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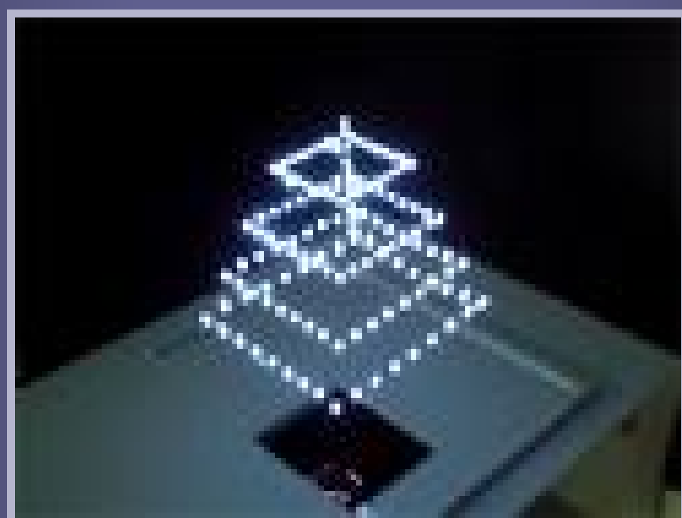

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INTRODUCTION

Plasma is an ionized form of gas and can be created using a controlled level of AC or DC power and an ionizing gas medium. It is an ensemble of randomly moving, charged atomic particles with a sufficient particle density to remain, on average, electrically neutral. Plasmas are used in very diverse applications, ranging from manufacturing integrated circuits used in the microelectronics industry through treating polymer films to the destruction of toxic waste.

Plasma processes can be grouped into two main classes — low-density and high-density — according to their electron temperature versus electron density. In low-density, direct-current and radio-frequency glow discharges, the electron and heavy particle temperatures are not equal. Low-density plasmas have hot electrons with cold ions and neutrals. Energetic electrons collide with, dissociate and ionize low-temperature neutrals, creating highly reactive free radicals and ions. These reactive species enable many chemical processes to occur with low-temperature feed stock and substrates.

Well-known types of plasmas encountered in surface treatment processing techniques typically are formed by partially ionizing a gas at a pressure well below that of the atmosphere. For the most part, these plasmas are weakly ionized, with an ionization fraction of 10-5 to 10-1. Electron cyclotron resonance (ECR) plasmas can have higher ionization at high power. Because these systems are run at low pressures, vacuum chambers and pumps are needed to create and contain these plasma processes.

The atmospheric plasma system allows creation of uniform and homogenous high-density plasma at atmospheric pressure and at low temperatures using a broad range of inert and reactive gases. The atmospheric plasma treatment process (ATP) treats and functionalizes material surfaces in the same way as the vacuum plasma treatment process on a wide range of materials; and has unique advantages over the presently used corona, flame and priming treatment technologies. APT production equipment testing has been successfully performed for the treatment of various materials, including PP fiber, PP and polyethylene (PE) nonwovens, polyester fiber, Tyvek®, nylon, wool, textile yarn, oriented PP film, PE film, PE teraphthalate (PET) film and polytetrafluoroethylene film. The surface energies of the treated materials increased substantially (without any backside treatment), thereby enhancing their wettability, printability and adhesion properties.

Plasma treatment has an explosive increase in interest and use in industrial Applications as for example in medical, biomedical, automobile, electronics, semiconductor and textile industry. A lot of intensive basic research has been performed in the last years, also in the field of textiles and technical textiles. This has resulted in an increasing knowledge of the possibilities of this process regarding demands as wet ability, shrinkage resistance of wool, dye ability, printability, coating and wash ability of conventional and technical textile. All day problems of wet ability and adhesion, together with the environmental driven forces have increased the interest of industry today. A fundamental problem at this moment for the implementation of this technique at a higher level is the lack of adapted machines.

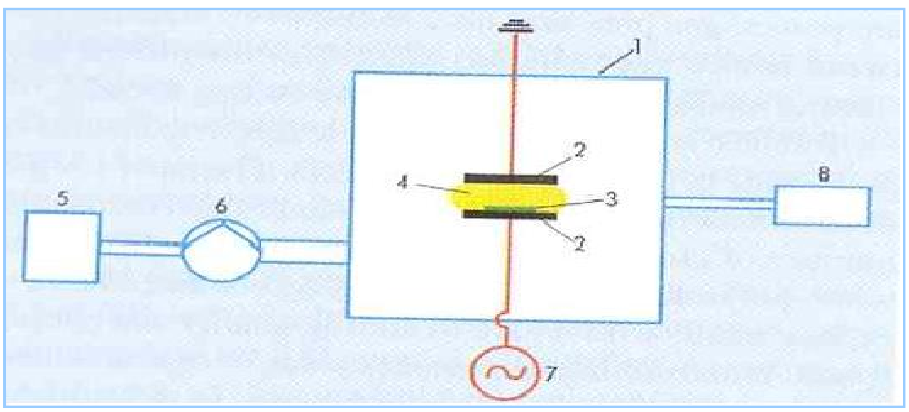
The plasma technology is considered to be very interesting future oriented process owing to its environmental acceptability and wide range of applications. Plasma treatments have been used to induce both surface modifications and bulk property enhancements of textile materials, resulting in improvements to textile products ranging from conventional fabrics to advanced composites. These treatments have been shown to enhance dyeing rates of polymers, improve color fastness and wash resistance of fabrics, and change the surface energy of fibers and fabrics. Research has shown that improvements in toughness, tenacity, and shrink resistance can be achieved by subjecting various thermoplastic fibers to a plasma atmosphere. Recently, plasma treatments have been investigated for producing hydroscopicity in fibers, altered degradation rates of biomedical materials (such as sutures), and for the deposition of anti wear coatings.

Need For Plasma Treatment

Textile manufacturers and end-users alike have been searching for ways to improve the surface properties of natural and man-made fibers. Specifically, there is a need to improve adhesion, wettability, printability and dyeability; as well as to reduce material shrinkage. Methods of modifying fiber properties to make polypropylene (PP) dyeable, including the process of copolymerization with polymers that can be dyed, have been evaluated. Traditional latex systems and primers with low melt points have been used to coat fabrics to promote ink adhesion, heat-sealing and thermoforming performance. PP nonwovens have especially been the focus of research to enhance colorfastness properties for the material because of its excellent chemical resistance, high melting point, low cost and adaptability to many fabrication methods. To date, the poor dyeability of PP has limited optimization of its applications in the manufacturing of yarns and knit fabrics, upholstery fabrics and industrial fabrics.

Fibers with polar functional groups can be dyed more easily than nonpolar fibers because polar groups will chemically bond with dye molecules. Because the molecular chains of PP are nonpolar and its surface is hydrophobic, the dye molecules will not bond chemically to the fibers. PP fiber is highly crystalline as well, which also restricts its dyeability. Functional groups may be introduced onto the fiber surface by using gas plasma treatments, improving fiber surface properties without affecting the fiber’s bulk properties. By creating a polar layer on the fiber surface, in reaction with functionality introduced, wettability of the fiber for dyeing is enhanced with hydrophilicity.

Plasma Application To Fibres

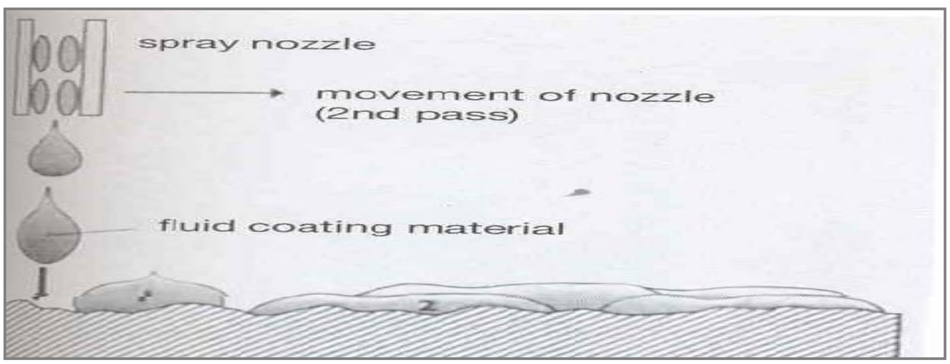


Parallel plate reactor for plasma polymerization
1 = vacuum chamber; 2 = electrodes; 3 = substrate;
4 = plasma; 5 = exhaust gas cleaner; 6 = vacuum pump;
7 = high frequency generator; 8 = gas supply (CH4).

The high-frequency electromagnetic transmitter which is often used for the generation of a technical plasma, primarily give their energy up to the electrons, because these are significantly less inactive that the ions. This means that the electrons are "heated" and thus their average kinetic energy, i.e. their temperature, increases. Collisions between electrons and ions cause electrons to pass their energy on to the ions. Due to the great mass difference this energy transfer is only small. A number of collisions are necessary to achieve a balance between ion and electron temperatures. The number of collisions which a particle undergoes depends upon the pressure. At a high pressure the number of collisions is high, and there is a rapid equalization of the average energy of electrons and ions. In low density plasmas, on the other hand, this thermalisation between the particle types is not effective, and a system is created made up of hot electrons and cold ions.

In addition to thermal equalization, collisions also play a role in the maintenance of the charge carriers. A mixture of electrons and ions will tend to form neutral atoms by the combination of the two particles. This process is known as recombination. This recombination leads to the two free charge carriers (electrons and ions) becoming a neutral atom, thus causing the plasma to lose some of its conductivity. Recombination is the process that converts an ionized gas into a "normal" gas. The stable burning of ignited plasma requires equilibrium between the destruction and generation of charged particles. This source consists of the above. Mentioned collisions between electrons and atoms or ions. If a hot electron hits an atom, it can knock out a captive electron (ionization). Whereas originally there was one free charge carrier, after the collision there are three. If equilibrium exists between recombination and ionization, then the plasma will burn in a stable manner. However, the ionization of an atom is not the only process that can be triggered by an electron collision. [n order for an electron to ionize an atom, it must transfer minimum energy to the atom during the impact, the ionization energy. If energy transfer due to the impact is less than the ionization energy, then the struck atom is excited. The excited states are usually not stable, and such an atom returns to its original state, the basic state, radiating light as it does so. This is the cause of the illuminated appearance of plasmas.

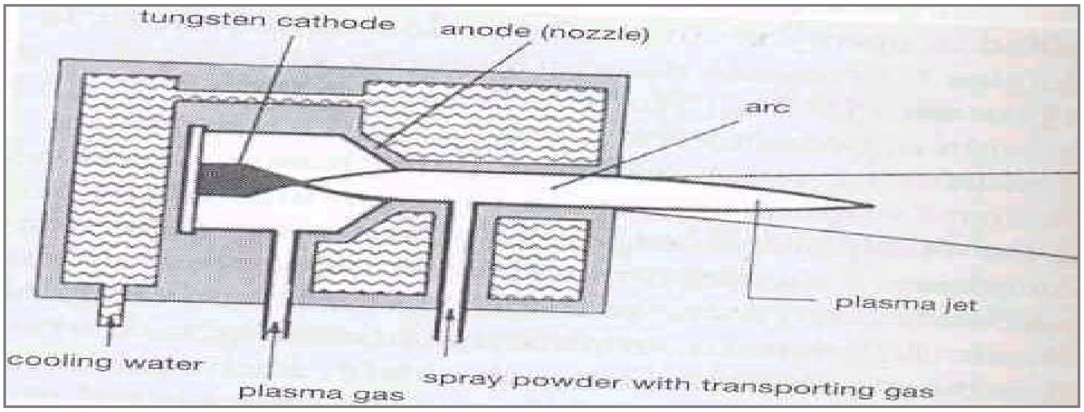
Plasma Spraying Technique



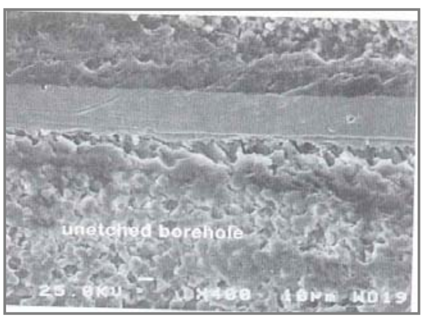
Plasma Spraying Process

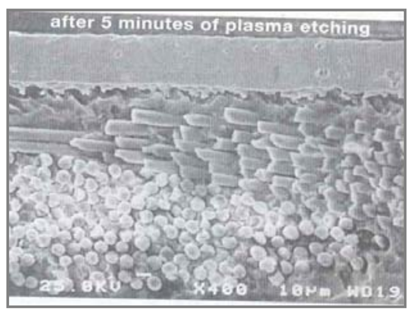
In plasma spraying, the surface being coated is sprayed with droplets in the same way as color spraying. In contrast to color spraying, the film material in plasma spraying is not liquid, and must first be melted by a high-energy heat source and then sprayed onto the cold surface of the fabric or three-dimensional body. When the droplets hit the surface they are flattened and cool off instantaneously due to heat transfer to the base material (substrate). The particles solidify and shrink. The films adhere primarily due to mechanical adhesion and locally due to chemical bonding forces of different types. In order to achieve a strong film adhesion, the cleaned surfaces are roughened by sandblasting. This gives good adhesion, because the particles penetrate into the surface roughness and shrink onto the peaks.

The heat source used in plasma spraying is an electric arc in a nozzle, which heats up a flow of gas (usually argon, nitrogen or helium) to very high temperatures. Gas temperatures in excess of 20000°C occur, which lead to the splitting of molecular gases and the partial ionization of atoms. As a result Of the high temperatures a marked increase in the volume of the gas (plasma) takes place, which flows out of the nozzle at high speed, in plasma spraying plants the flow speed of the plasma jet reaches several times the speed of sound. The powdered film material is injected into this high. Energy plasma jet with the aid of a carrier gas. The particles themselves are melted and blasted onto the pretreated base material. The particle speed itself, however, is below the speed of sound. Almost all materials which melt without decomposing and can be manufactured in a suitable grain size can be processed into high quality coatings by plasma spraying. Normal plasma spray coatings are generally chromium oxide coatings or aluminum oxide coatings. However, tungsten carbide cobalt coatings and pure tungsten coatings can also be applied by plasma spraying.



Plasma Spray

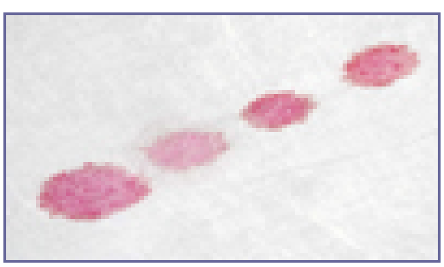


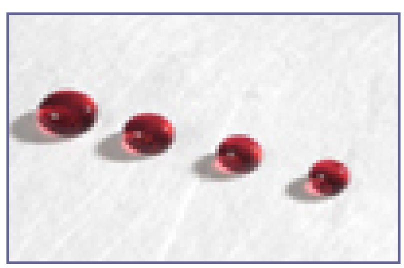


Gas Plasma Technology For Textile & Filtration Applications

Activation, hydrophilic, hydrophobic or other surface modifications are part of the possibilities gas plasma technology can offer to film & textile manufacturers and can be performed on real production scale.

We have a demo-unit available to evaluate on real scale how plasma technology can suit your specific surface treatment or modification needs.





Advantages

- Highest quality.

- Operator friendly.
- Dry, environmental friendly technique.
- Low operation cost.

Treatment Of Cotton With Different Kinds Of Plasma Gases

The specific surface area of cotton after oxygen plasma treatment is increased. On the other hand, the treatment with hexamethyldisiloxane (HMDSO) plasma leads to a smooth surface with increased contact angle of water (sessile drop method) up to a maximum of 130°. Thus, a strong effect of Hydrophobisation is achieved. Similarly, when hexafluoroethane plasma is used instead of HMDSO plasma the surface composition of the fibers clearly indicates the presence of fluorine and the material becomes highly hydrophobic. Still, the water vapor transmission is not influenced by the Hydrophobisation. Hydrophobisation in conjunction with increased specific surface area results in an effect generally known as Lotus effect: dirt particles are easily removed from the surface by water droplets. If intensive oxygen plasma treatments are applied to cotton fabric also negative effects can be observed namely a reduced tear and abrasion resistance. The negative impact can be minimized by selecting appropriate treatment conditions

Plasma Treatment Of Wool To Achieve Shrink-Resistance

The morphology of wool is highly complex; this is not confined to the fiber stem but extends to the surface as well. Cuticle cells are overlapping each other to create a directional frictional coefficient. Moreover, the very surface is highly hydrophobic. As a consequence, in aqueous medium, because of the hydrophobic effect, fibers aggregate and, under mechanical action, exclusively move to their root end. This is the reason for felting and shrinkage. Plasma treatment of wool has a two-fold effect on surface. First, the hydrophobic lipid layer on the very surface is oxidized and partially removed; this applies both to the adhering external lipids as well as to the covalently bound 18-methyl-eicosanoic acid Since the exocuticle, that is, the layer below the fatty acid layer of the very surface (epicuticle), is highly cross-linked via disulfide bridges plasma treatment has a strong effect on oxidizing the disulfide bonds and reducing the cross-link density. As the plasma treatment is surface-oriented the protein loss after treatment and extraction is very low (0.05 % o.w.f. for severe treatment). On the other hand, the specific surface area is significantly increased during plasma treatment from about 0.1 m 2 /g to ca. 0.35 m 2 /g, which is clearly demonstrated by means of atomic force microscopy. Again, due to the surface-directed activity of the plasma, the tenacity of the fibers is hardly influenced. As the surface is oxidized, the hydrophobic character is changed to become increasingly hydrophilic. The chemical and physical surface modification results in decreased shrinkage behavior of wool top; the felting density of wool top (before spinning) decreases from more than 0.2 g/cm to less than 0.1 g/cm.

Plasma Surface Modification In Bio-Medical Applications

New medical products, materials and surgical procedures keep improving current health-care practices. Many of these innovations involve polymeric devices that must meet certain clinical and cost requirements. Chief among these pressures is the need for biocompatibility between the physiological environment and the biomaterial surface. Plasma surface modification can improve biocompatibility and bio functionality. This article reviews the capabilities and applications of the technology. Engineered Biocompatibility The use of synthetic materials in biomedical applications has increased dramatically during the past few decades. Although most synthetic biomaterials have the physical properties that meet Surface Modification Methods or even exceed those of natural tissue, they often result in a number of adverse physiological reactions such as thrombosis formation, inflammation and infection. Modifying the surface of a material can improve its biocompatibility without changing its bulk properties. Several methodologies have been considered and developed for alter the interactions of biomaterials with their biological environments; plasma surface modification is one of these methodologies. The Process In the plasma surface modification process, a glow discharge plasma is created by evacuating a vessel, usually quartz because of its inertness, and then refilling it with a low-pressure gas,. The gas is then energized using techniques such as radiofrequency energy, microwaves, alternating current of direct current. The energetic species in a gas plasma include ions, electrons, radicals, meta stables, and photons in the short-wave ultraviolet (UV) range. Surfaces in contact with gas plasmas are bombarded by these energetic species and their energy is transferred from the plasma to the solid,. These energy transfers are dissipated within the solid by a variety of chemical and physical processes as schematically to result in the surface modification.

Plasma Treatment Of Synthetic Fibers

PP is a very interesting material for plasma treatment. PP is a very hydrophobic Material with extreme low surface tension. On the other hand PP is used in a large number of technical applications were an improved wet ability or adhesion properties are advantageous. This is also the case for PP technical textile applications such as filters, medical or hygiene applications, Using an oxidative plasma important improvements in surface tension can be obtained within a very short plasma treatment. In order to obtain an optimization of the plasma effects, a systematic approach (factorial experimental design) was followed for the evaluation of the plasma parameters upon the obtained effects PP non-woven filter webs were used as test samples. Parameters varied were: treatment time, vacuum level, treatment power. In addition some tests were performed with an adapted gas composition in stead of using O_2. The obtained effects were somewhat surprising. As expected we could observe for all plasma treatments an increase in surface tension. However the increase in surface tension is not in correlation with the intensity of the plasma treatments. We expected an increase in the improvement in the wet ability properties the higher the plasma power and the treatment time is and the lower the vacuum pressure. Once an optimum level is reached we expected the wet ability would become constant and independent from the treatment intensity. The results showed that an increase in wet ability can indeed be observed but only at relatively low treatment intensities. Once the optimum is reached a sharp drop in wet ability is obtained if the plasma treatment intensity is raised further.

Most trials were performed with O_2 as plasma gas, since it was thought this gas would offer the best results for an oxidative treatment in order to obtain wet ability. Some additional tests were performed using air or argon/O_2 blends as plasma gas.

The results indicated that often air or a blend of gases with a lowered amount of O_2 offer a better wet ability to the treated PP material. This effect can also be linked to the previous observations. Plasma treatment with pure O_2 seems to be so aggressive that very easily an “over-treatment” is obtained reducing again the wanted hydrophilic effects. Treatment with air as plasma gas might reduce the Aggressiveness of the treatment and as a consequence the plasma parameters becomes less critical.

When polyethyleneterephthalate (PET) fibers are used as an enforcing material for a polyethylene (PE) matrix, the Hydrophobisation of the PET fibers using ethylene plasma is quite impressive since the adhesion strength can be increased from 1 to 2.5 N/mm. The fracture morphology of these composite materials clearly shows the tight adhesion of the matrix to the fiber. Permanent hydrophilisation of PP by plasma-induced grafting of MAH. Fracture morphology of PET/PE-composites prepared from untreated and C_2H_4 -plasma-treated PET-fibers after application of the 180° peeling test.

Polyaramide fibers such as Nomex fibers are considered to be high-performance fibers; unfortunately, they are prone to hydrolysis. Thus, the application of a diffusion barrier to the surface should reduce the tendency to hydrolyze in respective media. Hexafluoroethane/hydrogen plasma is highly suitable to apply such a diffusion-barrier layer to the surface. The resistance to 85 % H_2SO_4 (20 h at room temperature) leaves the fibers completely intact while conventional fluorocarbon finishing under the given conditions produces significant shrinkage of the fibers in combination with loss of properties

Applications

The number of applications where plasma is or can be used successfully is very large. Also the type of application can be very different:

- Wet ability of filter material (paper and synthetic)
- Medical textiles and blood filters Fibers.

Technical textile:-
- Automobile textiles.

Safety textiles:
- Work wear.

Structural textiles:-
- Fibers for structural composites (building, sports wear) foils.
- Packing material and foils.

CONCLUSION

Plasma technology with all its challenges and opportunities, is an unavoidable part of our future. The possibilities with plasma technology are immense and numerous. The researchers are filled with optimism, and product based on their technology is beginning to their mar. the to which plasma technology will impact our lives only depends on the limit of human ingenuinity. It can rightly be said that plasma technology is slowly, but steadily in the industrial revolution

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