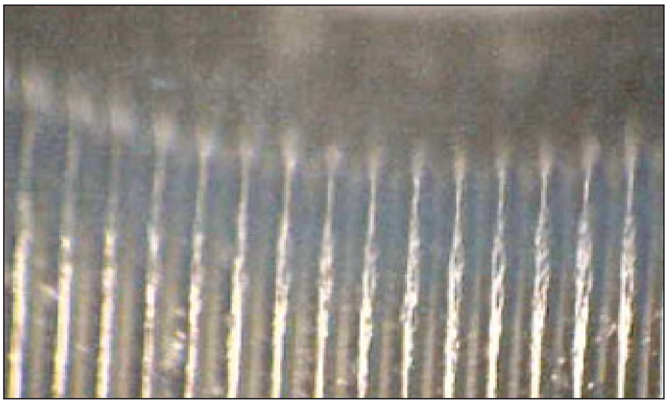

Figure 6. Polyester film after cleaning with Nanocleen

REFERENCES

1 Kohli, R, Adhesion of small particles and innovative methods for their removal,Particles on Surfaces 7, Ed K L Mittal, 2002, VSP BV Utrecht.

2 Mittal, K.L., Ed Particles on Surfaces – Detection, Adhesion and Removal, 1995,Marcel Dekker, New York

3 Mittal, K.L., Ed Particles on Surfaces – Detection, Adhesion and Removal 5&6, 1999, VSP BV Utrecht

4 Mittal, K.L., Ed Particles on Surfaces – Detection, Adhesion and Removal 9, 2006, VSP, Leiden

5 Cardona, C and Giraldo, J, Ed, Thin Films and Small Particles, 1988, World Scientific Publishing Co, Singapore