PLASMA PROCESSING UPDATE

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**Facilitation Centre for Industrial Plasma Technologies,
Institute for Plasma Research**

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Contents

Editor's note

Dr. S K Nema cites the advantages of plasma processing polyesters with a study carried out for sustainable finishing of polyester fabric with dielectric barrier discharge (DBD) in air to confer durable wettability and increase dye-uptake with natural dyes.

Plasma pyrolysis is mostly used for safe disposal and energy recovery of organic waste. Since this technology converts electrical energy into heat efficiently, it can be used to pyrolyse waste tyres to get valuable by-products like syn gas and other lighter gases. Mr. P.Vadivel Murugan has discussed about this in an article.

Dr. Ing. Suryakant B. Gupta, et.al. cites about the DAQ system for the spacecraft charging research facility. As per the ISO recommendations FCIPT, IPR has developed an experimental test facility [SPIX-II] for LEO and GEO like space environmental conditions. Moreover it is an India's first indigenous ISO test facility for spacecraft charging in above said environment and it is in final stage of commissioning.

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

Conference/Poster presentations from FCIPT

Name of the author	**Topic**	**Date**	**Place**	**Conference**
Vishal Jain, Anand Visani, R Srinivasan. S Mukherjee, V Agarwal	Atmospheric pressure plasma jet on floating electrode in air using half bridge resonant converter	July 2012	Edinburgh, UK	ICOPS-2012
Ms. Alphonsa Joseph	Plasma Nitrocarburizing process –a solution to improve wear and corrosion resistance of materials used for making control valves	August 2012	Kolkata	16th National Congress on Corrosion Control, NCCI-2012
Dr. C. Balasubramanian et.al	A comprehensive study and analysis of aluminium nitride nanostructures by inelastic neutron scattering and XANES, FTIR and luminescence spectroscopies	October 2012	Riga, Latvia	Baltic School on Application of Neutron and Synchrotron Radiation in Solid State Physics and Materials Science
G. Ravi and Vidhi Goyal	Role of external magnetic field and current closure in the force balance mechanism of a magnetically stabilized plasma torch	22 - 26 Oct 2012	Austin, Texas, USA	65th Annual Gaseous Electronics Conference
Ms. Alphonsa Joseph	Effect of temperature on the corrosion resistance properties of A-286 precipitation hardening stainless steel after plasma nitriding process	December 2012	Baroda	CICI 2012
Sagar Agrawal, R. Rane, S. Mukherjee	Poster on ZnO Thin Film Deposition for TCO application in Solar Cell	December 2012	KIIT, Bhubneshwar	International Conference on Solar Energy Photovoltaic (ICSEP) – 2012

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

Plasma processing of polyester fabric to improve dyeing properties with natural dyes

Dr.S.K.Nema & Hemen Dave

Polyester, the most consumed man-made textile have excellent chemical, physical and mechanical properties but a great disadvantage of polyester is low hydrophilicity and inert nature of the constituent polymer which causes variety of problems both during manufacturing, specifically in dyeing and consumer use due to poor moisture regains. The most conventional, and industrially most common, way of rendering polyester hydrophilic is alkali treatment, a controlled hydrolysing the polyester bonds at surface exposed to liquid. Besides alkali treatment being high energy demanding and chemicals consuming, the favourable bulk properties of polyester, particularly the strength, are also affected. Due to highly crystalline structure and chemically inertness polyester only be dyed by synthetic disperse dyes under high temperature (at 130°C) and high pressure which needs lot of energy and special equipment with high funds, also use of synthetic dyeing axillaries is essential. Moreover, water pollution caused by synthetic dyes and other additives, in particular the control of effluents continues to be a problem as bio treatability of many of these is poor.

The recent trends of the textile industry are aimed to improve the environmental performance by reducing consumption of energy, water and chemicals used in processing and dyeing and finishing as well as development of a new dyeing method to accelerate dyeing rate, improve dye uptake and lower dyeing temperature. Also, cleaner production methods in textile dyeing can be implemented by use of natural dyes and substitution of synthetic auxiliaries with products derived from natural sources. In the past decade, the use of non-thermal plasmas for selective surface modification of textiles has been a rapidly growing research field. In this context, the present study carried out for sustainable finishing of polyester fabric by environmental friendly plasma processing with dielectric barrier discharge (DBD) in air to confer durable wettability and increase dye-uptake with natural dyes.

The experimental study is carried out using the atmospheric pressure DBD plasma reactor developed by FCIPT. Plasma treatment of 100% polyester fabric (150 gsm) is carried out using atmospheric air as discharge producing plasma at optimized process parameters and it characterized using water contact angle, SEM, ATR-FTIR. Optical emission spectroscopy (OES) also employed for characterization of plasma. Dyeing of polyester is carried out using six different natural dyes. To measure and compare color intensities of dyed fabrics the reflection of dyed fabric at wavelength corresponding to the maximum absorbance, is measured using Reflective Spectrophotometer (Data Color Spectra flash SF 500). Reflection factor (R) obtained as the average of four measurements and used to find out relative color strength (K/S value).

FTIR-ATR used for highlighting chemical and structural features attributable to the effect of plasma on the polyester fabric and has proved to be a powerful tool to probe the conformational changes of Polyester polymers involving the ethylene glycol moieties, the benzene rings, or the carbonyl groups. Figure 1 represents the FTIR spectra of untreated and plasma treated polyester fabrics.

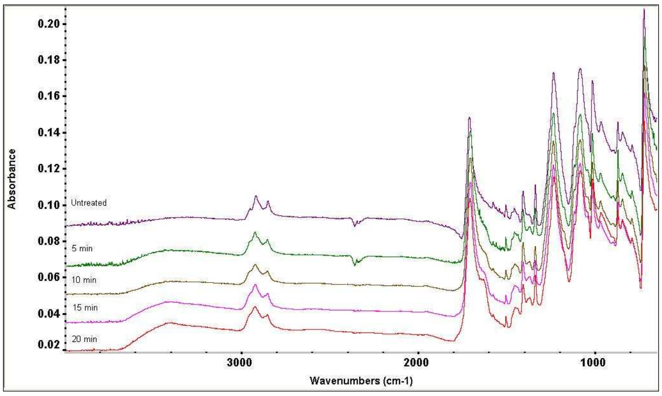


Figure 1: ATR-FTIR spectra of untreated and plasma treated polyester fabric for different treatment time

The bands at 1471, 1341, 1123, 972, and 849 cm^{-1} are markers of the crystalline structure of polyester, while those at 1371, 1044, and 898 cm^{-1} characterize the amorphous conformation. In addition, the higher wave-number component of the strong doublet at about 1120-1100 cm cm^{-1} is assigned to crystalline polyester, while that at lower wavenumbers to amorphous polyester. For all crystalline and amorphous marker bands changes appear in intensity of the spectra of polyester fabric treated with atmospheric pressure plasma. For a quantitative assessment of the degree of crystallinity, the values of the spectroscopic indexes A1341/A1410 and I1120/I1100 are calculated as absorbance ratios. Plasma treatment of polyester resulted in lower values of the A1341/A1410 and I1120/I1100 indexes. The fraction of glycol segment in trans conformation is carried out from intensity measurement of A1340, A1370 cm^{-1}, also the values of Full Width at Half Maximum of the carbonyl stretching band at 1715 cm^{-1} (FWHM1715) is used for quantitative assessment. Incorporation of polar groups due to plasma treatment is reflected in FTIR spectra as new bands near 1670cm^{-1} (COO-) and 3500cm^{-1} (OH).

Polyester is crystalline linear aromatic polymer with a small number of amorphous regions available for sorption and diffusion of dye, but results of characterization of indicate that plasma treatment at atmospheric pressure increase polyester hydrophilicity due to polar functional groups as well as amorphization of crystalline domains. Thus increase in dye uptake can be predicted with atmospheric pressure plasma treatment. In order to decrease dyeing temperature polyester with natural dyes and achieve good dye uptake various dyeing techniques including use of different solvents, mordents were studied. The solvent assisted dyeing using little amount of solvents such as alcohol, acetone along with water to prepare dye bath has been found as a best techniques to increase dye uptake for plasma treated polyester. With solvent assisted dyeing techniques dyeing of plasma treated polyester with six natural dyes is achieved using cold extracts of natural dyes at room temperature. Study has demonstrated dyeing time as low as one hour also gives good dye uptake. Reusability of the dye bath is also demonstrated. Results of increase in dye uptake after 15 min air DBD treatment of polyester and natural dyeing at room temperature is summarized in figure 2. Also improvement in color strength due to plasma treatment is summarized in table 1.

Table 1: Improvement in color strength calculated from K/S value

Dye	% Improvement in color strength for plasma treated sample
Hill Brown	127.7
Eco-orange	109.6
Garnet Brown	137.8
Turkey Red	208.3
Smoke Grey	96.25
Eco-Alizarin	152.5

Figure 2: Improvement in dye uptake after plasma treatment

This has clearly indicated an increase in color intensity on plasma exposed polyester fabric as well as an increase in the dye uptake as compared with the untreated fabric. Fastness properties of dye also improved after plasma treatment. Since ester fibres and disperse dyes do not typically contain any ionic groups, dye fibre attraction clearly originates in hydrogen bonding, dipole-dipole interaction, hydrophobic effects and dispersion forces. Thus, it can be concluded that increase in hydrophylicity and incorporation of polar groups by oxidation of polymer surface and amorphization by plasma treatment increase dye uptake of polyester fabric with natural dyes even at room temperature and atmospheric pressure dyeing condition. Though, the main objective of this study is to improve dye uptake properties of polyester with natural dyes, dye uptake improvement with synthetic disperse dyes can be predicated. The research herein has demonstrated that plasma treatment may opened up a new possibility for introduction of natural dispersive dyes in to modern dyeing procedure towards increase in sustainability by affording at least partial replacement of synthetic dyes and the technical aspects of dyeing.

Plasma Pyrolysis of Waste Tyres

Mr. P.Vadivel Murugan

Old tyres are piling up in landfill across the world because they are so difficult to dispose of, or reuse. The options for recycling are limited because the rubber used is vulcanised, meaning it has been combined with another chemical, usually sulphur, to improve its overall strength and durability. But vulcanised rubber does not melt, and is therefore difficult to reform and reuse. So many tyres are simply dumped in landfill, a process that releases heavy metals and other pollutants and risks starting dirty, long-burning fires

Once rubber has been vulcanised - treated with sulphur to make it harder, as part of the manufacturing process - it becomes immune to attack from the bacteria that usually break it down. As a result, dumped tyres stay where they are forever, or they catch fire. Hence, landfilling as an option of disposing such waste tyres is ruled out.

Conventionally these tyres have only one disposal method which is Incineration. However, the incineration of waste tyres poses a serious threat to the environment with emission of carbonaceous exhaust, particulate matters and other pollutants.

Similar problems are envisaged in India, with it's continuous growth, and increase in the number of vehicles on road. Country like India needs to find an alternate safe waste disposal technology for waste tyres.

The Plasma Pyrolysis Technology has been exploited by various organizations and countries across the globe for different kind of wastes such as medical waste, plastic waste, Municipal solid waste, combustible waste etc. Owing to the growing demand of using renewable energy or alternate fuels, the option of utilizing 'wastes' as a source of energy became a resourceful option. As a result many organizations have demonstrated energy recovery from medical, plastic and other combustible wastes. In other words, the waste having calorific value higher than 3000 kCal/kg can generate recoverable energy. FCIPT has carriedout studies on energy recovery of cellulosic waste (cotton & plastic waste) for Johnson & Johnson, USA and have also published papers on the same. Work on preliminary studies on plasma pyrolysis of tyre waste has been carried out by the Guangzhou Institute of Energy Conversion, China where they have concluded that energy can be recovered from plasma pyrolysis of tyre waste and the calorific yield of the output gases can be increased by addition of steam in the primary chamber.

Similar work had been carriedout by L. Tang et. al. which describes that the plasma pyrolysis of waste tyres generate high calorific value (combustible) gases such as H_2, CO, CH_4, C_2H_2, C_2H_4 etc. If steam is injected in the primary chamber during pyrolysis conditions, the yield of H2 and CO can reach upto 38.3% of the gaseous product, which are valuable syngas components. These gases upon combustion release significant heat energy and this heat energy can be utilized for process heating or for electricity generation purpose.

Global status of the technology

Plasma arc technology was developed and employed in the metallurgy industry during the late 1800s to provide extremely high temperature. During the early 1900s, plasma heaters were used in the chemical industry to manufacture acetylene from natural gas. Plasma arc heaters received renewed attention when the United States NASA Space program, during the early 1960s, evaluated and selected plasma arc heating technology for simulating and recreating the extreme high heat of reentry into the earth's dense atmosphere encountered by spacecraft from orbit.

Since 1980s, various companies like Pyrolysis Systems Inc. of Canada, Siemens, Germany, Plasma Energy Applied Technology Inc.,USA, Plasmapole in France etc. are active in the development of plasma systems using plasma arc technology. Westinghouse Environmental Services USA demonstrated a prototype unit of dc arc incinerator in 1987. Electrical Industry Research Institute at Hungary developed a plasma reactor pilot plant in 1988, for the destruction of halogenated chemical industry wastes. Retech Incorporation of California and U.S.Department of Energy initiated a collaborative program to destroy a variety of waste using plasma arc technologies in 1989 and later in 1994 developed a rotating plasma furnace. Plascon In-Flight Plasma Arc System is designed to treat chlorinated organic compound. Destruction efficiencies of better than 99.99% were achieved for organic contaminants. Plascon system yielded very high destruction performance and releases dioxins and furans in the range of 0.005-0.009 ng/m^3, which is well below the set limit of environmental standard in the world. Halogenated organic compounds were treated in hydrogen plasma, which was found suitable for the elimination of halogenated compounds and soot particles. In a pilot scale research furnace at MIT, a 10,000 ^{o}C plasma arc was used to melt waste material into a lava like liquid, which then solidified into a stable black glass that could be safely used as a construction material. Leading companies in the field of plasma technology have tested, treated and analyzed hundreds of waste streams at industrial capacity over many years. The waste streams, which were successfully treated and disposed of by plasma arc technologies, include: Municipal solid waste, Incineration ash, Automobile tires, Waste coal, Sludges, Polychlorinated biphenyl, Hazardous fly ash, Medical waste, Paints, Solvents, Contaminated landfill material, Low level radioactive waste etc.

Countries which have accepted 'Plasma Pyrolysis' as a waste disposal technology are:

- United States of America (U.S.A)
- European Union (EU)
- Russia
- China
- Taiwan ….. & many more.

The CSIRO/Siddons Ramset Ltd's Plascon, Retech, Westinghouse Plasma Inc., Plasma Energy Corporation and various other companies are in the business of design and development of large size custom-made plasma waste treatment systems. Currently implemented projects clearly demonstrate that the plasma arc technology is a well-proven, well-demonstrated commercially viable technology, which is utilized, in industrial plants to treat different waste materials worldwide.

About plasma pyrolysis technology

Plasma, the state of matter formed by removing the bound electrons from atoms, is an electrically conducting fluid consisting of charged and neutral particles. The charged particles have high kinetic energies. When the ionized species in the plasma recombine with the stripped electrons, significant amounts of energy in the form of ultraviolet radiation are released. The particle kinetic energy takes the form of heat and can be used for decomposing chemicals. In addition, the presence of charged and excited species render the plasma environment highly reactive which can catalyzes homogeneous and heterogeneous chemical reactions and decomposition of even very stable compounds like aromatic chloro-fluoro carbons (CFCs, PCBs) becomes easy in an plasma environment.

Plasma pyrolysis integrates the thermo-chemical properties of plasma with the pyrolysis process. Plasma pyrolysis uses extremely high temperatures of plasma arc in oxygen starved environment to completely decompose waste material into simple molecules. Hot plasmas are particularly appropriate for treatment of solid waste and can also be employed for destruction of toxic molecules by thermal decomposition. In plasma pyrolysis the most likely compounds that form from carbonaceous matter are methane, carbon monoxide, hydrogen, carbon dioxide and water molecules.

The workhorse of plasma based waste destruction technology is the plasma torch. Plasma torches are electrical discharge plasma sources with the plasma being extracted as a jet through an opening in the electrode and out of the confines of the cathode-anode space. The inherent thermal and electromagnetic instabilities of the arc column are stabilized by forced gas flow along the current path or by interaction with a guiding wall or by external magnetic fields. DC, RF and microwave power sources can be used to produce the arc.

DAQ system for the spacecraft charging research facility – SPIX-II

Dr. -Ing. Suryakant B. Gupta, Keena Kalaria, Naresh Vaghela, Dr. S Mukherjee

Introduction

In space plasma environment, satellite surface components floats negatively with respect to the surrounding space plasma environment. Due to various reasons charge distributes in inhomogeneous fashion and thus an inverted potential difference arises. When the potential difference between two surface materials exceeds a certain value, electrostatic discharge (ESD) or primary arc [PA] may occur at the surface of satellite components like solar panel etc. This ESD may trigger a secondary arc that can destroy the solar panel circuit and severely damage the substrate [1].

To meet the increasing demand from various users it is essential to place more transponders in a communication satellite which essentially requires more power. Considering various aspects, increasing satellite bus voltage is preferred. Increased bus voltage leads to arcing on solar arrays surface, which is a serious threat to the spacecraft. Therefore there is a need to test the performance of satellite solar panels at ground conditions.

Recently, based on the collaborative research work in France, USA and Japan, international standards for space solar panels have been finalized. This ISO document [ISO-11221] specifies qualification and characterization test methods to simulate plasma interaction and electrostatic discharges on solar panels in the space [2].

Indian Space Research Organisation (ISRO) is the primary agency doing space related activities in India. ISRO Satellite Centre (ISAC) located at Bangalore, designs and builds the satellites of ISRO. Spacecraft Charging Analysis, Radiation Impact Analysis, Atomic Oxygen impact analysis and other environmental impact analyses are routinely carried out at ISAC for its different programs.

Traditionally, ISRO has been designing and manufacturing 42V bus for power conditioning and distribution. However, in the past few years, ISRO has developed a 70V bus and it is likely that bus voltage may go further up. Although ISRO has never had a failure of its satellite in orbit due to arcing, it was felt that prophylactic measures should be taken to prevent such an eventuality.

The first major step toward developing an understanding of the charging and arcing problems were taken during the time of INSAT-II satellite system by the internal experts of ISAC [3]. Later on it was felt that the expertise of the Institute for Plasma Research (IPR) in the field of Plasma has to be utilized for modelling and experimental work in the area of Solar Panel Plasma Interaction. Thus a collaborative project called Spacecraft Plasma Interaction eXperiment (SPIX) was initiated in 2002. This involved elements of both theoretical modelling and experimental simulation. The theoretical modelling work was carried out to calculate the charging potentials and potential differences which would result in arcing.

A linear circuit model was also developed in the frame work of SPIX-I to explain the experimental results by representing the coverglass, solar cell interconnect and wiring by an LCR circuit and the primary arc by an equivalent LR circuit. The aim of the circuit analysis was to predict the arc current which flows through the arc plasma. It is established from the model that the current depends on various parameters like potential difference between insulator and conductor, arc resistance, stored charge in the solar cell cover glass and the external capacitor that simulates wire harness. A close correlation between the experiments and circuit model results was observed [3, 4, 5, 6, and 7].

Additionally, from the experimental results conducted at KIT, Japan and the development of the ISO standards inspired ISRO to augment the SPIX-I facility to an ISO test facility and closely following the latest international standards and conventions in circuitry and other experimental conditions. Accordingly as per the ISO recommendations FCIPT, IPR has developed an indigenous experimental test facility [SPIX-II] for LEO and GEO like space environmental conditions. This is based on the in-house developed plasma source, a flood beam electron gun; non-contact surface potential measurement assembly and a Lab-VIEW based high speed data acquisition system. In the following sections details of SPIX-II facility and its associated instrumentation are described.

SPIX-II facility has been designed to carry out solar panel arcing experiments for LEO and GEO like space environments. A low energy plasma source and an electron gun most resemble the LEO and GEO space environment respectively. The major goals of this proposed facility were to detect primary arcing threshold and to establish dependence of secondary arcing threshold for various panel configurations. To do so development of suitable diagnostic was essential which can measure the arcing rate and it was equally important to establish a correlation between optical and electrical signal by suitable software and high-speed data acquisition system. It is expected that based upon the experimental findings one can arrive at guidelines to choose solar array material, configuration and electrical design that can survive in the space environment.

Experimental set up

Vacuum pumping system

A vacuum chamber is required to simulate the interaction between solar cells and plasma at variable densities. A horizontally mounted cylindrical chamber (with side dished ends) of 1 m long and of 1 m diameter which is made out of SS304L steel is used for creating space like environment. Solar panels of size 300mm X 300mm will be used for the proposed study.

The experimental chamber has to be pumped down to the base pressure using a high vacuum pumping system comprising of a diffusion pumping station. A Varian make diffusion pump having the pumping speed of 4200 l/s and back streaming rate better than $2X10^{-7}$ $mg/cm^2/min$ has been employed for this purpose.

Plasma Source

In order to create a LEO like space environment Thoriated tungsten filament based plasma source is used. Primary electron emitted from heated filament gets accelerated to ionize the background gas to form plasma. The plasma density was measured with Langmuir probe and it is controlled by varying total discharge power. The coupon bias voltage shall be varied to cover all the possible charging potentials in orbit.

Electron Gun

An electron gun is used to simulate the energetic electrons during sub storms in GEO. Solar panel coupons surface can be irradiated by this electron gun. A large coupon implies a large radiation area for the electron beam to cover. SPIX-II facility can accommodate a coupon of 300 mm x 300 mm, therefore a beam spot size of 450 mm diameter is necessary to irradiate the above coupon surface [Fig. 1].

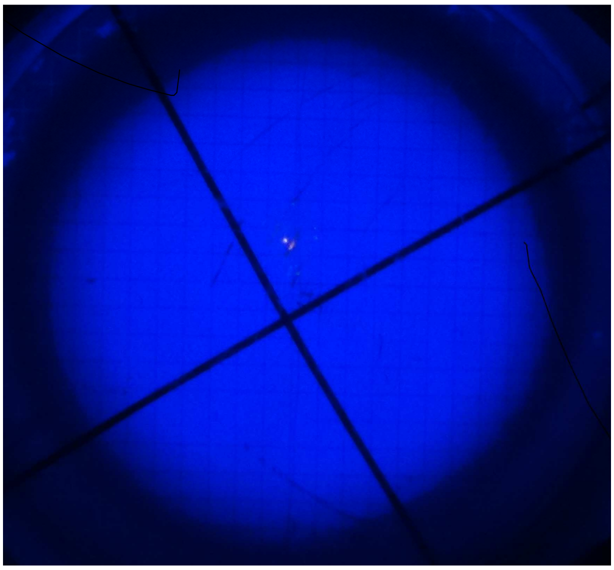


Fig. 1 Spot of electron beam covering a diameter of approximately 200 mm, which can be extrapolated to 450 mm spot size at the usable distance [Beam energy 30 KeV]

To cover a larger area, in various publications use of a thin Aluminium foil is recommended. Instead of using a collimated beam gun with Aluminium foil, flood beam type electron gun is specially designed and fabricated for covering the entire solar panel coupon having 300 mm x 300 mm surface area. At the mouth of this electron gun an electro- mechanical shutter is provided that can be operated electronically using a command signal from control panel.

DAQ system

As per ISO documents four major experiments [viz. LEO primary arc, LEO secondary, GEO primary arc, and GEO secondary arc] are planned. Further depending upon the duration, arcs are categorized 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] as shown in fig.2.

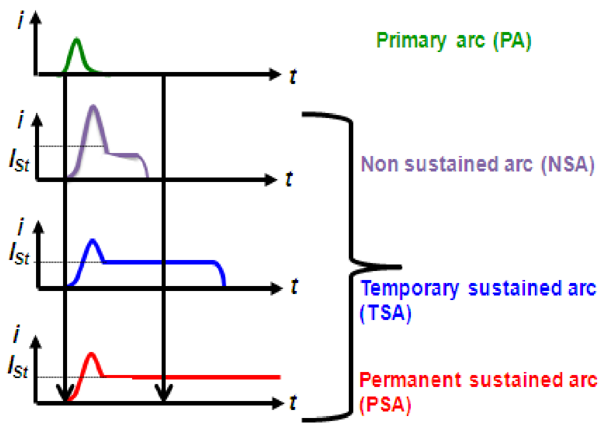


Fig. 2 Categorization of secondary arcs - Primary arc [PA], Non-sustained arc [NSA], Temporary sustained arc [TSA], and Permanent sustained arc [PSA].

A **LabVIEW** 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. **LabVIEW** is a graphical programming language developed by National Instruments. A NI-PXI system with dual core embedded controller using Real-Time Operating System (RTOS) is used for data acquisition. Its hard drive stores DAQ software developed for above experiments and the associated experimental data. Controller contains various ports for serial and parallel communication with other devices. It is linked using an Ethernet cable with the host computer and performs the operations instructed by the experimenter operating it by using the virtual instruments on the host window.

Thus Host computer and remote terminal serve as a master-slave model. Data captured by RT is transferred to the host using TCP/IP for off-line analysis. NI-PXI 5105 (high speed digitizer module), NI-PXI 6281 (data acquisition module) and NI-PXI 8252 (Image acquisition module) are connected to the PXI. NI-PXI 5105 and NI-PXI 6281 are configured with the sampling rate of 20 M Samples/ sec and 5000 samples /sec. Camera captures 30 frames per second. Thus NI-PXI 5105 makes the software capable of detecting an arc of 50 ns duration also.

Experiment can be conducted in four modes i.e., LEO primary, LEO secondary, GEO Primary and GEO Secondary. Arc is sensed by the high speed data acquisition module and depending upon the selected mode, other operations are followed. To determine the surface potential, a non-contact surface potential probe is mounted on a linear dual axis stage, which is finally controlled by DAQ software. The minimum differential charging voltage can be derived from analysis of the ESD locations and the test coupon surface potential distribution. On detecting an arc, camera connected to NI-PXI - 8252 by 1394b IEEE cable is triggered through software for obtaining frames before and after the arc. Image buffer is created using the software for pre-arc frames. For LEO experiments, chamber pressure and plasma density are kept constant. For GEO experiments, along with chamber pressure, electron energy is also kept constant and shutter is opened / closed by software or manually according to the requirement.

LEO experiments

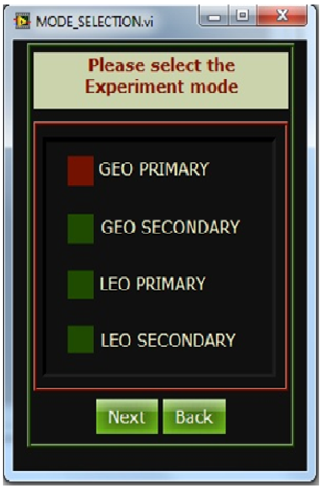
In LEO whenever an arc occurs, it is captured by NI-PXI 5105 and the software stores the arc voltage and current waveforms and pre defined camera images in a specific folder. From the captured arc images the maximum intensity arc image is selected and a dedicated program identifies its location including arc coordinates.

In secondary arc experiments, software additionally discriminates the different type of arcs like PA, NSA, TSA and PSA. At the end of the experiment, a statistic table is generated automatically showing the details of all arcs like arc number, arc time, arc type, voltage and current amplitude and duration, arc coordinates, total experiment time, etc.

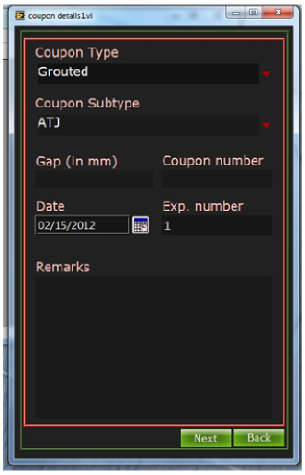
GEO Experiments

Arc is captured by NI-PXI 5105 even in GEO experiments. High energy electron gun charges the surface uniformly. A shutter is used to obstruct electron beam impinging on the solar coupon surface. Using an in-house developed hardware circuitry and a motor the beam exposure time is controlled by DAQ system. As soon as arc occurs shutter is completely closed and a non-contact surface potential probe carries out the potential measurement at each point of the coupon surface. The trek probe is connected to one of the eight differential analog channel of NI-PXI 6281. Trek probe is attached to a two axis stage controller which serially communicates with RT using RS-232. According to the user defined starting and ending coordinates, the stage controller carries the trek probe at the pre-defined location. Voltage data acquisition starts only after the probe reached at the initial coordinates to be scanned. After completing the scan, trek probe is parked at its pre-defined home position.

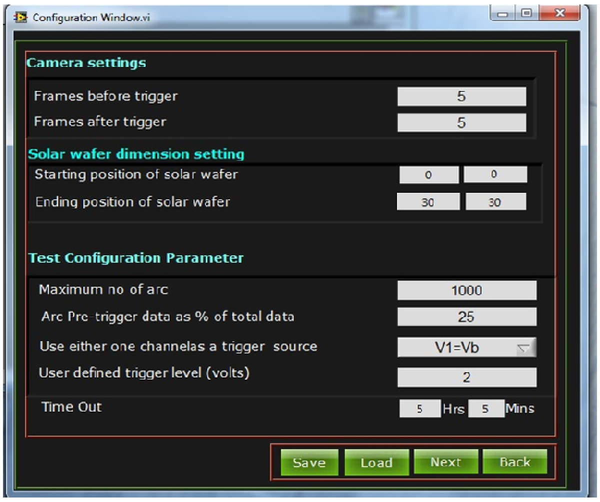
As shown in Fig. 3, the entire software comprises of various selection, setting, configuration and display screens. First of all, out of four pre-defined experiments user has to select the experiment to be performed [Fig. 3-A]. User has to enter coupon details [Fig. 3-B]. From this given data the software automatically creates a folder containing relevant information and data of that particular experiment. Configuration window [Fig. 3-C], is provided where the user has to enter required experimental test parameters.



[A]



[B]



[C]

Fig. 3: GUI for the SPIX-II facility [A] Experiment mode selection window [B] Coupon details window [C] Configuration window.

To obtain pre and post arc frames for optical arc image analysis, NI-PXI 8252 is software triggered by arc signal. Data is acquired primarily in RT and then transferred to the host. Also the images captured by the camera are continuously sent to host which helps to gather the position of trek probe and stage controller assembly for GEO experiments.

Results and Discussion

During initial test experiment many arcs occurred and the location of all the arcs captured during the experiment is marked on the reference image for further analysis. An image depicting all primary arcs are shown in Fig. 4. In another experiments different types of secondary arc were captured and their locations were marked on the reference image for analysis [Fig. 5]. To differentiate different types of arcs a predefined color scheme is used.

Arc parameters are automatically stored in the dedicated folder created in the beginning of that particular experiment. Relevant information related to the arc event like arc image, video, arc waveforms, intensity plot, number of arcs etc. can be retrieved from the main experiment screen. One of such PSA image is shown in Fig. 6.

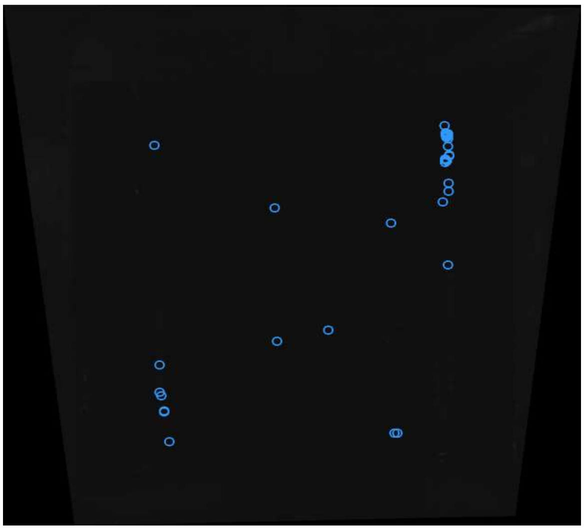


Fig. 4. Image showing location of all arcs occurred during primary arc experiment

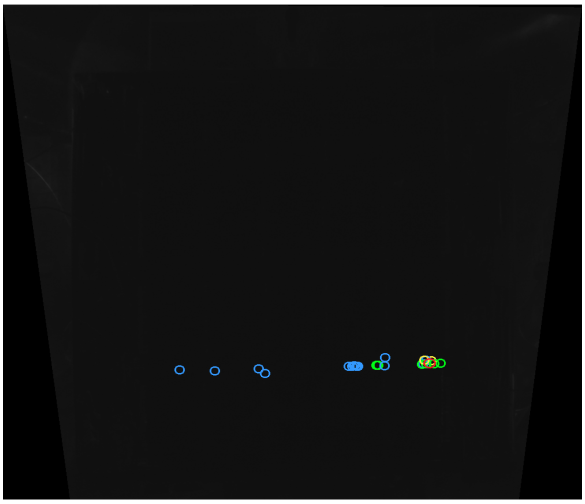


Fig. 5. Image showing location and colour coded type of all the arcs occurred during secondary arc experiment (Blue – PA, Green – NSA, Yellow – TSA, Red – PSA)

The purpose of these experimentsis to determine the arc threshold in terms of differential voltage between solar array circuit components. This differential voltage can be used as a tool to estimate the number of ESD events during the mission lifetime in orbit. In brief overall aim of conducting these experiments is to qualify a given design of solar panel for flight. It may not be always possible to represent the worst condition in orbit via the ground experiment, such as the low temperature at the end of eclipse, the effects of thermal cycling on gap distance and grouting and the out gassing period in orbit. The best effort shall be made, however, to simulate the worst condition or extrapolate the test result to obtain the result that would have been obtained in the worst case.

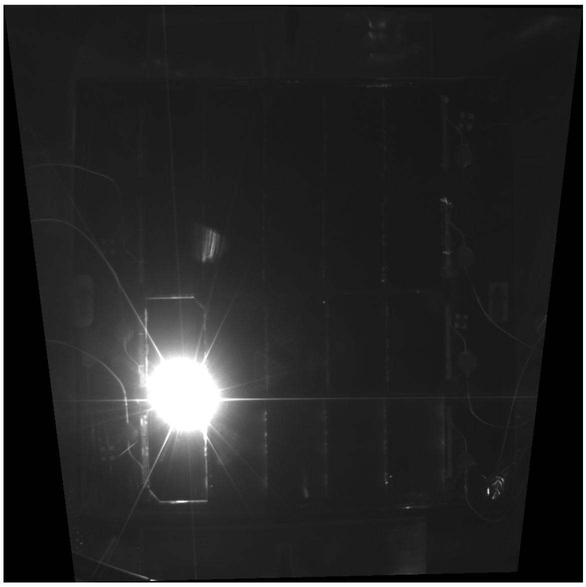


Fig. 6. Optical image of a PSA (Permanent sustained arc) by the camera.

Conclusion

ISRO Satellite Centre, with its long experience in satellite design, manufacturing and testing has taken several measures to address the negative impacts of the interaction of space plasma with the satellite, especially the solar array. A fruitful interaction of ISRO with IPR resulted in the joint experimental and modelling project called SPIX-I. The experience gained in SPIX-I have further led ISRO to continue the collaboration and to augment the existing testing facility. This new venture has been named as SPIX-II.

SPIX-II facility is designed as per the recommendations of ISO document [ISO-11221]. Various subsystems like non contact electrostatic probe, Electron gun, and vacuum compatible 2-D linear stage, are successfully installed in the SPIX-II chamber. Test jigs are developed in-house to validate the performance of each subsystem individually. Dedicated LabVIEW based data acquisition software has been developed for the SPIX –II facility which is capable to capture the optical and electrical signals of the arc simultaneously. Advanced data acquisition software has improved the accuracy of captured data and further this has helped to make the complete facility user friendly. Identification of arc coordinates and their correlation with electrical signals has been successfully demonstrated. To distinguish different types of arcs (PA, NSA, TSA and PSA) and their locations a code has been developed in house. Various preliminary experimental results of LEO and GEO arc experiments are reported.

India's first indigenously ISO test facility for spacecraft charging in LEO and GEO environment is in its final stage of commissioning. This facility will be helpful in improving our understanding about the spacecraft charging induced ESD on satellite solar panel coupons which will in turn be helpful towards the design and manufacturing of the upgraded solar arrays that are more immune to ESD problem.

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OTHER NEWS

Procurement of Atomic Force Microscope (AFM)

The versatile and multifunctional NTEGRA Prima model Atomic Force Microscope (AFM) from NT-MDT, Russia was procured and installed at FCIPT campus. The AFM has following measurement modes:

1. Contact and Non contact mode
2. Phase imaging
3. Lateral Force mode
4. Scanning Kelving Probe measurement
5. Magnetic Force measurement
6. Scanning Capacitance imaging
7. Electrostatic Force measurement
8. Piezo Force measurement

- The Nanoindentation option with Berkovich diamond tip can be used to measure hardness in the range 1 – 100 GPa

- An external magnetic field source with in-plane variable field of upto 0.35 T is also available.

Emission analysis of a plasma pyrolysis system installed at Shree Chitra Tirunal Institute for Medical Science and Technology (SCTIMST), Trivandrum.

A Plasma Pyrolysis system was installed and commissioned at Shree Chitra Tirunal Institute for Medical Science and Technology, Biomedical Wing, Trivandrum in March 2012. FCIPT, IPR has done the emission analysis on the system during July 2012. The samples were collected and analyzed by M/s. Vimta Lab Hyderabad. Below is the photograph of the system.

Fig. 1: Plasma Pyrolysis system installed at Trivandrum

ISO surveillance Audit

The first ISO Surveillance Audit was carried out at FCIPT on 20th July 2012. Various aspects related to Quality, Purchase, Calibration, Job shop, Human Resources and Management Representative functions were audited and the auditors expressed their satisfaction with the processes and functions. There was no Non Conformance (NC) – either minor or major

Indo – Italian bilateral Project

DST, New Delhi has sanctioned three year Indo – Italian bilateral project on “Investigation of local structure and magnetism of Co nanostructures” in August 2012.

Indo – Italian bilateral Workshop

A Two days’ school and two days’ workshop titled ”Nanoscale Excitations in Emergent Materials **(NEEM 2013)**” is to be held during November 22 - 26 2013 (tentatively), jointly by Italian Republic and The Republic of India. This Indo-Italian Workshop is on the use of Synchrotron and other advanced X-ray characterization facilities for study of nanophase materials.

This School cum Workshop is sponsored by the Italian Ministry of External Affairs (MAE) through their Consulate in New Delhi, India, also partly funded by various Government of India funding agencies. Young researchers who have started working or will be working in the area of nanoscience and plan to use synchrotron facilities in the near future will be the potential participants in the school cum workshop. A limited participation from other SAARC nations (Afghanistan, Bangladesh, Bhutan, Mauritius, Nepal, Pakistan, and Sri Lanka) is also being planned. Dr. C Balasubramanian can be contacted for more details (balac@ipr.res.in).

Atomic Force Microscope installed at FCIPT

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