Plasma Processing Update

Issue 72 July 2015

A Newsletter from

Facilitation Centre for Industrial Plasma Technologies
Institute for Plasma Research

In this Issue

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Message from Director

I am happy to share with you Plasma Processing Update, Issue – 72 for July 2015; A quarterly Newsletter from Facilitation Centre for Industrial Plasma Technologies (FCIPT), Institute for Plasma Research (IPR). Apart from interesting articles on Plasma Processing & Industrial Applications in this issue, I also would like to throw light on couple of significant achievements of IPR. The existing Aditya Tokamak is being upgraded into a machine with divertor operation and improved plasma control to support the future Indian Fusion program in a big way. On behalf of our SST-1 team, I am very pleased to convey that phase – I Operation was successfully concluded. First upgrade activity with the inclusion of the first wall in the machine has been completed and the machine has started preparations for the next campaign.

Prof. Dhiraj Bora

Editor's Note

The July 2015 issue of Plasma Processing Update speaks about Plasma surface functionalization of polymer surface for printing application, plasma etching of synthetic fibers for enhancement in anti-pilling characteristics and space-craft plasma interaction experiments. These results may lead to potential application developments in field of packaging, textiles and space science.

This issue also throws light on in-house use of plasma pyrolysis technology at IPR Campus. Upcoming one day seminar on "Applications of Cold Plasma in Surface Engineering" at FCIPT is announced in brief.

Do stay in touch with us on www.plasmaindia.com.

Yours sincerely,

Dr. S. Mukherjee

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Co-Editors

Mrs Purvi Dave

Mrs Nisha Chandwani

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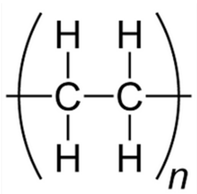
Eco-friendly printing for Polyethylene

Mrs. Purvi Dave

Polyethylene is the most popular plastic in the world. It has a very simple structure, the simplest of all commercial polymers. A molecule of polyethylene is a long chain of carbon atoms, with two hydrogen atoms attached to each carbon atom as shown below.



When ethylene is polymerized the result is relatively straight polymer chains. From the main chain they can branch out. We get different kinds of Polyethylenes from the varying degree of branching in their molecular structure. Low density polyethylene (LDPE) is used mainly in film applications for both packaging and non-packaging applications. Other markets include extrusion coatings, sheathing in cables and injection moulding applications. ***Polyethylene has very low wetting properties and high chemical resistance.*** Low wetting properties of polyethylene surface results in poor adhesion with printing inks. Thus, this adhesion problem leads to the printed ink rubbing off, coatings or paint not sticking on the surface along with failed gluing and weak sealing.

To overcome this limitation of polyethylene, it is required to alter the polyethylene surface property. For this purpose polyethylene surface is exposed to cold plasma processing.

When PE surface is exposed to the oxidative (air or oxygen) plasma, four chemical reactions; chain scission (C-C bond dissociation), hydrogen abstraction (C-H bond dissociation), oxidation and chain cross-linking are anticipated. These processes are explained in the figure below.

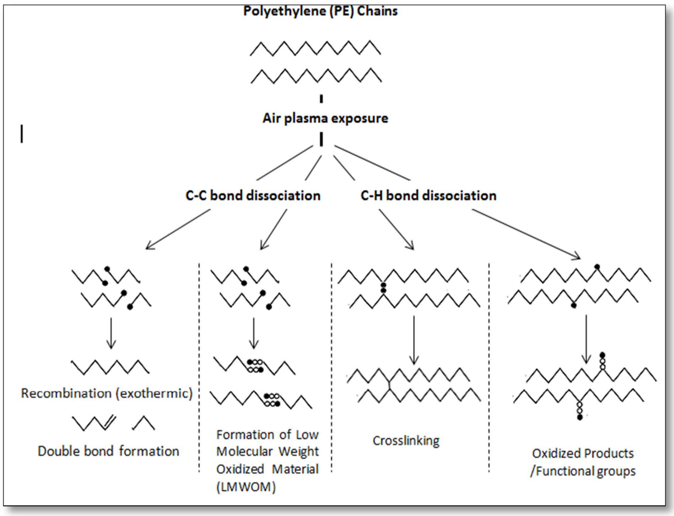
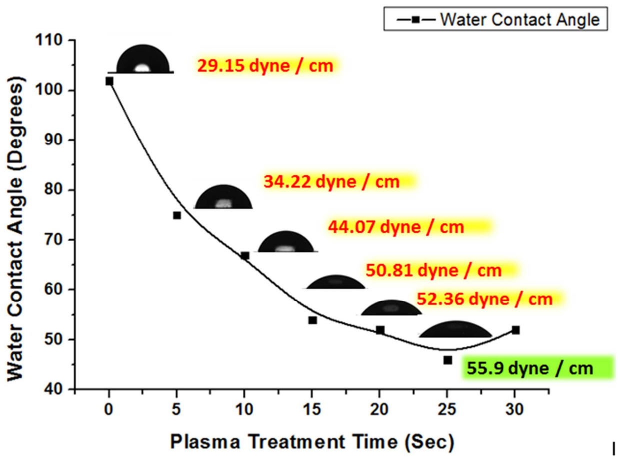


Fig.-1 Plasma Polymer Interaction

During chain scission, free radicals are produced at or near the PE surface. These free radicals react with oxidative plasma species and form oxygen based groups such as C-O, C-OH and C=O. Cross-linking between neighbouring chains is also induced by the free radicals produced by the breakage of C-H bonds.

The use of gaseous plasmas for the modification of polymeric materials is well established. In this context, appropriate cold plasma systems are capable of inducing changes to surface chemistry and / or topography without affecting the bulk properties. Non thermal plasmas operating at atmospheric pressure without the use of vacuum chamber leads to increasing scope of potential industrial applications. DBD is a form of cold plasma that operates at atmospheric pressure and ambient temperature. The plasma is created between two electrodes; the working electrode and ground electrode separated by a gap of 1 – 3 mm. Applying high voltage to the working electrode results in a creation of plasma discharge. In the case of DBD plasma at atmospheric pressure formation of low molecular weight oxidized products were observed as a result of polymer chain scission. Further oxidation of these intermediate fragments in discharge results in formation of gaseous products such as CO_2, H_2O, CO and H_2 through so called polymer etching.

In the present work we have done plasma surface activation of polyethylene at atmospheric air plasma. Plasma treatment is given for 5 to 30 seconds. Polyethylene surface becomes hydrophilic gradually with plasma exposure time. This is ensured by video contact angle measurements. One can visualize this looking at below figure.



Generally packaging film surfaces are activated by corona treatment. This treatment increases surface energy of Polyethylene up to 40 dynes / cm. With this surface energy only solvent based inks can be used. In order to make this eco-friendly water based inks can be used which requires surface energies above 50 dynes/cm.

By atmospheric pressure air plasma treatment, surface energy up to 56 dynes/ cm has been achieved at FCIPT. This is an eye-catching results for printing industries.

Pill free synthetics by Plasma

Mrs. Nisha Chandwani, Mrs. Kruti Mungara

Acrylic is a synthetic fabric having warm feel like wool. Now-a-days, it is being used as replacement of wool in hand knitted products, hosiery garments, blankets and carpets. It has got high strength, better elasticity, good dye-uptake, colour fastness, light weight and is much easy to wash. Pilling is one of the drawback of acrylic fabric and other synthetic textiles. Once the pills are formed on the surface, they not only give the bad look, but also result in premature wear of the fabric.

A pill, is basically, a small bundle of fibres that forms on a piece of cloth, during washing and wearing. A pill's evolution involves three major steps: first, abrasion on the fabric—the fibers rubbing against themselves or another surface—cause"fuzz." Further agitation then causes a collection of fiber to form small clinging balls called pills that are anchored to the fabric. Finally, as mechanical and physical action weakens the pill's ability to cling over time, it falls off the fabric in its last stage known as depletion or removal.

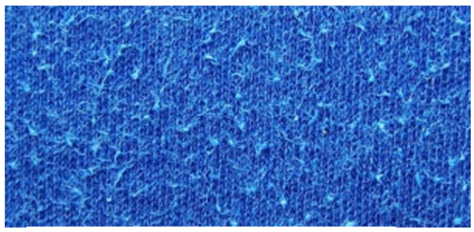


Fig 1: Pills on a fabric

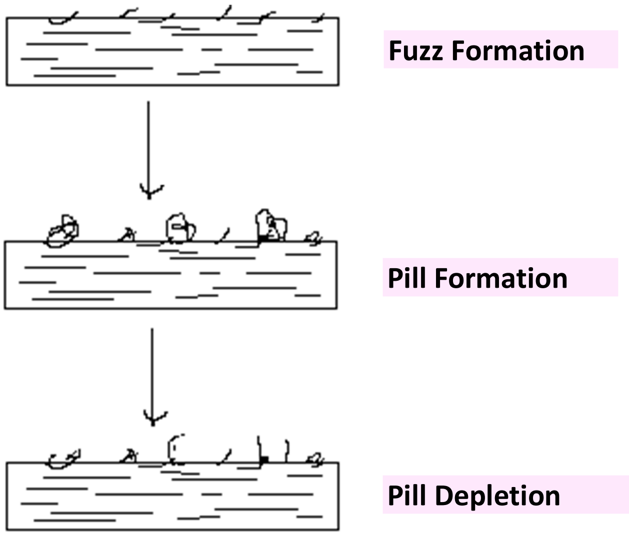


Fig. 2: Pill Formation Mechanism

The various fiber properties such as low coefficient of friction, higher fiber tenacity, higher hairiness, lower fiber length etc. are responsible for pilling. Natural fibers like cotton exhibit some pilling, but it goes unnoticed because of its inherent weakness: the pills are tiny and fall off quickly. Synthetics like polyester and acrylics contain strong “anchor” fibers for the pills to cling- so strong that fewer pills fall away.

The various methods have been explored to create synthetic fabric with no - pilling characteristics. However each of process have their drawbacks, for example singeing gives only temporary solution, application of resins make uncomfortable feel, techniques to reduce fiber strength make it inefficient and harder for mills to process. Moreover these chemical treatments use substantial amount of water and chemicals

FCIPT has initiated some exploratory work to improve antipilling properties of acrylic fabric using atmospheric pressure plasma. In the present work, two varieties of Acrylic Fabric have been exposed to plasma and surface morphology and pilling properties are studied. The surface morphology of the acrylic fiber is studied by SEM (Scanning Electron Microscope). The SEM image of untreated and plasma treated acrylic fiber is shown in figure3. The untreated fiber has a smooth surface and less roughness, while the roughness of plasma treated fiber has increased significantly. This helps in increasing the cohesion among the fibres and hence the tendency of slipping of fibres decreases. Since the formation of pills is due to migration of fibres from the constituent yarns in the fabric, in theory, reducing the migration tendency of fibres by plasma treatment can help improving pilling resistance.

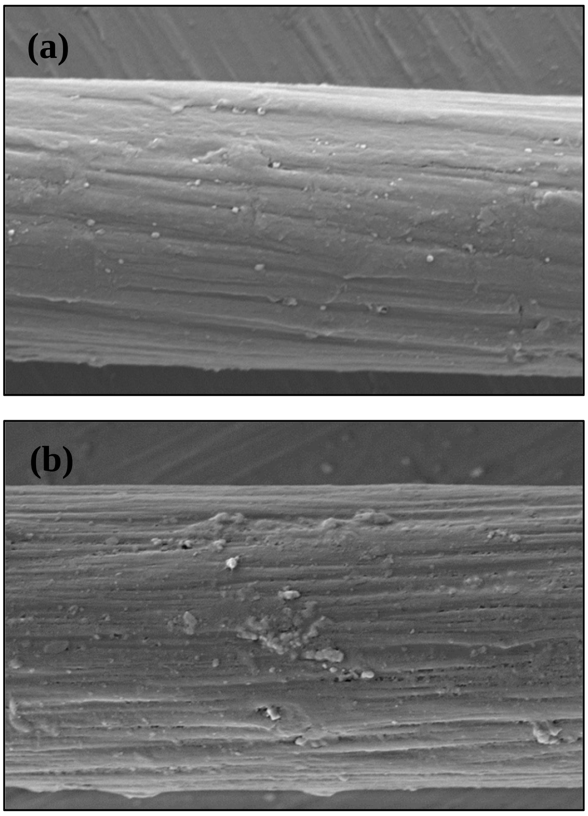
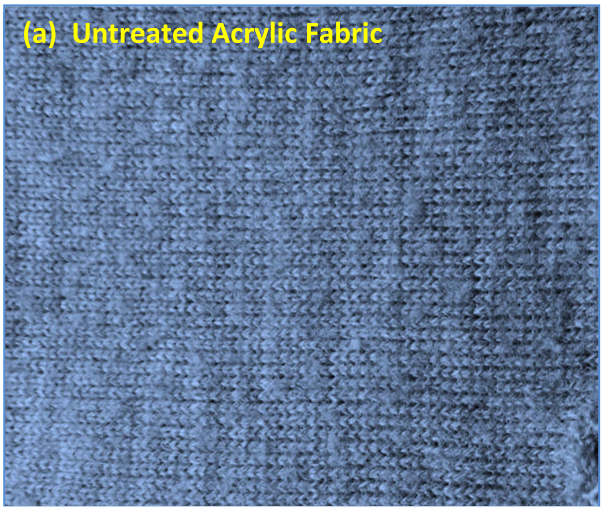
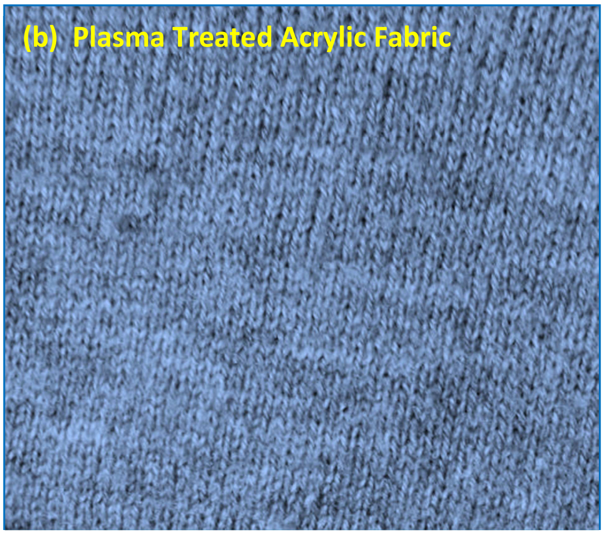


Fig. 3 SEM Image at 10000x Magnification (a) Untreated Acrylic Fiber (b) Plasma Treated Acrylic Fiber

Anti-pilling performance of untreated and plasma treated acrylic fabrics have been evaluated by using **ICI pilling box method** under the standard **IS 10971**. After testing, fabric samples are visually assessed by comparing them with a set of photographic standards on the following scale : 5 — no pilling; 4 — slight pilling; 3 — moderate pilling; 2 — severe pilling; and 1 — very severe pilling. The results obtained for plasma treatment are shown in Table 1.





The preliminary results of this exploratory work are quite promising. It can be concluded,

Table 1: Pilling Test Results

Sample Details	Pilling grade	
	Untreated	Air Plasma Treated
Knitted Acrylic fabric GSM:306 Count:2/24	1	5
Woven Acrylic Fabric GSM:90 Warp:2/24,Weft:2/40	3	5

Plasma processing can provide an eco-friendly solution to improve the pilling properties of acrylic fabric and other synthetic textiles.

Satellites with better Solar panels

Mrs. Keena Kalaria

Spacecraft or satellite is used for variety of purposes including communications, earth observations, navigation, planetary explorations etc. The growing demands of satellites for new application have led to increased power requirements. One of the major challenges is to fulfill these power requirements by solar panels, which are the only power source in any satellite. The higher power generation requires the solar panel to be operated with high bus voltage. This leads to increase in chances of arcing on the solar array surface, when satellite interacts with the space plasma. The arcing happens due to development of electrostatic (ESD) charges. The arcing is a serious threat to Space-craft as it may lead to disruption of entire power of the satellite.

Indian Space Research Organization (ISRO) being the primary agency doing space related activities in India realized the necessity to develop an experimental setup for understanding the charging-arcing phenomenon in solar panels. In 2003, Indian Space Research Organization (ISRO) decided to use the expertise of Institute for Plasma

Research (IPR) for this activity. Thus a collaborative research project which involved the elements of both theoretical modelling and experimental simulation was started. As an outcome of this collaboration, the experimental facility was set-up at Facilitation Centre for Industrial Plasma Technologies (FCIPT). The project was initiated with Lower earth orbit (LEO) set-up which included theoretical modeling to calculate the charging potentials and potential differences which would result in arcing along with the arcing experiments. In 2010 the facility was upgraded to study both Lower earth orbit (LEO) and Geosynchronous Earth Orbit (GEO) satellites solar panel coupons with indigenously developed plasma source, high speed data acquisition (DAQ) and analysis system. The experimental setup integrated at FCIPT is shown in figure 1. The experiments follow the international standard ISO 11221.

The purpose of these experiments is to determine the arc threshold in LEO as well as GEO environmental conditions. This helps to qualify a given design of solar panel for flight. According to ISO 11221, the arcs are categorized depending upon the time duration, as primary arc [PA- few µsec], non-sustained arc [NSA – few tens of µsec], temporary sustained arc [TSA – few hundreds of µsec], and Permanent sustained arc [PSA – few **msec**], which is shown in fig.2.

The primary arcs are not much destructive; however they are often converted into sustained arcs like NSA, TSA and PSA on gaining energy from neighboring solar cell strings.

LEO and GEO like environments are created in a vacuum chamber using special power sources. Flood beam type electron gun is used to conduct irradiation studies in GEO experiments, while tungsten based filamentary plasma source is used to simulate LEO conditions and perform plasma studies**.** A Lab VIEW based SPIX software is developed, which can perform four different types of ESD experiments, namely LEO primary, LEO secondary, GEO primary and GEO secondary experiments. The various types of solar coupons with different inter-string gaps, grouting architectures have been tested under accelerated conditions for arcing. These experiments lead to various arc mitigation techniques which included the design modification in alignment of solar cells, grouting pattern, inter-string gap etc.

The twelve years of fruitful collaboration between ISRO-IPR has led to development of internationally accepted ISO test facility for spacecraft charging in LEO and GEO environment. This test facility has been helpful in making guidelines towards the design and manufacturing of the upgraded solar arrays that are more immune to ESD problem.

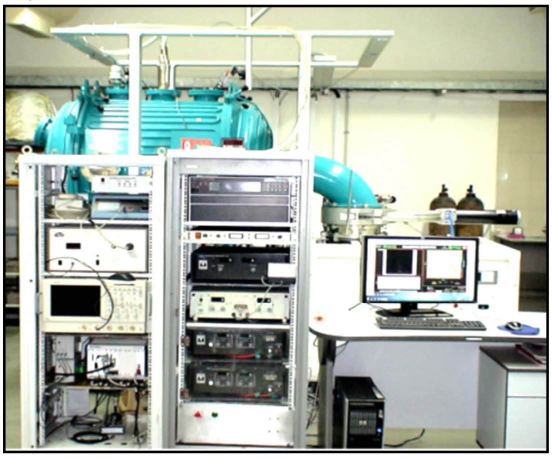


Fig 1: Experimental setup for testing arcing phenomenon

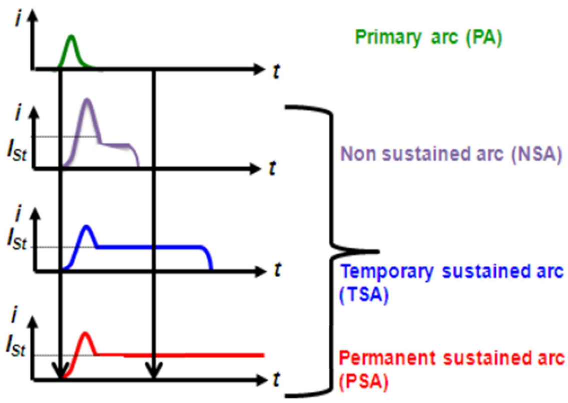
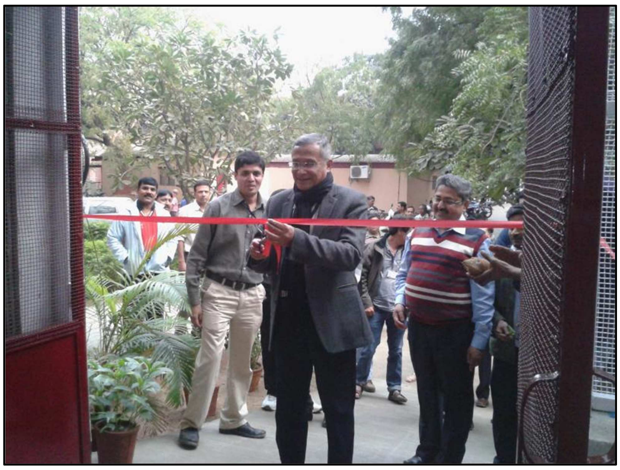


Fig. 2 Categorization of secondary arcs - Primary arc on solar coupons [PA], Non-sustained arc [NSA],Temporary sustained arc [TSA], and Permanent sustained arc [PSA].

News & Events

IPR using Plasma Pyrolysis for In-house waste disposal

Institute for Plasma Research (IPR) has started using the Plasma Pyrolysis for the disposal of In-house waste. The Director, Institute for Plasma Research inaugurated the 15Kg/hr Pyrolysis plant on 1st Jan 2015. This plant also serves the purpose of technological demonstration on an actual scale.



Prof. Bora inaugurating the plasma Pyrolysis Plant at IPR

Plasma Pyrolysis System Functional at IPR

Upcoming One-day Seminar

FCIPT-IPR is planning to organize a Workshop on ***"Applications of Cold Plasmas for Surface Engineering"***

Who Should Attend: Industrialists, Machinery manufacturers, Research Institutes and Academic researchers interested in learning about the cutting-edge development in various non-thermal (cold) plasma processing technologies

Industrial Sectors/Applications: Biomedical, Forensic, Textiles, Solar, Auto-mobiles, Polymers, Metals etc.

Date: 11th September 2015

Venue: FCIPT Seminar Hall

The details of the workshop will be displayed shortly on our website.

Need a Technological Solution from us?

FCIPT works on industry and society specific technology development. We invite all industries to contact us for any specific technological solution needed. Possibly, plasmas may prove out to be a better solution. Contact us on below mentioned address or email your queries to fcipt@ipr.res.in, or just log on to:www.plasmaindia.com

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