Acteco – plasma treatment for textile materials

Plasma technology has been studied for many years, also regarding textile applications. The use of this inherently eco-friendly technique by industry remains however fairly limited. The European project Acteco aimed at developing a new generation of plasma technologies that offer dramatically innovative functional surface properties with a lifetime equal to or approaching that of the finished product in the domains of food packaging, biomedical applications and textiles. The basics of plasma treatment and its use on textiles will be briefly highlighted here, as well as the main aspects regarding practical industrial implementation.

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Textile materials have valuable intrinsic properties, such as flexibility, low specific weight, strength, a large surface to volume ratio and a good 'hand' or touch. Because of these, they form a very good carrier for adding functionalities like hydrophobic, oleophobic or antibacterial properties. Traditional wet methods of applying these finishes require the use of large amounts of chemicals, water and energy. As plasma is a dry processing technique, it can lower the need for these resources. This potential explains the interest for plasma treatment of textiles.

Within Acteco, an EC supported Integrated Project within the 6th Framework Program, this potential was explored. The project aimed at developing eco-efficient plasma processes for hyper functional surfaces with applications in the food packaging/processing, biomedical and textile industry. Focus was mainly on the scaling up of plasma processes toward industrial implementation.

Basics of plasma and plasma treatment

A simplified definition of plasma refers to it as a gas which contains a certain fraction of charged particles: the atoms/molecules are ionized, i.e. they lost or gained one or more electrons. As a plasma is generated by placing a gas inside an electric field, which then ionizes the gas (break down), one also speaks of a "discharge".

A fundamental way to categorize plasmas is by plotting the charged particle density versus the charged particle energy. In this density-energy space, one can define different domains corresponding to different plasma regimes, e.g. the plasmas used for nuclear fusion or for lighting. Most of the industrially used plasma technologies for surface processing are based on the use of so-called non-thermal reactive plasmas. These typically consist of a gaseous mixture of charged particles (electrons, ions) and neutral activated species including gas molecules, free radicals, metastables and UV-photons.

All these species have their own specific reactivity and will interact with the treated surface in their own way. The actual plasma-substrate interaction is determined by a whole range of parameters like the gas(ses) used to generate the plasma, the electrical power input, the geometry of the plasma, the gas pressure at which the discharge is operated or the kind of substrate being treated. The interaction of the active species in the plasma with the substrate can either lead to "adding something" to the substrate or to "removing something" from the substrate. In the latter case, one speaks for example of etching or cleaning, in the former case typically the following main interactions are identified:

- Surface activation refers to the temporal increase of the surface energy. Such a treatment enhances the substrate affinity for other substances and is especially needed for synthetic materials which typically have a low intrinsic surface energy (e.g. polypropylene or polyethylene). The process is based on the implantation of oxygen and typically realized via a standard corona in open air.
- Functionalization refers to the permanent grafting of chemical groups onto the surface, e.g. the incorporation of nitrogen based groups (e.g. amines and amides). This is possible via a DBD or plasma jet, with for example nitrogen as process gas.
- Plasma finishing/coating refers to the deposition of a very thin coating (in the order of some nanometers) onto the substrate. This is achieved using a plasma device (corona, DBD, plasma jet, low pressure glow discharge, etc.) with a unit to add a precursor. The precursor can be chosen according to the targeted functionality. This technique can be used for imparting functionalities like oleophobic or antibacterial properties onto textiles. A key advantage is the realization of the functionality with a very limited add-on so that the typical textile properties (hand, softness, flexibility, etc.) remain unaltered.

Potential applications for plasma on textiles

In the previous part, the fundamental processes that take place when a plasma interacts with a (textile) substrate were described. Here, the practical textile treatments that can be obtained are discussed. When looking at the relevant literature, it quickly becomes clear that a very large range of potential applications can be envisioned. The most common treatments include [1]:

- imparting hydrophilic properties
- increasing adhesion
- enhancing printability, dyeability
- changing the electrical conductance
- imparting hydrophobic and oleophobic properties
- application of antibacterial agents
- application of fire-retardant agents
- anti-shrink treatment of wool
- sterilization
- de-sizing of cotton.

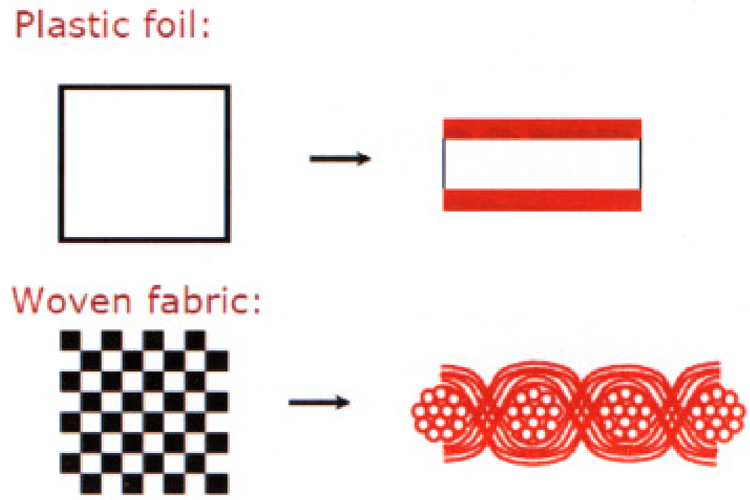
A more extensive overview of examples of the use of plasma on textiles can be found in the review article from Morent et al. [2] and in a book on this topic [3].

Within Acteco, the consortium worked on some of the following applications: imparting hydrophilic properties, increasing adhesion, enhancing printability, imparting hydrophobic and oleophobic properties and application of antibacterial agents. The more fundamental aspects of these specific research topics will not be detailed here. More information on these can be found in a book sprouting from the Acteco project [1]. Here, concentration is on the issues related to scaling up and maturing these techniques for actual industrialization.

Aspects for industrialization

A main challenge is the step from laboratory scale to industrial scale. Given the discrepancy between the amount of research performed and the actual number of industrial scale systems running for textile treatment, it is clear that this step is not evident. Indeed, some typical textile material related issues exist that still hamper industrialization. Here the main aspects identified for use on textiles are considered [1]:

- variation of material (mixture) to be treated
- moisture absorption
- cleanliness of substrate
- 3D structure
- large surface area.



Schematic representation of the surface area to be treated: in case of a plastic foil (top) and in case of a woven fabric (bottom)

Variation of material (mixture)

The effect of a plasma treatment depends on the type of material that is treated: the same plasma conditions will lead to a different effect if applied on a different material. Within the textile sector various materials are commonly used, e.g. of natural, artificial or synthetic origin. It means the process needs to be fine tuned for each material separately. Moreover, very often a textile material consists of a blend (e.g. a PET/cotton fabric), which complicates the treatment.
Further, for natural fibers the composition is complex and depends on a variety of factors, e.g. geographical or seasonal variations. All these aspects can influence the effect of the plasma treatment.

Moisture absorption

Textile materials typically contain an important amount of water. During atmospheric plasma treatment, most of the water and air contained in the textile substrate will desorb and, as a result, (negatively) influence the plasma composition near the surface. For low pressure plasma treatment, the pumping capacity must be sufficiently high to enable good degassing, especially of the natural fibers. A pre-treatment drying step might be required.

Cleanliness of substrate

Plasma treatment is a surface treatment, influencing only the very top layer of the material. This means that the substrate to be plasma treated needs to be very clean, otherwise the plasma only interacts with the contamination. Hence, introducing a plasma-based production step may require new cleaning steps in the textile manufacturing process involved ahead of the plasma treatment.

3D structure

When considering the interaction of a plasma with the textile substrate, the latter has to be considered as a porous, 3D structure. It is not evident for the active plasma species to penetrate into this structure, and thus, to ensure proper treatment throughout the textile. Several studies regarding this topic have been conducted. Crucial parameters are the gas pressure at which the plasma discharge is operated and, logically, the structure (thickness, density) of the textile material to be treated.

Large surface area

The basic building blocks of textile materials are individual fibers or filaments and, as a result, the surface area to be treated is much larger for a textile substrate than for a flat film. This difference between coating a foil and a fabric is schematically represented in the figure. Indeed, if one considers 1 cm^2 of substrate it can be estimated that the total surface area to be treated for a typical woven textile fabric is almost one order of magnitude larger than the total surface area of a foil sample with the same dimensions [4].

Summary

Compared with current traditional finishing processes, plasmas have the crucial advantage of a reduced usage of chemicals, water and energy. This potential explains why plasma treatment has already been investigated quite extensively on laboratory-scale. In contrast to this, industrial application is still limited, mainly because from a plasma viewpoint, a textile material has to be considered as a 3D porous structure with a large surface area. Nevertheless, the mentioned potential ensures ongoing efforts for further developments and first industrial applications are emerging. ■

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Dow Corning & Devan
New softener for flame-retardant textiles

The new DS-9000 Eco Repel softener by Dow Corning Corp., Midland, MI/USA, and Devan Chemicals, Ronse/Belgium, is an eco-friendly multifunctional encapsulated silicone additive for technical textiles. This technology allows the increase of softness and hydrophobicity on existing flame-retardant finishes without impacting flame-retardancy. The new softener provides the following features and benefits:

- silicone fluid encapsulated in a silica shell using a patented process
- formaldehyde-free
- formulated with a low amount of surfactants to reduce environmental impact
- suitable for multifunctional formulations due to the silicone encapsulation
- good compatibility with fluorocarbons and flame-retardants
- formulation of soft and water-repellent textile finishes
- specially adapted for formulations aimed at providing flame-retardancy features to textiles. ■