Advances in Contact Cleaning for Yield Improvement

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Abstract

There is an increasing trend towards coatings containing nanoparticles being applied to webs to enhance their functionality, in particular their optical properties. These coatings are extremely thin and as such are very susceptible to defects caused by microscopic particles of contamination on the surface of the web. The only effective method of removing such small particles from the surface of sensitive webs in through the use of contact cleaning technology. However because this involves touching the surface of the web with the cleaning roller there is an interfacial reaction between the roller and the substrate which can have a detrimental effect on the quality of extremely thin coated layers

This paper will outline some recent developments in contact cleaning technology which mitigate the interfacial reaction while providing particle removal down to the submicron level. This new process provides very substantial improvements in yield to applicators of nanocoatings.

The growing markets for Plastic Electronics, Photovoltaics and Flat panel Displays are driving the web coating industry towards the limits of current coating technology by demanding thinner, more consistent, defect free coatings. This level of quality can impact process yields and therefore costs for the coating company.

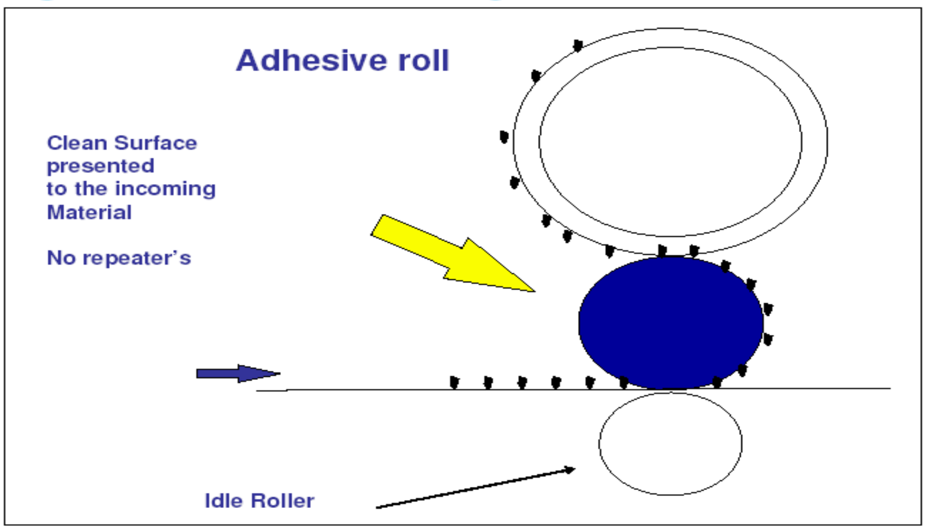
THE BACKGROUND OF CONTACT CLEANING

Contact cleaning is a very well established yield improvement technique already used by many coating and converting operations to increase competitiveness. The process was invented by Teknek over twenty years ago, initially for membrane switch production though for many years the main applications were at various stages of the printed circuit board (PCB) manufacturing process. As different configurations and widths of machines were developed the technology was incorporated into lines processing web materials such as food and medical packaging, photographic films and functional coatings on polyesters and polycarbonates. More recently the technology has been incorporated into flat panel display, OLED and photovoltaic manufacture. In each of these applications users have benefited from significant increases in yields through the removal of loose contamination from the web. This current technique can remove particles as small as 1 micron.

THE PRINCIPLE OF CONTACT CLEANING

The basic principles of contact cleaning involve a specially formulated proprietary elastomer roller rotating in contact with the web. See Figure 1. Due to its special formulation the elastomer roller picks up all loose dirt and contamination from the web and transfers it to an adhesive roll ensuring that the surface of the elastomer which comes in contact with the web is always completely clean. The elastomer must also contain no plasticizers or surfactants which might migrate onto the material being processed.

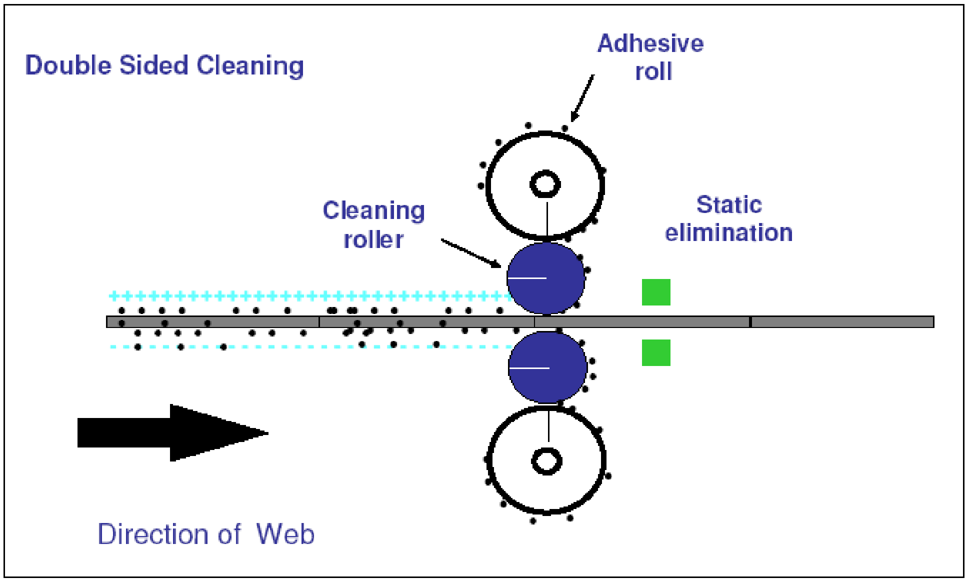
Figure 1: Contact Cleaning Mechanism



The adhesive comprises a paper or film base coated with a pressure sensitive adhesive and wound on a core with the adhesive side facing outwards. It is essential that the properties of the pressure sensitive adhesive are tailored specifically for contact cleaning as it must be fully compatible with the elastomer and yet have sufficient adhesive and cohesive strength to ensure that there is no risk of transfer of any of the adhesive to the elastomer roller and subsequently to the product being cleaned.

The system can be configured to clean one or both sides of the material and in some applications static control is added to the outlet of the equipment to minimise the risk of statically attracted particles recontaminating the web. See Figure 2. The equipment can be as small as 150mm (6") wide and as large as 4000mm (13') and can be specially designed to retrofit into an existing coating or metalizing line.

Figure 2: Double-Sided Contact Cleaning



ELASTOMER PERFORMANCE

Teknek currently offer four types of elastomer for specific applications:-

Panel - this was the original elastomer developed for sheets of rigid substrate such as printed circuit boards and also used for glass.

Film - used to clean films over 250 micron thick, such as in membrane switches

F3 - used for thin films less than 250 microns

Soft - used for rigid substrates with substantial topography

The differences are mainly to do with shore hardness and their mechanical properties such as their ability to transport delicate substrates.

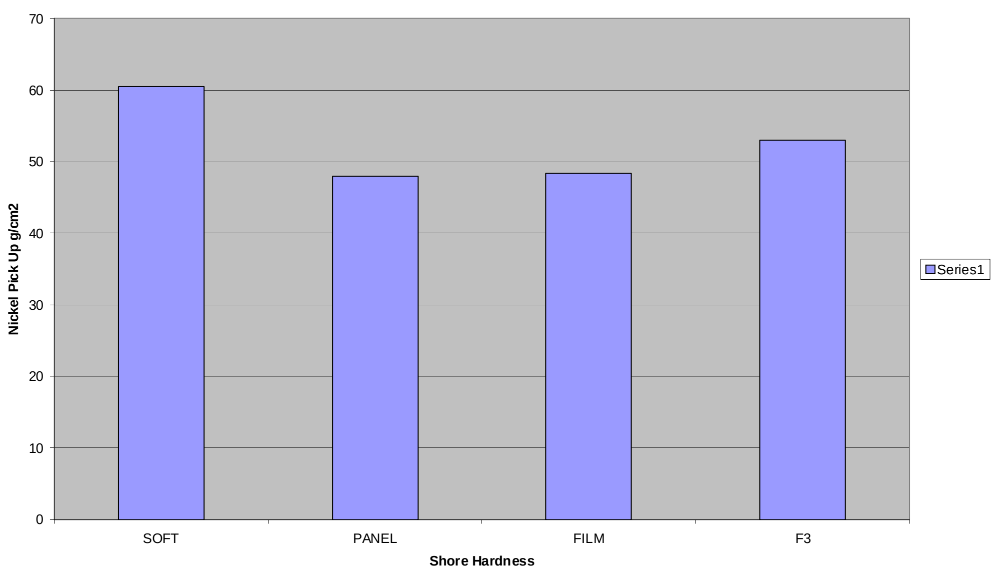
With the impact of particle related defects on yields increasing there was a demand to know the cleaning efficiency of the elastomer rollers however there were no standard methods available to provide this information. The closest method was related to measuring the number of particles on a surface both before and after cleaning. While we do use this technique it is very dependent on the type of substrate and the material, morphology and density of the contamination. This makes it useful for very specific application measurement but is not a reliable measure of the efficiency of the rollers.

We therefore developed in our laboratory our own test which is designated the NPU test. For this test we take standardised nickel powder with a particle size of 25 micron, which is sieved and dried to ensure standard conditions. The test roller is then rolled in the nickel powder until the whole surface of the roller is completely saturated. Any loose particles are then removed by tapping the end of the roller.

A sheet of test adhesive is then weighed and the nickel covered roller rotated in contact with it to transfer the nickel powder to the adhesive which is then reweighed. The difference in the weights is then related to the cleaning efficiency.

As a secondary check the deposit on the adhesive is measured using a colour densitometer which shows the consistency of the nickel transfer.

The NPU results for the current elastomers are shown in the Figure below with the elastomers shown in order of ascending shore hardness. As you can see these two parameters are not related.



ELASTOMER DEVELOPMENT

The current elastomer rollers clean well but with increasingly small particles able to cause defects some of our customers were still seeing defects and required a higher level of cleaning at submicron level. To achieve this we set out to develop a new type of elastomer from scratch. The design specifications for the new elastomer are given below.

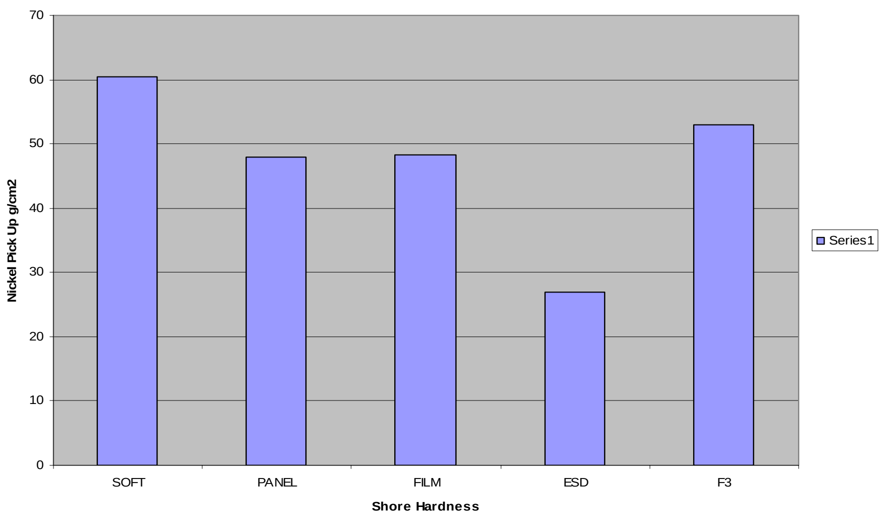
- High cleaning performance
- Removes particles smaller than 1 micron
- No leaching
- Able to process substrate

- Does not affect charge characteristics of substrate

When setting out on this development programme it was believed that the static charges, caused by the rolling friction, between the roller surface and the substrate inhibited and changed the surface energy out the substrate leading to occasional spontaneous dewetting. The key focus of the development was therefore on the electrical properties of the roller elastomer.

The resultant ESD roller elastomer allows the static charges to dissipate although, using normal measurement techniques it is not conductive.

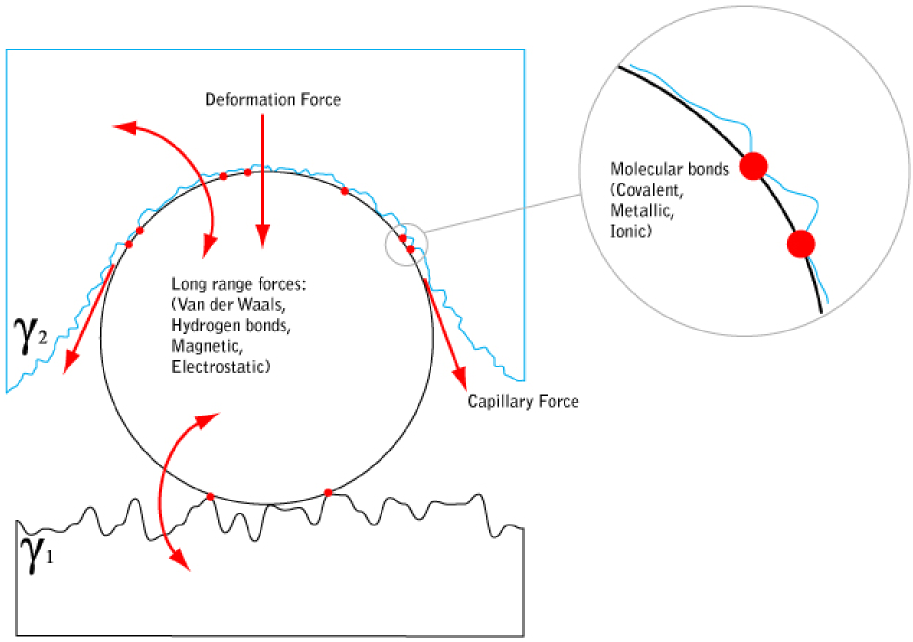
Having developed a new elastomer which seemed from practical experimentation and customer feedback to meet the parameters we then measured its cleaning efficiency using the NPU test. This gave the results below. The results were very disappointing and unexpected. The cleaning performance was much worse than the current elastomers.

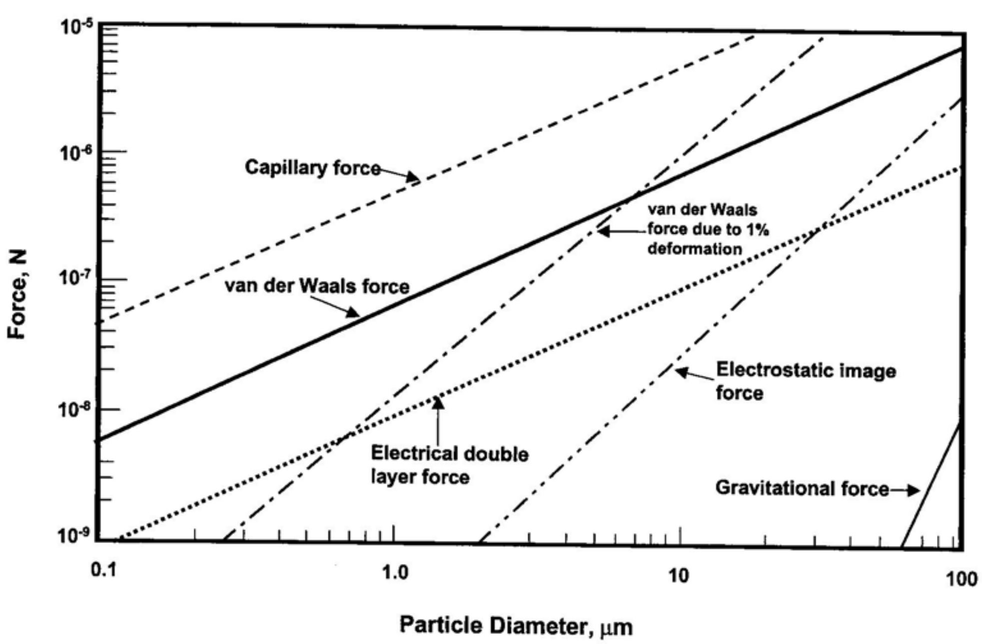


RESEARCH

In an effort to understand the reason for this drop in performance we decided to review published academic research. Almost all the published research on removal of small particles related to cleaning of silicon wafers for the semiconductor industry where the substrate was small and most of the removal techniques involved fluids either water, solvents. None of these techniques would transfer easily to a wide web of thin flexible film and so the research results were not considered particularly relevant. We then widened the search to include published research into the fundamental nature of the interfacial forces between particles and substrates was reviewed. From this the forces affecting the interface were identified as shown below.

Constituitive Adhesion Forces





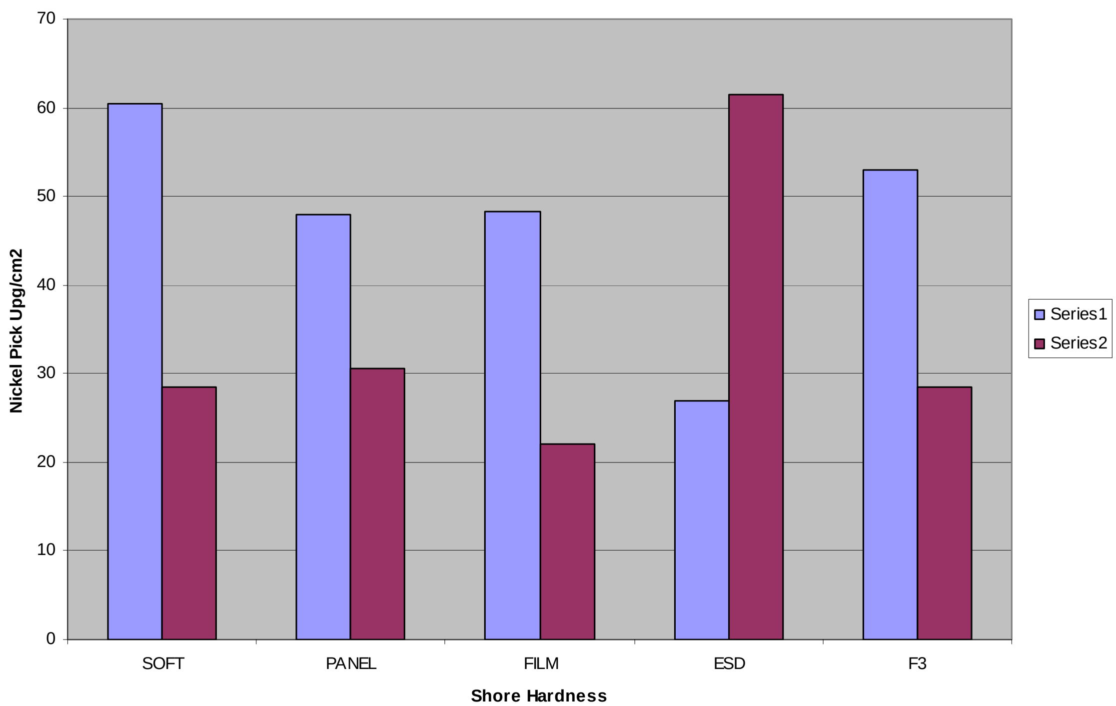
The adhesion forces are shown as a function of the diameter for an Al_2O_3 particle on a Si substrate [20-21, 37].

The main factors affecting the level of these forces were found to be surface energy, which we had already tackled through the ESD elastomer, plus humidity, deformation pressure and surface roughness. These factors were then calculated for the rollers and the calculated values assessed against the NPU test results. The factor which correlated most closely to the NPU results was the surface roughness and so experimental work focused on optimising the surface topography to change the cleaning performance.

EXPERIMENTATION

Teknek rollers are moulded and so by default have an apparently smooth surface. We then tried several different techniques to change the surface roughness of the moulded roller. Each type of elastomer was subjected to each modification technique and the samples tested using the NPU test. The results were compared with the as moulded performance.

The graph below shows the change is performance with the surface modification.



Interestingly while the performance of the new elastomer, named Nanotek, improved significantly the surface modification had a detrimental effect on the standard elastomers and more work will have to be done to establish the cause of this.

THE FUTURE

We have just applied for a Patent relating to the enhancing of the cleaning performance of an elastomer roller through surface modification.

We have further work to do to improve our understanding of the contact cleaning mechanism.

We need to fully productionise the surface modification procedure.

CONCLUSIONS

While standard Teknek contact cleaning elastomers work well for most known applications as the coating industry moves toward thinner applications of coatings containing nanoparticles there is a need for the cleaning process to be able to pick up particles smaller than 1 micron.

Research has shown that smaller particles are more strongly attracted to microroughened surfaces.

A technique has been developed which allows moulded elastomers to have their surface modified to greatly enhance their cleaning performance.

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