



Surface modification techniques for plastics fabrication

PLASTICS
FABRICATION

by Frank Hild

The technology of surface modification has been around for some time. The need to change surface characteristics intensified as plastics became widely used and continues to be a growing issue for many industries. Medical device manufacturers, biotechnology, diagnostic and some industrial companies are discovering the cost, manufacturing and yield benefits of using surface modification equipment or services.

The role of surface modification in plastics fabrication

Most polymers and elastomers need a pretreatment to improve the adhesion properties of the material's surface. This adhesion property could be in the form of improved adhesive bonding or the ability of inks or other coatings to adhere to the material. A particularly important area is the preparation of polymers and elastomers for optimum bonding to other substrate materials.

Identifying the proper surface modification process is based on understanding the specific application. This will ensure the best possible solution to your bonding problems and can improve the adhesion of paints, inks and even biomedical

coatings to specific polymers and elastomers. Additionally, surface modification processes can de-tack elastomers for better handling, prepare elastomers to receive low friction coatings such as paralyene or PTFE or improve hydrophobic or hydrophilic properties of the material.

Comparison of surface modification techniques

There are several techniques for surface modification: plasma, corona, photolysis or chemical. Let's examine each technique to help make the proper choice for an application.

I. Plasma

Plasma is the fourth state of matter: a quasi-neutral cloud of ionized gas. Positive ions, negative ions, electrons and radicals in a concert of reactions and collisions as long as an electric potential difference exist. Plasma is very reactive and can readily prime any surface for adhesion, painting, coating or printing applications. Plasma is ideally suited for most all clean polymers, ceramics and some metals where high precision cleaning or exact surface preparation is needed. A plasma-treated device is usually bonded, painted or coated. The level of adhesion is usually extremely high.

Pros — Plasma's main advantage is surface chemistry selectivity. Plasma systems control the treatment conditions by controlling the gas type, flow, pressure and concentration. Moreover, there is control over energy frequency, wattage and electrode configuration. Another advantage is that plasma is a three-dimensional treatment: any object placed inside a plasma chamber will be treated on all sides (excluding areas shielded by physical contact or masking). Finally, plasma is also a green process with no hazardous bi-products resulting from the treatment process.

Cons — The main disadvantage to plasma is the system price and throughput. The price of a system is related to the size of the system mainly due to

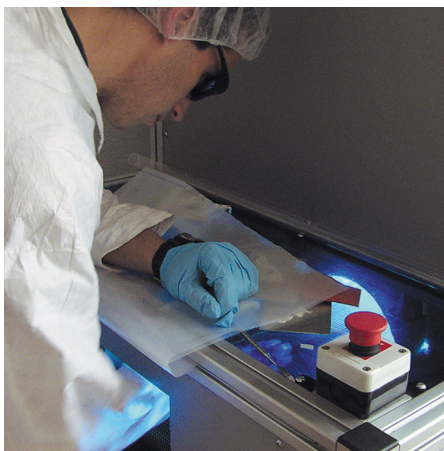


Device being treated for hydrophobicity.

the pump and power requirements. An engineer must consider the cost advantage for two smaller systems relative to one large system. This should be weighed against throughput, yield and budget requirements. The throughput of a plasma system is restricted by the batch-to-batch logistics of a plasma process. There have been attempts to make in-line plasma systems, but the acquisition price and maintenance costs usually do not justify purchasing a system for in-house treatment; very often it makes more sense to contract plasma-treatment requirements to qualified contract service companies.

II. Corona

A corona discharge is plasma at standard atmospheric pressure. This plasma is produced by high voltage and the close proximity of two metal plates (electrodes) in atmosphere. When there is an electrical discharge in atmosphere, ions and ozone are nearly always generated. The ozone compound is relatively short-lived and may dissociate to molecular oxygen (O₂) and oxygen radical (O[·]). The oxygen radical is then free to do work on the polymer or other molecules in the air. Usually a corona system is used for reel-to-reel thin film, webs, tape or fiber applications.



A device being treated for enhanced adhesion.

Pros — Corona systems are relatively inexpensive compared to plasma systems when product requirements demand in-house processing. Corona systems are fairly robust, easy to maintain and easy to use. The considerations for choosing this technique are polymer type, residence time in the discharge region and footprint of the system.

Cons — The main disadvantage is the lack of surface chemistry selectivity. Most corona systems are designed to operate in open air conditions, therefore the treatment is as consistent as the air around the system. Moreover, the treatment is limited to air chemistry (78 percent nitrogen, 20 percent oxygen, 2 percent other). It is this design that limits the polymers that can be treated by this technique; more stable polymers usually cannot be treated by this method. Another disadvantage is limited polymer choice. Lastly, the treatment is two-dimensional.

III. Photolysis

Photolysis systems operate on principles between corona and plasma. These systems use high voltage and excite a gas in an emitter, which then radiates the surface of a polymer. The radiation is intense and fine tuned to chemically modify a polymer to be receptive to most adhesives, paints, coatings and inks. Photolysis is ideally suited for in-line production or reel-to-reel surface treatments. An adhesive, paint or coating is usually applied after photolysis. This maximizes treatment effectiveness.

Pros — The main advantage is the high throughput treatment of stable polymers (nylon 6 and nylon 12) and elastomers (EPDM, isoprene, silicone). These systems are very efficient and effective due to the specific wavelength emitted by the radiation source. Moreover, there is no electrical discharge across the sample needing treatment, making it safe and easy for electrically or charge-sensitive devices. These systems can easily fit on nearly any conveyor system, and system cost is relatively moderate and directly related to the size of the system (usually large systems are needed for highly stable material and high throughput).

Cons — The main disadvantage of photolysis systems is surface chemistry selectivity. These systems, like the corona systems, are operated in standard atmospheric conditions. Therefore, treatments are restricted to air chemistry. Another disadvantage is that photolysis treatments are line-of-sight (two-dimensional). Though system design can be modified to

treat three-dimensional objects, the treatment is still determined by the placement of the radiation sources.

IV. Chemical

Many chemicals are used to prepare a surface for adhesion or coating systems. These types of systems are usually short lived but are easy to do without large capital outlays for equipment. Some polymers require special etchants that attack the molecular level of the polymer to expose carbon, especially fluorocarbon polymers. Chemical surface modification is ideally suited for dirty or difficult polymers. There are times where liquid chemicals must be used due to the need for a highly concentrated etchant.

Pros — Chemical processes are simple and there is no particular requirement for capital equipment. With proper storage and handling, chemical preparation of materials can be done in most work environments and cost per application is fairly low.

Cons — Chemical solvents and etchants are very dangerous to handle and store. Disposal is also an issue with some of these products. Chemical processes are material specific as well, so one solvent doesn't necessarily treat all polymers and elastomers. Fluorocarbon products are especially dangerous as the etching solutions are sodium-based materials that are highly explosive and will burn if not handled properly. (Chemical treatments should be at the users own risks.)

Industry applications

From enhancing cell culture trays to bonding dissimilar materials, a wide range of industries and applications use surface modification to modify the surface of polymers, elastomers and films in order to dramatically increase (or, if desired, to decrease) the bond strength of adhesives, paint, markings or specialty coatings. Here is a quick snapshot of how it is applied in different industries:

- Medical devices: Plasma-cleaning and functionalizing devices (catheters, endoscopes, stents, intra-ocular lenses, etc.) prior to the application of a specialty and/or lubricious coating, adhesive or marking.

- Optical devices: Plasma-cleaning and/or photolysis treatments to functionalize materials (polycarbonate, glass, PMMA, urethane, etc.) for lenses, films, depositions and micro optical electro mechanicals (MOEMs).

- Pharmaceutical: Functionalizing devices for drug delivery and storage.

- Biotechnology: Plasma-cleaning, functionalization and silane deposition treatments for microarrays, micro-fluidics, micro electro mechanicals (MEMs), etc.

- Aerospace, automotive and commercial products: Improving the adhesion of gaskets and other dissimilar materials, removing the "tack" from silicon devices, and dramatically increasing the adhesion of elastomer material to metal, polymers and other elastomers.



Different perspectives of a lab technician measuring the surface energy on a plasma cleaned, aluminum cap.

Summary

The need to modify polymer surfaces is a growing trend in manufacturing and research applications today. Whether you are looking at plasma, corona, photolysis or chemical, it is important to choose the appropriate technique for your application. The throughput requirements, polymer type, surface needed, capital equipment budget, research budget and project time-line are important considerations to weigh before relying on one approach. ■

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