Application of Plasma Technology for Coated Textile

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Abstract--More than 99% of the visible matter in the universe is in the plasma state. It can be seen in its natural form on earth as lightning or as polar light in the Arctic and Antarctic. Plasma was first discovered by Irving Langmuir in 1928. Plasma technology is based on a simple physical principle. Matter changes its state when energy is supplied to it: solids become liquid, and liquids become gaseous. If even more energy is supplied to a gas, it is ionized and goes into the energy-rich plasma state, the fourth state of matter.

I. INTRODUCTION

Since their introduction in the 1960s, the main industrial applications of (low-pressure) plasmas have been in the micro-electronics industries. In the 1980s their uses broadened to include many other surface treatments, especially in the fields of metals and polymers. The prospects of very good technical and economical results, as experienced in the microelectronics industry, are stimulating efforts world-wide to apply plasma processing more widely to the processing of textiles and nonwovens. Undoubtedly, tremendous advantages are afforded by plasma technology as a uniquely effective engineering tool for achieving, in a flexible and versatile way, a broad range of fictionalizations of textiles and nonwovens. [4]

Textiles increasing, due to the necessity of adding value to products and to the introduction of new pollution-free processes. Plasma is a partially ionized gas, composed of an equal number of positive and negative elements (ions, positive radicals, electrons) and of a certain number of unionized molecules. The mechanisms which are involved in gas plasma are essentially excitation, relaxation, ionization and recombination. In order to maintain a steady state, it is necessary to apply an electric field to the gas plasma, which is generated in a chamber at low pressure. [1]

II. WHAT IS PLASMA?

The coupling of electromagnetic power into a process gas volume generates the plasma medium comprising a dynamic mix of ions, electrons, neutrons, photons, free radicals, meta-stable excited species and molecular and polymeric fragments, the system overall being at room temperature. This allows the surface functionalisation of fibres and textiles without affecting their bulk properties. These species move under electromagnetic fields, diffusion gradients, etc. on the textile substrates placed in or passed through the plasma. This enables a variety of generic surface processes including surface activation by bond breaking to create reactive sites, grafting of chemical moieties and functional groups, material volatilisation and removal (etching), dissociation of surface contaminants/layers (cleaning/scouring) and deposition of conformal coatings. In all these processes a highly surface specific region of the material (<1000 A) is given new, desirable properties without negatively affecting the bulk properties of the constituent fibres. [4]

Plasmas are acknowledged to be uniquely effective surface engineering tools due to:

- Their unparalleled physical, chemical and thermal range, allowing the tailoring of surface properties to extraordinary precision.
- Their low temperature, thus avoiding sample destruction.
- Their non-equilibrium nature, offering new material and new research areas.
- Their dry, environmentally friendly nature.

The field of industrial plasma engineering has grown in the last few years to meet increasing demand from the textile industry. Aside from its generation process, plasma is a very reactive material which can be used to modify the surface of a certain substrate (typically known as plasma activation or plasma modification), depositing chemical materials (plasma polymerisation or plasma grafting) to impart some desired properties, or removing substances (plasma cleaning or plasma etching) which were previously deposited on the substrate. The advantages of an industrially viable plasma processing system over traditional textile processing are summarized in Table 1.

Medium	No wet chemistry involved. Treatment by excited gas Phase	Water-based
Energy	Electricity – only free electrons heated (1% of system mass)	Heat – entire system mass temperature raised
Reaction type	Complex and multifunctional; many simultaneous processes	Simpler, well established
Reaction locality	Highly surface specific, no effect on bulk properties	Bulk of the material generally affected
Potential for new processes	Great potential, field in state of rapid development	Very low; technology static
Equipment	Experimental, laboratory and industrial prototypes; rapid industrial developments	Mature, slow evolution
Energy consumption	Low	High
Water consumption	Negligible	High consumption

Table. 1: Plasma Treatment Vs. Traditional Textile Processing

III. EFFECT OF PLASMA ON FIBERS AND POLYMERS

Textile materials subjected to plasma treatments undergo major chemical and physical transformations including (i) chemical changes in surface layers, (ii) changes in surface

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layer structure, and (iii) changes in physical properties of surface layers. Plasmas create a high density of free radicals by disassociating molecules through electron collisions and photochemical processes. This causes disruption of the chemical bonds in the fibre polymer Surface which results in formation of new chemical species. Both the surface chemistry and surface topography are affected and the specific surface area of fibres is significantly increased. Plasma treatment on fibre and polymer surfaces results in the formation of new functional groups such as —OH, —C=O, —COOH which affect fabric wettability as well as facilitate graft polymerization which, in turn, affect liquid repellence of treated textiles and nonwovens.

Adhesion problems, especially for synthetic fibre-based fabrics, often arise in coating, bonding and printing of textile materials. The characteristic low surface energy of many polymeric substrates results in intrinsically poor adhesion. Adhesion is fundamentally a surface property, often governed by a layer of molecular dimensions. Many types of wet-chemical surface treatments for adhesion enhancement are becoming increasingly unacceptable Because of environmental and safety considerations. [4]

IV. COATING

"A material composed of two or more layers, at least one of which is a textile fabric and at least one of which is a substantially continuous polymeric layer. The layers are bounded closely together by means of an added adhesive or by the adhesive properties of one or more of the component layers."

Coating is the process of depositing a resin over a textile substrate, on one or two side to influence its external characteristics and physical properties significantly. Coatings used in the production of technical textile are largely limited to those products that can be produced in the form of a viscous liquid, which can be spread on the surface of a substrate. Coating can involve every textile form. The thermoplastic polymers used for coatings technical textile are long chain linear molecules directly influence the durability and performance of the end product some of which have ability to crosslink.[3]

V. COATING FOR TECHNICAL TEXTILE

Technical textiles are manufacture primarily for their technical performance and function properties. Function is the primary criterion and important than form. Durability is more important than tactile effect.

Use of coated textile fabrics has spread into every sphere of industrial textiles. Coated fabrics are finding use in various end products meant for automotive textiles, architectural textiles, protective textiles, recreational textiles, etc. A coated fabric consists of closely woven, knitted or a nonwoven substrate that is coated on one or both sides with a man-made or natural polymer. In some cases, a binder is used to improve the adhesion between the polymer and the substrate. One of the major uses of coated textiles is in the protective textile sector. Among the protective textiles, fabrics meant for whole body protection from cold form an important application worldwide. Such fabrics are designed to act as thermal insulators and retain the body heat so as to afford protection from cold to the wearer in designing such fabrics the contribution of both the components i.e., the textile substrate and the polymeric coating have to be taken into account. [2]

There is range of variable to be considered in the selection of substrate for coating. Main fibres used are acrylic, nylon, polyester, cotton, wool, polypropylene, aramid, carbon and glass. The fundamental requirement for any coated woven or non-woven fabric is that coating or material joined to the fabric must be strongly combined to the fabric for lifetime of the product. As per requirement of the final, substrate must have parameters like

- Good mechanical properties such as elasticity, elongation at break, strength, frictional resistance.
- Dimension stability
- Adhesion, absorption
- Thermal stability
- Uniformity

Fiber	Density(G/Cc)	Melting Point	Tenacity(G/Den)	Loi(%Oxygen)
Acrylic	1.12-1.19	150d	2.0-5 OHT	18
Nylon 6	1.13	215	4.3-8.8HT	20
Nylon 66	1.14	260	4.3-8.8 HT	20
Polyester	1.40	150d	3.2	18
Cotton	1.51	132d	1.0-1.7	25
Polypropylene	0.9	165	4.0-8.5HT	18
Aramid	1.38-1.45	427-482d	5.3-22	29-33
Carbon	1.79-1.86	3500d	9.8-19.1+	64+
Glass	2.5.2.7	700	6.3-11.7	Not burn

1- d = does not melt but start to decompose
2- HT= high tenacity

Table. 2: Properties of Fiber Commonly used in Coating

VI. EFFECT OF PLASMA ON COATED FABRIC

The field of industrial plasma engineering has grown in the last few years to meet increasing demand from the textile industry. Aside from its generation process, plasma is a very reactive material which can be used to modify the surface of a certain substrate (typically known as plasma activation or plasma modification), depositing chemical materials (plasma polymerization or plasma grafting) to impart some desired properties, or removing substances (plasma cleaning or plasma etching) which were previously deposited on the substrate. The deposition of chemical substances on the surface involves different processes such as cross linking, grafting, or simply deposition of nonreactive material on the surface, depending on the chemical nature of both gas plasma and surface.

In some cases, plasma treatment can just have the role of activating the surface in order to increase the adhesion with a particular material with a view to a subsequent coating process. The advantage of plasma treatment, with respect to traditional coating processes, is that the small thickness of the coated material allows modification of surface properties without changing the bulk properties of the substrate; in addition, the small consumption of chemicals makes the process convenient from both the economic and ecological points of view.

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Plasma treatment can modify the surface properties of different kinds of fibres, depending on the chemical nature of the gas used, without changing the tensile strength of the fibres, with few exceptions of some natural fibres.

VII. APPLICATIONS OF PLASMA TREATED AND COATED FABRIC

The fabrics studied are used for outdoor applications such as outdoor awnings, car tops, beach umbrellas, and outdoor furnishings. These fabrics have to be coated with a waterproof material which makes them impermeable. Traditional coating methods need a previous washing of the fabric, with water or solvent, in order to eliminate the finishes introduced during fibre production and to allow the adhesion of the coating material to the surface, an essential condition to obtain a good waterproof product. Washing of fabrics requires the use of solvent or water with unavoidable creation of pollution.

The possibility of cleaning the surface of the fabric with plasma treatment was studied by exploring different types of plasma gases and studying the effect of plasma process parameters such as time of exposure. The plasma cleaned fabrics were traditionally coated with a waterproof material in order to give them impermeable properties. The characteristics of the plasma cleaned and traditionally coated fabrics were compared with the properties of fabrics subjected to traditional finishing processes (washing and coating).

Coated fabrics are employed in a wide variety of applications, ranging from protective clothing to architectural materials. Established technologies involve the application of elastomers and silicones, polyurethane (PU), and polytetrafluoroethylene (PTFE) to textiles using processes such as direct coating, transfer coating, online coating, extrusion coating and calendering. However, recent advances have included plasma coating, nanocoating and inkjet deposition, with the aim of improving functionality, reducing costs and improving the level of environmental friendliness of manufacturing operations.

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