# PLASMA

# PROCESSING UPDATE

**A newsletter from the**


*Issue 68 (July - Dec 2013)*

## Contents

# Editor's note

Mr. Akshay Vaid cites the application of cold plasma in treatment of seeds to increase the yield and in other hand also reducing the fungal infection. He throws light on the initiatives at FCIPT in seed treatment and how the experiments are actually planned. The benefits of this treatment is also been discussed.

Mr. Mukesh Ranjan, discusses about the arc mitigation via solar panel grouting and curing under simulated Lower Earth Orbits (LEO) like environment. Electro Static Discharge (ESD) is a common phenomenon in satellite solar arrays due to surface charging by low density space plasma which may sometimes permanently damage the array. He also discusses about the set of experiments carried out in Si solar cells. The results were discussed and concluded with suggestions.

Mr. Hemen Dave cites about the improvement of wettability property of grey cotton fabric by using air dielectric barrier discharge. In this article he presents the study on removal of non-cellulosic impurities from grey cotton fabric by plasma treatment, which improves the wettability and discussed the result of the experiment with various analyses like ATR-FTIR spectra, SEM, Contact angle analysis of the fabric after plasma treatment at different time scale.

**Editor: Dr. S. Mukherjee**
**Co-Editor: P.Vadivel Murugan**

## Conference/Poster presentations from FCIPT

| Name of the author | Topic | Date | Place | Conference |
|---|---|---|---|---|
| Ms. Alphonsa Joseph | Low Pressure Plasma Based Technologies for Surface Modification | August 2013 | Chennai | SERIA-2013 |
| R. Rane | Langmuir probe Diagnostics | October 2013 | Kathmandu University, Nepal | Workshop On Experimental Plasma Physics and its applications |
| N.I. Jamnapara, A. Sarada Sree, E. Rajendra Kumar, S. Mukherjee, A. S. Khanna | Compatibility studies of plasma grown alumina coating against Pb-17Li under static conditions | October 2013 | Beijing, China | InternationalConference on fusion reactor materials (ICFRM-16) |
| R. Rane | Development of Duplex Plasma Based Process for Improvement of Surface Properties of Steel | December 2013 | KIIT, Bhubaneshwar | 28 th National Symposium on Plasma Science and Technology |
| R. Rane | Magnetron Sputtering for Thin film Deposition | December 2013 | SVNIT, Surat | Workshop on Thin Film and Vacuum Technology |

## ABOUT FCIPT

### Facilitation Centre for Industrial Plasma Technologies

The Institute for Plasma Research (IPR) is exclusively devoted to research in plasma science, technology and applications. It has a broad charter to carry out experimental and Theoretical research in plasma sciences and emphasis on the physics of magnetically confined plasmas and certain aspects of nonlinear phenomena. The Institute also has a mandate to stimulate plasma research activities in the universities and to develop plasma-based technologies for the industries. It also contributes to the training of plasma physicists and technologists in the country. IPR has been declared as the domestic agency responsible in INDIA to design, build and deliver advanced systems to ITER (International Thermonuclear Experimental Reactor) to develop nuclear fusion as a viable long term energy option.

The Facilitation Centre for Industrial Plasma Technologies (FCIPT) links the Institute with the Indian industries and commercially exploits the IPR knowledgebase. FCIPT interacts closely with entrepreneurs through the phases of development, incubation, demonstration and delivery of technologies. Complete package of a broad spectrum of plasma-based industrial technologies and facilitation services is offered. Some of the important areas in which FCIPT has been working on include Plasma Surface Engineering, Plasma Pyrolysis/ Gasification/ Energy Recovery, Plasma Diagnostics, Plasma Based Nano Patterning and Nano Synthesis, Textile Engineering, Solar Cell Development, etc. The Centre has process development laboratories, jobshops and advanced material characterisation facilities like Scanning Electron Microscopy, Microhardness Testing facilities, which are open to users from industry, research establishments and universities. For further information, please visit our website.

This newsletter is designed to update the readers with the latest developments in the important field of plasma processing and plasma based technology development and to look for new industrial opportunities.

Please visit our website: [http://www.plasmaindia.com](http://www.plasmaindia.com)

## Cold Plasma Treatment for seeds for increasing yield & reducing fungal infection

*Mr. Akshay Vaid & Mr.R Rane*

**Introduction:**

In India where the majority of the population is agriculture oriented, the seeds plays the vital role. Number of hybrid and genetically engineered varieties of seeds are coming in the market in order to have better yield and infection resistance. While number of methods for the germination of seeds have been used which are having disadvantages and effects the species in habitat restoration, ex-situ conservation and horticulture.

Here at FCIPT, we are trying a novel plasma discharge method for the treatment of seeds which serves two benefits:

a) Improved germination of seeds.
b) Killing of fungal spores on seed coats.

Increase germination rates & decreased rates of fungal attacks will benefit the cultivation & conservation of various species.
Dielectric Barrier Discharge is used to treat seeds of different species. Changes in the seed coat would be investigated using swelling, measurement of seed coat thickness & germination experiments.

**Procedure:**

The experiment would be carried out as follows:

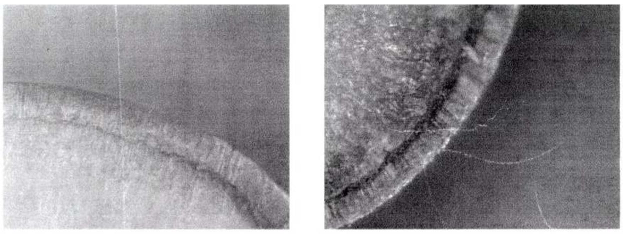
- 100 seeds would be considered and procured from Agriculture University, Palampur.
- The seeds would then be treated with Dielectric barrier discharge Plasma.
- The treated and untreated seeds would be grown on a moist filter paper in petri-dishes and would be kept for 5-7 days (before the first sprout forms) in a thermostat at 20-22 degrees.

- A plot would be used for the field test.
- The estimation of seed germination would be performed on the 3rd, 7th & 10th day of cultivation.
- The vitality would be evaluated as a ratio of number plants in the ripeness stage to the germinated ones.

**Applications:**

- Can increase the water uptake and increase the germination yield.
- Can kill fungal spores carried on seed coats.
- Detoxification of seeds.

Plasma treatment of seeds enhance water uptake as it removes effectively the very thin lipid layer that makes the seeds water repellant and also reduces the length of the bio-polymer chains that make up the seed coat which allows the water transport through the seed coat for the embryo.



Untreated Kennedia Rubicunda    Plasma treated Kennedia Rubicunda

*Figure 1: Photo Micrograph of seed coats of untreated & Plasma treated Kennedia*

Plasma Treatment of seeds results in the increase of the field germination of seeds and also in the reduction of the seed contamination level with fungal infection

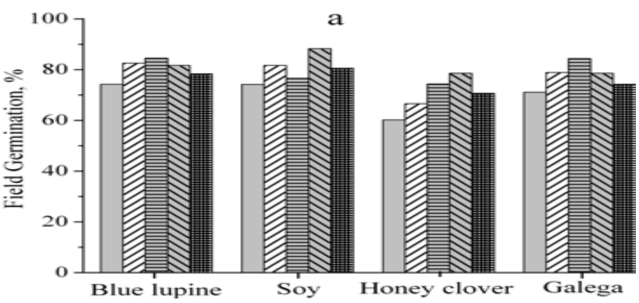



*Figure 2: Field germination of untreated and treated seeds*

## Arc mitigation via solar panel grouting and curing under simulated LEO like plasma environment

***Dr. Mukesh Ranjan***

**Introduction:**

Electro Static Discharge (ESD) is a common phenomenon in satellite solar arrays due to surface charging by low density plasma present in both Geosynchronous (GEO) and Lower Earth Orbits (LEO). Such ESD events may be classified as minor arc or major arc depending on the duration of the arc. Nowadays, these arcs are further classified as primary arc, non-sustained arc, temporarily sustained arc or permanently sustained arc, depending on the arc duration. Occurrence of permanently sustained arc in the solar panel may lead to permanent failure of the panel. Therefore ground experiments are required to simulate arcing events that occur in space. Arcing events due to spacecraft charging is known from last two decades [1-7]. Negatively biased, high-voltage solar arrays in Lower Earth Orbit (LEO) are known to undergo arcing above a threshold voltage in presence of low plasma density ($\sim 1\text{x}10^6$ cm$^{-3}$). This phenomenon had also been verified in laboratory under simulated LEO conditions (Te = 0.1-2 eV and $\sim 1\text{x}10^6$ cm$^{-3}$) under various panel configurations [1-7, 15]. Arc sites, arc voltage threshold, arcing frequency and arcing current duration depend on plasma parameters, solar cell circuit and type of solar cell in use. For example there are two well know configurations Cho's [2, 3] in which a column of solar cells is short circuited from top and bottom and then biased from the external circuit to simulate charging effect, and NASA type [4, 5] in which two parallel solar columns are connected by a DC supply to simulate the potential generated by solar cells. Minor or sustained arcs respectively can be observed in LEO plasma environment depending on the solar array configuration. Cho's configuration is used to study primary arcs. In this configuration, there is no application of differential voltage between the solar cells strings. Therefore, the primary arc cannot get sustained. In the NASA configuration, differential voltage is introduced between strings and varied to see the point where sustained arc occurs. In this study all experiments were carried out in Cho's configuration. The study of primary arc is important because primary arc is a necessary precursor to sustained arc. Over the years several researchers performed various experiments and developed models to study the arcing phenomenon in a solar panel [8-14]. Now this field of research is so matured that even the standardisation (ISO-11221) of ESD testing of the solar panel is completed [15]. In spite of the detailed experimental work done in this field and with all the preventive actions, satellites still suffer from interaction with space plasma. Due to increasing demand of higher power in satellites, ESD phenomenon is more likely to occur [1, 4], since higher power requirement requires longer transmission cable; consequently require higher voltages and that is more prone to arcing. Use of plasma thrusters is another new possibility that leads to spacecraft charging if plasma plume is not well converging [16].

In the present work experiments are presented that show that continuous arcing in presence of plasma reduces the rate of arcing drastically with time and that the rate can be reduced even further via grouting the panel gap. This process of letting the coupon to arc in the presence of plasma, resulting in the reduction of arc rate will be referred to as plasma curing in the rest of the paper.

## Experiment:

Experiments were performed in a vacuum chamber of 1m length and 1m diameter with several ports equipped with various diagnostics (Figure 1). Base pressure of the chamber and pressure during Ar plasma generation was $1.7 \times 10^{-7}$ mbar and $5 \times 10^{-5}$ mbar, respectively. Plasma source was installed on the top flange close to coupon. These experiments were performed under LEO like plasma conditions i.e. plasma density ~ $1 \times 10^{6}$ $cm^{-3}$ ($T_e$ ~ 0.1 eV) obtained using filamentary discharges of argon gas. Thoriated tungsten filaments were heated to emit primary electrons which were accelerated to ionize the background gas by the process of impact ionization to form plasma. Plasma density is characterized such that a value of about $10^{6}$ $cm^{-3}$ exists in the surrounding of the coupon. To maintain ~$10^{6}$ $cm^{-3}$ plasma density, we need to provide 10.5V/23.1A to filament heating power supply and 63V/0.02A to filament biasing power supply. The plasma density was controlled by controlling the total discharge power. Plasma density and temperature were measured using a Langmuir probe. The plasma generator was cooled by passing cold water through copper tubes brazed on the outer surface of the chamber. Once the required plasma density was achieved and it remained stable for 15 minutes, external biasing to the solar panel coupon was applied.

A ceramic coated heater (400 W) compatible to high vacuum conditions was mounted on a movable rod from the back side of panel at a sufficient gap not in the direct contact with solar panel. An aluminium plate of the similar size as solar panel was fixed on the backside of the coupon. This plate was not in direct touch with solar panel backside but at a few mm distance. Metallic plate was used to ensure that there should not be any temperature gradient. Now heater was push backside of this aluminium plate. Used heater is a ceramic coated, so there was no risk if heater touches the aluminium plate. Two vacuum compatible thermo couples were installed to monitor the temperature of the solar panel front as well as back surface. In all experiments, the coupon was heated to 110°C for one hour before the experiment. This is a practice followed by other researchers also [8]. One hour time of degassing was chosen after comparing the outgassing time of 1h, 3h and 5h, respectively using a RGA analysis. It was observed that already in 1 h time number of arcs become stable and degassing stopped playing a crucial role.

Solar panel coupon was set inside the vacuum chamber on a Teflon stand, facing towards the view ports (Figure 1). Position of the coupon was such that it can be focused completely from one of the view ports using a CCD camera. All the ends of solar cells were connected with Kapton insulated wire to the outside circuit through a side flange and high voltage vacuum compatible connectors (Figure 1). The connectors were shorted and were connected to an external capacitor (33 pF), which in turn was connected to an external power supply (0 to -600 V) through a 200 kΩ resistance. This capacitance simulates that of all cover glasses on the solar array panel wing of a typical real satellite .The solar cell arrays could be biased from -300 V to -600 V. To avoid the sustained arc and permanent damage of solar cell, most of the study was performed in decoupling mode (connecting a high resistance, which in this case is 220kΩ, with biasing power supply so as to decouple the power supply from the coupon circuit) and in current limiting mode [2, 14].

Data acquisition was performed in the following manner. The pulsed arc current was measured with two current transformers CT-1 and CT-2 (both having response of 1.0 V/A). A Tektronix make (Model no: P6015A) 1000 X HV probe was used to monitor the applied voltage waveform on oscilloscope. A 350 MHz digital oscilloscope with 1 Gb/s sampling rate was used for fast data acquisition during arcing events. The output of 1000 X HV probe, CT-1 and CT-2 are connected to different channels of the oscilloscope.

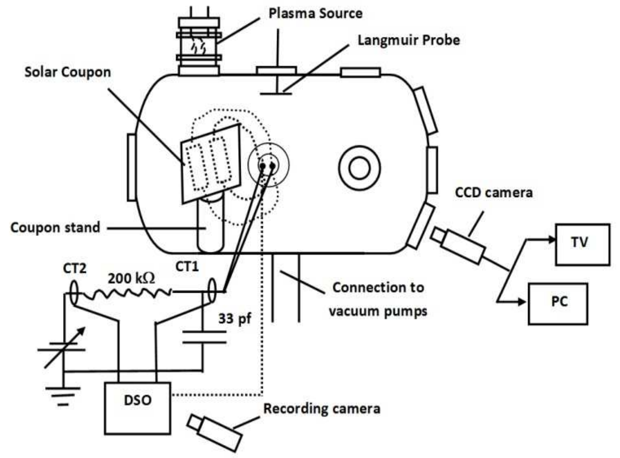


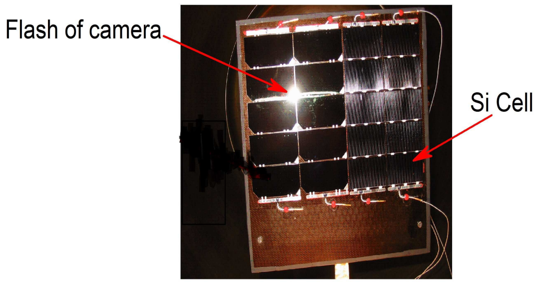

*Figure 1: Schematic diagram of the experimental setup, solar arrays connected in decoupling mode. CCD camera is facing the panel surface and recording camera to DSO.*

Arcing events were counted by triggering oscilloscope near threshold voltage. CCD camera of 32 f/s was focused on the solar panel coupon and the camera output was connected to computer to store the arc events in the form of a continuous movie. A compact digital movie recording camera was also focused on the oscilloscope to record the oscilloscope traces in the continuous mode. The movie of oscilloscope traces is very important, as the number of arcs stored in the oscilloscope was cross checked based on this movie. Number of arcs was counted for interval of every 10 minutes. In above condition each coupon was cured for more than 5 h and then kept outside the chamber exposed to the environment (In between experiments, the coupons were repacked and kept in a box, the temperature and humidity being that of a standard room) and the same experiment was repeated again with same conditions and parameters. Plasma density variation (Table-1) was done after the coupon had fully cured and almost stable value of arcs achieved. While varying the plasma density, gas pressure was kept constant only the filament current and biasing voltage was varied for this purpose .The same process was done for both types of solar arrays, that is, with and without grouting.

| No. | Filament Bias | Biasing power supply | Plasma Density ($cm^{-3}$) |
|---|---|---|---|
| 1 | 10.5V/23.1A | 63V/0.02A | $0.65 \times 10^6$ |
| 2 | 11.5V/24.1A | 119V/0.03A | $1.85 \times 10^6$ |
| 3 | 12.5V/25.2A | 140V/0.04A | $2.28 \times 10^6$ |

*Table 1: Plasma density variation parameters.*

Cross-sectional view of the Si solar cell used for the study is shown below in Figure 2. The cells have the configuration from base support of ~0.1 mm to top anti-reflecting coating of $MgO_2$ less than 1µm thick. Silicon cell thickness is 200 µm. Silicon solar cell connectors are made of ~ 4µm thick Palladium-Silver. An actual coupon used in the experiments is shown below. One column having 4 solar cells was used at a time during the experiment. So wires coming out from top and bottom of the solar columns were shorted and were connected to the outside circuit as described above. All the coupons were fabricated using substrates which consisted of Al honeycomb core with CFRP face skin with the same dimension of 300 mmx300 mm. The coupons were 20 mm thick. The cells were bonded using RTV-S-691 onto a 50 micron thick Kapton insulator which was co-cured with the substrate during its manufacture. There was Kapton only on the cell lay-up side.




**Mounting of Solar cells during the experiments**

*Figure 2: Cross-sectional view of Silicon solar cell, showing various layers and their thicknesses.*

## Results and Discussion:

Figure 3(a) corresponds to a bias of –500 V with 200 kΩ resistance. The yellow signal (top signal) represents the biasing voltage, pink (middle signal) represents the current in CT-1 and sky blue signal (lower signal) represents the current in CT-2, respectively. During arcing, the voltage signal reduces in magnitude with flat top of nearly 5 µs and recovers in timescales of nearly 100 µs. These types of arcs are most predominant at these parameters. There is a marked difference between the CT-1 and CT-2 signals. This is because in this decoupling mode, the capacitor discharges first and then takes a certain amount of time to charge again. These results are similar to those reported elsewhere [1]. Typical arc observed in between the two solar cells at a triple junction is shown in Figure 3(b, c). Arcs appear at random places (in between two solar cell, cover glass etc.) until they become a sustained arc

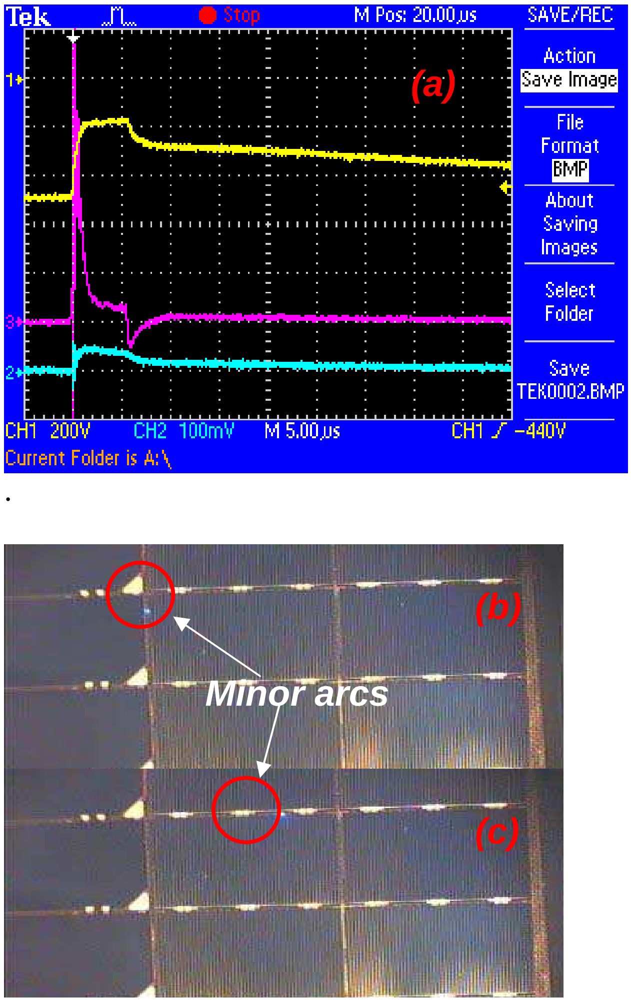



*Figure 3: (a) Oscilloscope traces for the experiment corresponding to array bias of -500 V, external resistance of 200 kΩ. The yellow signal (top signal) represents the biasing voltage, pink (middle signal) represents the current in CT-1 and sky blue signal (lower signal) represents the current in CT-2, respectively. Voltage is measured in 200 V/div, while current is measured in 10.0 mA/div. (b, c) recorded minor arc images using CCD camera during the experiment.*

In Figure 4, curing data for Si solar array without grouting is shown. Red data points correspond to the first experiment and black indicates the repetitions of the same experiment after 2 days. Coupon was kept outside the chamber in between the experiments. Within first 10-15 minutes, the number of arcs reduced drastically from 350 to about 50 in per 10 minute time. Number of arcs starts getting saturated after 50 minutes of curing and was reduced to some mean value just after 2 h of curing. In the next experiment after 2 days, the number of arcs again starts from the same initial value and not from the saturated value of the previous experiment. This experiment indicates that possibly during curing the solar panel coupon, trapped gases and moisture comes out. This may be the primary reason of arcing, since the trapped gases generate higher local pressure and they get easily ionised and this leads to arc initiation. Those trapped gasses which could not come out during the normal degassing process (Vacuum pumping and Thermal Curing) possibly come out after plasma curing. Plasma is generated at a higher pressure that leads to higher collision rate with ion-neutral and electron-neutral and also generates more secondary electrons in the vicinity, due to this even the trapped gases ionised and burst off and release from the coupon which was not possible in thermal curing process at 110$^{o}$C before plasma curing started.

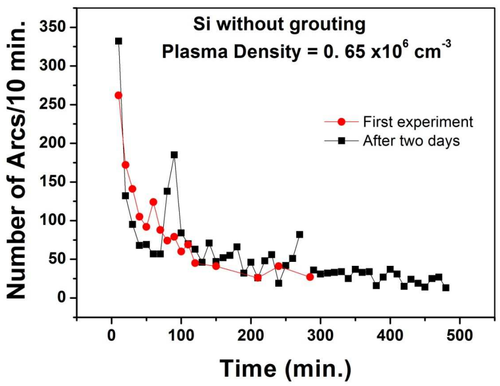



*Figure 4: Curing data for Si without grouting first experiment (red) and then repeated it again after two days (black). After exposing to atmosphere number of arcs again start from the same initial high values.*

Figure 5 shows curing data for Si with fully grouted solar array. Fully grouted solar array means all the inter connectors and gap in between the cell were covered with the material which was used for bonding the solar cell strings to the substrate which in this case is RTV-691-S. Similar experiment was performed like in the case of un-grouted Si solar array. Two experiments were performed with a gap of two days with same conditions and parameters. To see the effect of curing, the panel was kept outside the vacuum chamber for two days. In this case initial number of arcs is found to be much less than the un-grouted case. There is a large difference of around 230 arcs. Due to grouting there are fewer triple junctions as well as gas trapping sites that lead to reduction in number of arcs. In this case as well, the effect of curing can be seen clearly i.e. number of arcs gets saturated again in 50 minute time but when the experiment was repeated again after 2 days initial number of arcs were found to be much less (~20 arcs/10 min.). That is, arcing starts with a rate nearly equal to the saturated value.

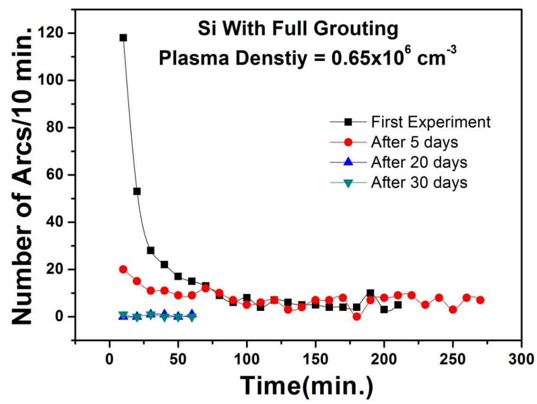



*Figure 5: Curing data for Si with full grouting, experiments were also performed after gaps of several days. It shows very good effect of curing and grouting.*

From the above two results of Si solar arrays it is clear that the arc rate is lower in case of Si with fully grouted and effect of curing is also observed. The same solar panel was again checked after a month time but the number of arc/10 min. reduces after every experiment. Therefore in the final experiment it reduced to only 1-2 arcs/10 min. All these experiments were performed at a plasma density of 0.65 x 10$^{6}$ cm$^{-3}$. Similar experiments were performed at higher plasma density as well which is given in Table - 1, but same trend in arcs variation was observed. Also it was observed that initial number of arc increases when the plasma density was increased from 0.65 x 10$^{6}$ cm$^{-3}$ to 2.28 x 10$^{6}$ cm$^{-3}$ and their saturation values were higher for higher plasma density.

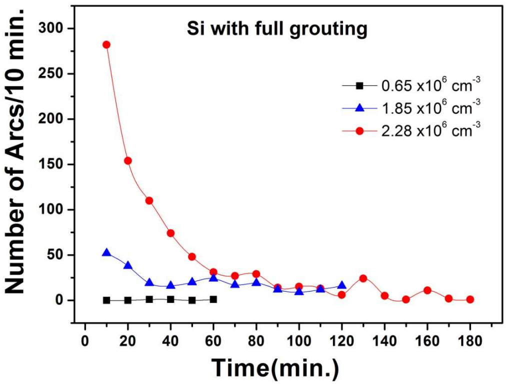



*Figure 6: Density variation results for Si with fully grouted coupon. As plasma density increases arc rate increases initially and then reduces to the same saturation value.*

Plasma density variation effect for grouted Si coupon is shown in Figure 6. The coupon that was showing only 1-2 arcs per 10 min starts generating around 280 arcs per 10 min. After curing for 50 minutes number of arcs saturated to the same value like in the case of lower density i.e. 1-2 arcs/10 min. It is possible that arcing can occur once there is an opening in the insulator where the buried conductor with a negative potential above threshold value, is exposed to space. The arcing is triggered by charging of insulator material via plasma and field intensification at the conductor surface, especially at the junction with the insulator, which is called a triple junction, because three materials with different electrical conductivity (conductor, insulator, and vacuum), meet there [4]. When the plasma density is increased, panel charging occurs in faster time scale and directly affects the arc initiation, which may be the reason why we have observed higher number of arcs initially in our experiments at a higher plasma density.

There are many ways for a triple junction to be formed. One example is an interconnector between solar cells, where the triple junction is formed with the interconnector exposed to space, the cover-glass, and the vacuum [3]. Another example is a hole in the grouted material exposing the underlying conductive surface produced by impact of a small particle on the surface. So a proper grouting material should sustain in the plasma condition for a long period of time to avoid the arcing.

## Conclusions:

The arc statistics performed for Si solar arrays under decoupling mode show the clear effect of curing and grouting. Number of arcs reduces substantially after first 1 h and then remains stable for a long time. In the case of ungrouted panel, if it is again exposed to the atmosphere then the arcs start with the almost the same number as in the previous experiments. This indicates that it is essential to remove all the trapped gases from the panel structure. The possible solution is grouting the interconnectors and the gap in between the solar cells. Grouted solar cell arrays show much reduced number of arcs and maintain this value even after the panel get exposed to atmosphere. With the increase in plasma density the number of arcs increases but again it is found to be less in the case of grouted solar cell.

This study suggests that curing of solar panels in LEO-like plasma reduces the probability of arcing. However, this effect (reduction of arcing rate) is short-lived in the case of ungrouted panels. A combination of grouting and curing is suggested as a prophylactic measure to mitigate the possibility of arcing. However, more experiments need to be done to confirm this finding.

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## Wettability improvement of grey cotton fabric by air dielectric barrier discharge

***Mr. Hemen Dave***

Cotton fibre is composed of mainly 'cellulose' the most abundant, renewable and biocompatible polymer and is the 'king of textile' fibres. However, natural cotton fibres contain not only cellulose but also non-cellulosic constituents such as wax (0.4-1.2%), pectin (0.4-1.2%), proteins (1.0-1.9%), ashes (0.7-1.6%) and others. The fabric made from such raw cotton fibres is termed as "grey" in textile terminology. Grey cotton fabric shows hydrophobic characteristics due to presence of these non-cellulosic impurities at surface in the cuticle layer and primary wall which are the outermost layers of cotton fibre, and since fibre surface is mostly responsible for the majority of properties of textile product this leads to some problems in quality of dyeing and finishing in subsequent wet processing. Alkaline scouring is commonly used in industries for removal of non-cellulosic impurities from cotton fabric by treating it with hot sodium hydroxide solution which is not an eco-friendly process, as use of dangerous chemicals and production of hazardous effluents with high chemical and biological oxygen demand, pH, and salt content cause severe environmental problems. With development in science and technology of plasma, atmospheric pressure plasma recently emerged as attractive means for textile processing which offer several advantages like no requirement of costly vacuum equipment, continuous processing of textile and possibility of integration with existing set up for industrial applications. Thus, plasma treatment is found to be promising as an alternative to alkaline scouring in terms of environmental performance.

In this recent study, removal of non-cellulosic impurities from grey cotton fabric by plasma treatment and resulting improvement in its wettability is successfully demonstrated. The sized grey stage cotton fabric is treated using experimental atmospheric pressure air dielectric barrier discharge (DBD) system developed by FCIPT. The plasma treated samples are characterized by ATR-FTIR and SEM and compared with conventionally scoured cotton fabric samples. ATR-FTIR spectroscopy is a surface sensitive technique, and since the waxes and other impurities are located in outermost layers of cotton fibres this technique can measure their presence semi quantitatively[1]. Figure 1 shows the comparison of ATR-FTIR spectra of grey and treated cotton fabric with different plasma exposure time as well as that of alkaline scoured. The removal of non-cellulosic impurities due to plasma treatment is identified by changes in intensity of broad C-H stretching peak appeared at 2817-2979cm$^{-1}$. Two distinguished peaks corresponding to the symmetric and asymmetric stretching mode of methylene groups in long alkyl chain are clearly visible in spectrum of grey cotton fabric at 2852.24cm$^{-1}$ and 2917.81cm$^{-1}$ respectively. This indicates presence of non-cellulosic impurities as –$CH_2$– groups from cellulose never give separate peaks corresponding to the symmetric and asymmetric stretching mode in ATR spectra (as seen in case of alkali scoured fabric which is free from such impurities). From results of ATR-FTIR characterization removal of wax and other impurities of cuticle layer after plasma treatment are clearly reflected in ATR-FTIR spectra as disappearance of these peaks. The spectrum of grey fabric showed small absorbance band of C=O stretch near 1749cm$^{-1}$, which indicates free fatty acids and cutin present in wax and free and esterified carboxylic groups of pectin. However, in the case of scoured and plasma treated fabric it merely presents as weak absorbance, indicating removal of these impurities[1]. Another noticeable change in the spectra of plasma treated fabric is increase in absorbance at 1641cm$^{-1}$ which is comparable with scoured cotton fabric. Further, ATR-FTIR spectroscopy provided a fast and satisfactory assessment of removal of impurities from cotton surface when untreated and plasma-treated cotton fabric is exposed to HCl vapor and subsequently spectra are collected. We observed a strong carboxyl peak is induced at 1749cm$^{-1}$ in case of untreated cotton. While for plasma-treated cotton fabrics substantial variation in the intensity of 1641 and 1749 cm$^{-1}$ peak in observed with increase in plasma treatment time. The initial decrease (up to 3 minute plasma treatment) in intensity of 1749 cm$^{-1}$ is due to removal of non-cellulosic impurities from the surface, while on longer exposure (more than 3 minute) formation of polar functional groups like carboxylate due to sub-sequent oxidation of cellulose by active plasma species (such as ozone) results in increase intensity of 1749 cm$^{-1}$ peak[1].

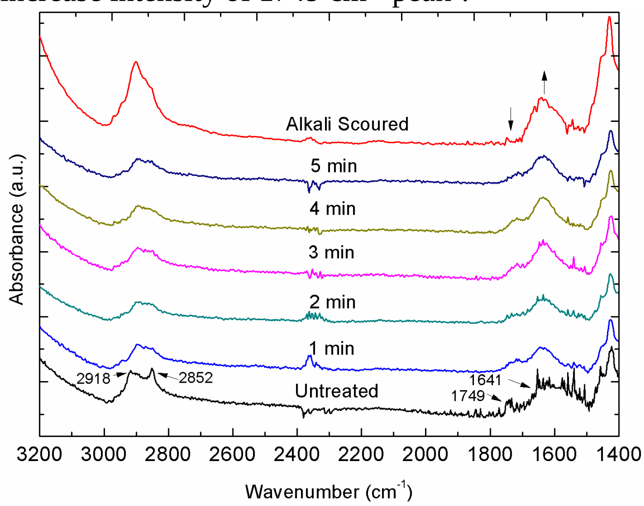



*Figure 1: Comparison of ATR-FTIR spectra of grey, grey fabric treated with air DBD for different time duration (1-5minutes) and alkali scoured cotton fabric (Regenerated image, Source: Reference 1)*

The morphological analysis of surface by SEM analysis (Figure 2) showed that plasma treatment significantly changes surface morphology and it is similar to that of Alkali scoured cotton[1].

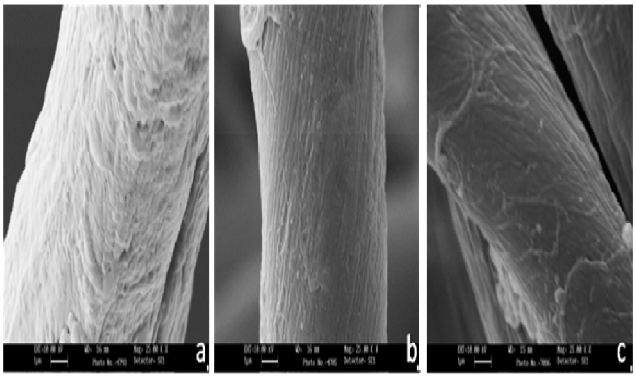



*Figure 2: Observed surface morphology by SEM (a) Grey cotton (b) 3 min plasma treated (c) alkali scoured cotton (Source: Reference 1)*

Thus, the removal of non-cellulosic impurities by plasma treatment results in significant improvement in wettability of grey cotton (Figure 3) which is quantified by water dynamic contact angle measurement and vertical wicking test. Water contact angel measurement demonstrated that water contact angle decrease with increase in plasma treatment time and also decrease in time for water droplet absorption is observed. Figure 4 shows the variation in the surface contact angle of cotton fabric for different treatment times in the range of 0–4 min for air DBD treatment. The contact angle of the untreated surface (140◦ ) is considerably reduced after plasma treatment even for short exposure (5 min) shifting it to lower values of 80◦ . Similar trend is observed in water droplet absorption time as presented in Figure 5. Plasma treatment up to 5min results in decrease water droplet absorption time nearly 5 sec. Typical photographs of spread of water drop on surface of grey and plasma treated fabric is presented in Figure 6.

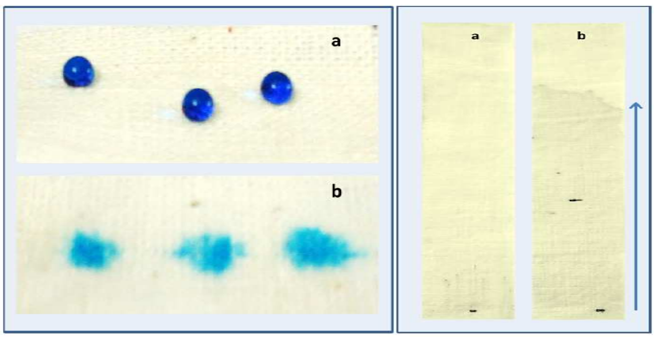



*Figure 3: Improvement in wettability of grey cotton fabric after plasma treatment (a) Grey cotton fabric (b) Grey cotton fabric treated with air DBD for 5 min (Source: Reference 1)*

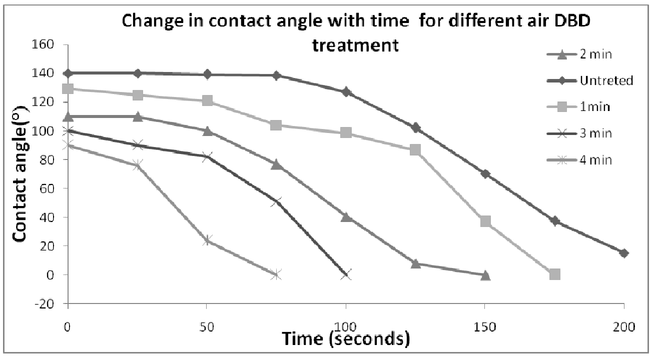



*Figure 4: Reduction in water contact angle for grey fabric after plasma treatment and its change with time*

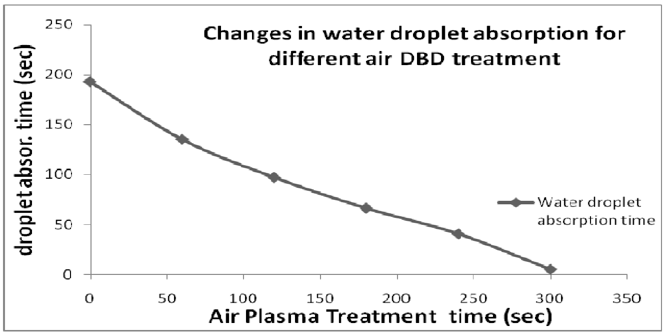



*Figure 5: Decrease in water droplet absorbance time with increase in plasma treatment time*

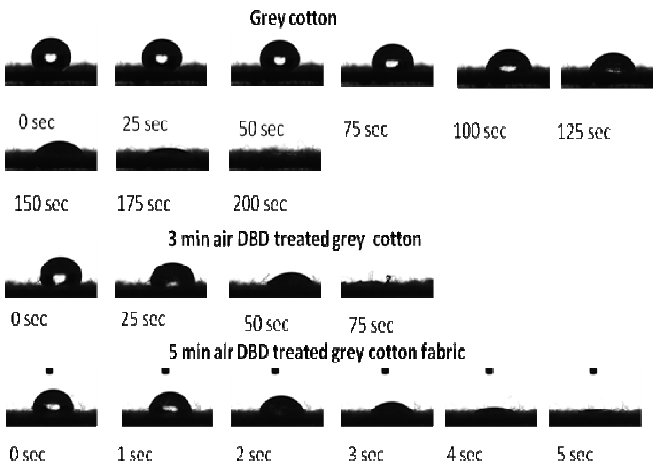



*Figure 6: Typical photographs of water contact angle on surface of grey and plasma treated grey cotton fabric.*

These results are further conformed by vertical wicking test. It is seen in Figure 7 that the boundary of the capillary rise increases with air DBD plasma treatment time. The wicking rate of the grey cotton fabric is zero because of its poor wetting nature. The wettability is perquisite for wicking; if a liquid does not wet, it cannot wick into a fabric capillary space.

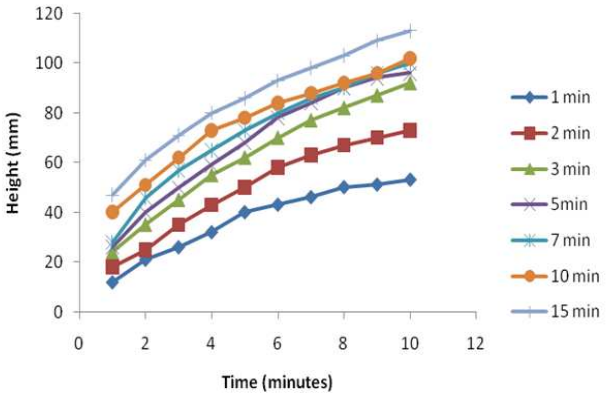



*Figure 7: Increase in capillary height of water with increase in plasma treatment time*

Thus, it is confirmed in this study that plasma treatment with air DBD removes non-cellulosic impurities from surface of grey cotton fabric. With increase in time of exposure the plasma species interact with the fabric surface for longer time and hence removes the most of non-cellulosic impurities, resulting in improvement of wettability after plasma treatment as observed by contact angle measurement and vertical wicking test. Also the plasma treatment considerably enhances the formation of polar functional groups on the fabric surface due to subsequent oxidation of cellulose. For the same reason the vertical wicking rate of the plasma-treated fabric increases with increase in the exposure time. The results obtained by plasma treatment are comparable with that of alkaline scoured cotton fabric. Thus, the study clearly indicates that the atmospheric pressure plasma has a great potential to process gray cotton in environmental friendly manner.

**Reference:**


1. H. Dave, L. Ledwani, N. Chandwani, N. Chauhan & S. K. Nema, (2013) The removal of impurities from grey cotton fabric by atmospheric plasma treatment and its characterization using ATR-FTIR spectroscopy, *Journal of the Textile Institute*, in press, DOI: 10.1080/00405000.2013.827900


## OTHER NEWS

### ISO surveillance Audit

The second ISO Surveillance Audit was carried out at FCIPT on 27th August 2013. Various aspects related to Quality, stores, Calibration, Job shop, maintenance, research and development, technology commercialisation and Management Representative functions were audited and the auditors expressed their satisfaction with the processes and functions."

### Procurement of Spectroscopic Ellipsometer

A Spectroscopic Ellipsometer of J.A.Woollam Co., Inc was procured and installed at FCIPT. This instrument has the spectral range of 190-1100 nm with the configuration of Rotating Analyzer Ellipsometry (RAE) with patented AutoRetrader® and Automated wavelength selection via monochromator. This instrument is acquire data with the data acquisition rate typically 0.1 to 3 seconds per wavelength, depending on reflectivity of sample. Some of the characterizations which can be performed by this instrument are listed below

1). UV/Vis region

- Thin film parameters
  - Thickness
  - Optical Constants
- Band Gap
  - Direct/Indirect Transitions
- Surface temperature
- Alloy Composition
- Grain Size

2). IR Region

- Free Carrier absorption
  - Carrier Concentration
  - Carrier Mobility
  - Conductivity

## ACNM & NEEM -2013

School on **"Advanced Characterization methods for Nanophase Materials (ACNM)"** was held on 22, 23 November 2013 at Hotel Gateway Hotel Ummed, Ahmedabad. The Keynote address was given by Dr. Augusto Marcelli (INFN – LNF and Co-Chairperson of the Scientific Programme committee of both ANCM & NEEM) and Dr. S. Mukherjee.
There were 14 lectures delivered by 12 speakers from India (RRCAT, SINP, IUAC), Italy, France, Japan and USA.

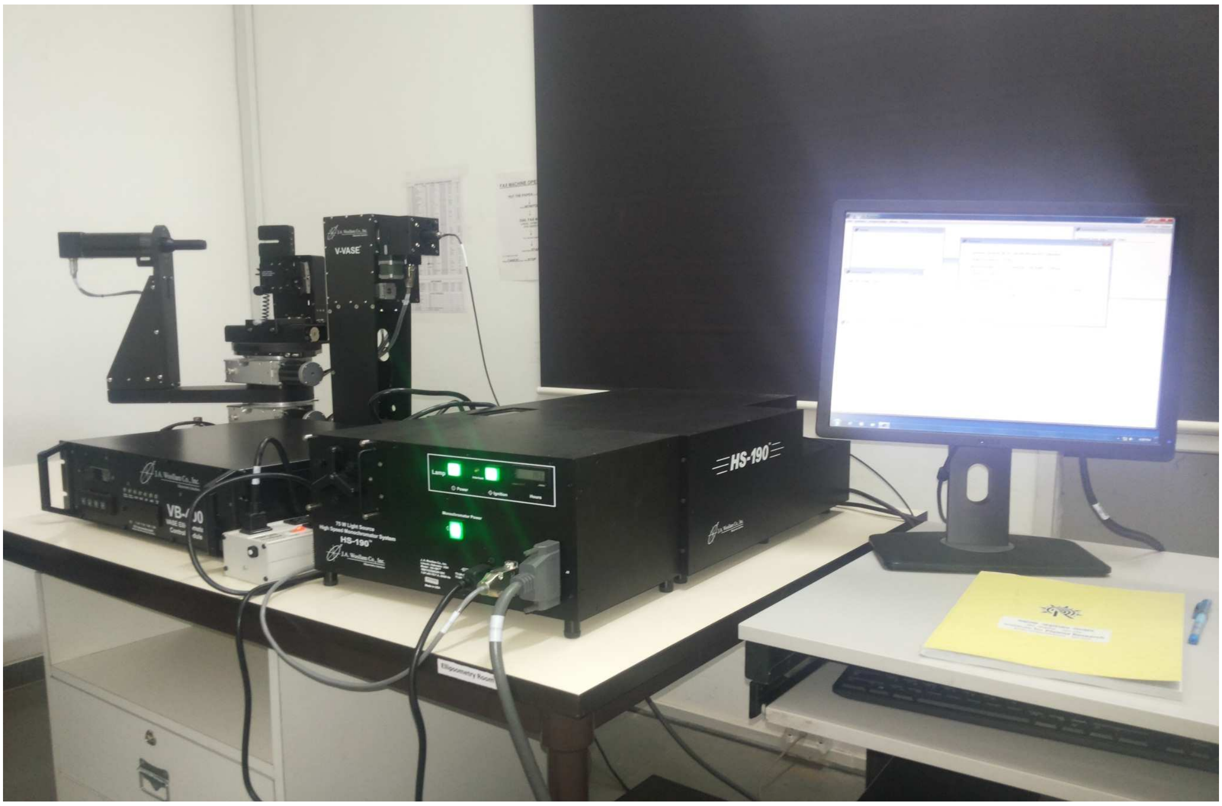
**Inauguration of NEEM-2013**

The topics covered were XRD, XAFS, XANES, Raman spectroscopy, Photoemission spectroscopy, Optical spectroscopy, Muon spin resonance etc.

The Workshop was followed by **School on Nanoscale Excitations in Emergent Materials (NEEM)** from 25-26 November 2013.

The Programme Chief Guest, Ambassador of Italy to India, His Excellency Daniele Mancini, inaugurated the function while Prof. Abhijit Sen delivered the Welcome address. There were a total of 15 speakers from both India and Italy.
Prof. Lidia Szpyrkowicz, the Scientific Counsellor in the Italian embassy gave a talk on *"Indo – Italian educational and research collaboration possibilities"*, while Shri Rajiv Kumar, affiliated to the Bilateral Cooperation Division of DST, gave an overall view of India's research collaboration with Europe and other countries. Best poster awards were also presented to Ms. Jethva Sadaf Alibhai from Saurashtra University and Mr. Shammi Verma from IUAC, New Delhi.

**Participants of ACNM-2013**




**Spectroscopic Ellipsometer installed at FCIPT**

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