PLASMA PROCESSING UPDATE

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Contents

Editor's note

Thermal plasmas are known for their special characteristics such as high energy densities, high fluxes of radical species, very high quench rates etc. Due to its unique advantages, thermal plasma has been and is being successfully used as a medium of material processing in a variety of applications. In recent years many new thermal plasma applications – such as deposition of multilayered coatings for solid oxide fuel cells, hazardous waste treatment etc. – have emerged. Dr. G. Ravi explains about these new emerging trends in thermal plasma applications.

International Thermonuclear Experimental Reactor (ITER) is basically an experimental test reactor for carrying out controlled fusion experiments. Test Blanket Module (TBM) is a part of the ITER machine and serves a dual purpose of extracting the heat generated by the fusion reactions, and generates tritium with the help of breeding reactions. During this process, the internal components and the structural material of TBM are exposed to very high energy neutrons, highly corrosive liquid Pb-Li flows, etc. In order to survive under these conditions, the exposed surfaces need to be modified with a coating that can tackle the issues such as tritium permeation, corrosion etc. Graded aluminide coatings with top layer of alumina have been observed to be more reliable in this regard. Mr. Nirav Jamnapara gives more details about hot dip aluminizing process to develop these coatings.

The Indian textile industry is one of the largest in the world with a massive raw material and textiles manufacturing base. The textile industry, across the world, is being transformed by technical developments throughout the manufacturing chain from fibre to finish product. The development of textile products with increasing level of functionality would be the key to success in the future. The exposure of the textile fibres to plasma has shown to impart various functionalities to the fibres and the plasma technology has been observed to have distinct advantages over the conventional ones in this regard. Prof. P.B. Jhala has described about the status of the plasma textile technology on the world stage and about the initiatives that FCIPT has taken in this direction.

Editor : *Alphonsa Joseph*
Co-editor : *A. Satyaprasad*

Conference Presentations from FCIPT

Name of the Author	*Topic*	*Date*	*Place*	*Conference*
Dr. P.M. Raole	Scanning Electron Microscopic study of surface modified materials	19-24 Jan. 2009	S.P.University, Vallbh-Vidyanagar, Gujarat	Workshop on Scanning Electron Microscopy
Mr. R.S. Rane	Development of titanium nitride hard coating using magnetron sputtering	26-27 Feb. 2009	NAL, Bangalore	National conference on Recent Advances in Surface Engineering '09
Mr. A. Satyaprasad	Deposition of teflon like coatings using EPA and PECVD	26-27 Feb. 2009	NAL, Bangalore	National conference on Recent Advances in Surface Engineering '09

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 with 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's 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 notable achievements of FCIPT are: plasma nitriding of industrial components to increase wear resistance and hardness, coating of quartz-like films on brassware to inhibit oxidation and tarnishing, thermal plasma technologies for waste treatment, plasma processing for textile industries, deposition of TiN coatings to increase abrasion resistance, deposition of amorphous silicon coatings for anti-reflection properties, etc. The Centre has process development laboratories, jobshops and material characterisation facilities like Scanning Electron Microscope, X-ray Diffractometer, Microhardness testing facilities, which are open to users from industry, research establishments and universities.

This newsletter is designed to help you keep abreast with the developments in the important field of plasma assisted manufacturing and to look for new industrial opportunities. We would be very happy to have you write to us on ways of improving this service or visit us for further discussions.

Please visit our website: *http://www.plasmaindia.com* *or* *http://www.ipr.res.in/fcipt*

New and emerging trends in Thermal Plasma Technology

Dr. G.Ravi is a scientist at FCIPT, working on developing thermal plasma technologies

Thermal plasmas are of great technological interest because they exhibit special characteristics such as (i) high energy densities and (ii) ability to use electricity as primary energy source [1]. The former results in high processing rates, high fluxes of radical species and wide choice of reactants and the latter assures independence from oxygen potential of the medium to be processed. Thermal plasmas are characterized by the equivalence between electron and heavy particle temperatures $T_{electron} \approx T_{gas}$ and existence of quasi-chemical equilibrium conditions [2]. Temperatures (~2000–20000K), enthalpies and heat fluxes obtained from thermal plasmas are far higher than any other known technique. Depending on phase of the medium to be processed, specific property of the thermal plasma can be used for a particular application. For example, high throughputs and particle velocities obtainable in thermal plasma can be used for processing of dispersed solid/liquids for plasma spraying applications, fast chemical reactions and high quench rates for gas/vapour phase materials and increased heat transfer for surfaces/bulk materials [1].

Thermal plasma technology has evolved into a well-established inter-disciplinary science mainly due to a strong need for developing more effective techniques and processes for the production or treatment of high performance materials. An optimal match between process requirements, characteristics of the plasma source and reactor design are often necessary to achieve a viable plasma technology. Industrial thermal plasma systems are in use in a variety of applications such as plasma spraying, powder treatment, reactive spraying, waste treatment, process gas heating, particle synthesis, chemical vapour deposition, metal melting, smelting, welding, cutting, spacecraft re-entry simulation etc. Power levels of these systems range from few kW (plasma spray) to tens of MW (metallurgical and space applications) [3].

In spite of the promise shown by thermal plasma technology, the number of successful industrial applications is still limited mainly due to (i) the lack of fundamental studies to support the technical development required to achieve reproducible process conditions (ii) unfavourable process economics when plasma processes are used for low value added products (iii) difficulty of process automation due to presence of large number of independent process parameters. In recent times, several attempts have been made to overcome many of these limitations. Intelligent programming strategies involving gas flow rate, device power and sensors for on line measurement of particle trajectories, temperature and velocity have been developed for closed-loop control systems, which will result in computer controlled automation. Use of artificial intelligence also offers promising prospects. Also, there is an enhanced cooperation between manufacturers, research workers and industrialists for initiating fundamental studies for better understanding of plasma characteristics and process parameters.

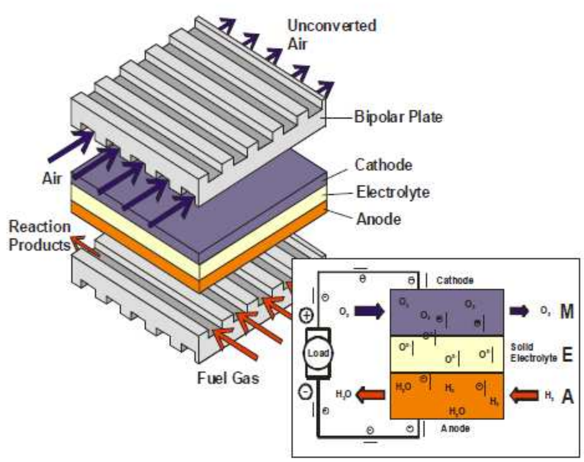
FCIPT has been involved in developing many thermal plasma technologies for over a decade. Some examples are (i) Spherodization of irregular alumina (Al_2O_3) resulting in free flowing particles used in plasma spraying and paint mixing (ii) Dissociation of

Zircon sand ($ZrSiO_4$) to ZrO_2 and SiO_2 (iii) Pyrolysis of medical and plastic waste, which involves thermal disintegration of carbonaceous material in the absence of oxygen. Many new thermal plasma applications have emerged in recent years. In this article we shall talk about the research and development activity across the world in some of these areas.

Solid oxide fuel cells

Portable and mobile electricity supply is envisaged to be in great demand in the near future. There has been a rapidly increasing interest in auxiliary power units (APU) for cars, trucks and other mobile applications including electric vehicles and hybrid cars. APUs make use of on-board fuel e.g. gasoline, diesel, natural gas or other hydrocarbons and are expected to become an electrical power source responsible for all functions. For portable or mobile applications some stringent requirements have to be fulfilled, such as high power density at low volume and weight, low degradation rate and long life time, short start-up time and stability against thermal cycling and vibrations, producible with low cost materials. In order to fulfil these demands, work is primarily aimed at development of efficient fuel cells, the backbone of an APU, which directly convert chemical energy into electrical energy with very high efficiency.

Solid Oxide Fuel Cells (SOFC), at the upper end of the temperature range (~1000^oC) are of particular interest due to their specific properties such as (i) absence of sensitive catalysts in contrast to low temperature fuel cells (e.g. polymer electrolyte fuel cells), hence the high resistance against fuel impurities (ii) large variety of suitable liquid and gaseous hydrocarbon fuels (also bio fuels) (iii) high temperature of released heat of cells. SOFCs are multilayer compounds with ceramic electrolytes e.g. yttria doped zirconia (YSZ), with cermet anodes (e.g. Ni and YSZ), and with cathodes of mixed conducting oxides (e.g. perovskite type ceramic lanthanum-strontium-manganite).



Design and principle of a planar SOFC [5]

A planar SOFC consists of a gas tight electrolyte, conducting only for oxygen ions, attached on both sides to the electrodes, which are porous. Oxygen molecules are dissociated on the cathode side and the resulting atoms are ionised. These ions move through the electrolyte to the anode interface where they react with fuel components (H_2 and/or CO) forming H_2O and/or CO_2 and releasing electrons, which return to the cathode side for production of useful electrical power. With present cells, power densities of about 0.5 to 1W/cm^2 can be realized. Although conventional processes of wet powder processing for production of SOFCs are well established, long times at very high temperatures limit the spectrum of useable materials or the technology. Besides this, number of possible sintering steps in the manufacturing of multilayer cells should be minimized which has not been possible with conventional technology because different cell layers are made up of different materials with disadvantageously different sintering and shrinking behaviour.

Advanced thermal plasma processes can play a major role in the production of SOFCs and can be used advantageously for making such multilayer designs because (i) they are fast, resulting in very short exposure of the material with high temperatures (ii) all kinds of materials like controlled porous thin or thick layers with constant or graded concentration can be produced. Promising preliminary experiments have been performed by researchers and dc torches along with supersonic nozzles, have been successfully used by DLR in Stuttgart, Germany for producing such SOFCs. However, parameters and materials have to be optimized for desired quality, high production rate and deposition efficiency. Future work should involve building powerful thermal plasma sources along with automation of the processes and control of resulting products.

Gasification of biomass & synthetic gas production

Just as any other “waste”, biomass is seen today as a resource and an abundant source of energy. Biosyngas containing mainly CO and H_2 is a key intermediate for the production of renewable transportation fuels, chemicals and electricity. Biomass gasification is not a new process, however a conventional biomass gasifier uses air as a gasifying agent due to which low calorific value gas (3-5 MJ/m^3) is generated. Low temperature gasification contains only 50% of the energy in syngas components CO and H_2, diluted by CO_2 produced by partial oxidation, whereas remainder is contained in CH_4 and higher aromatic hydrocarbons [5].

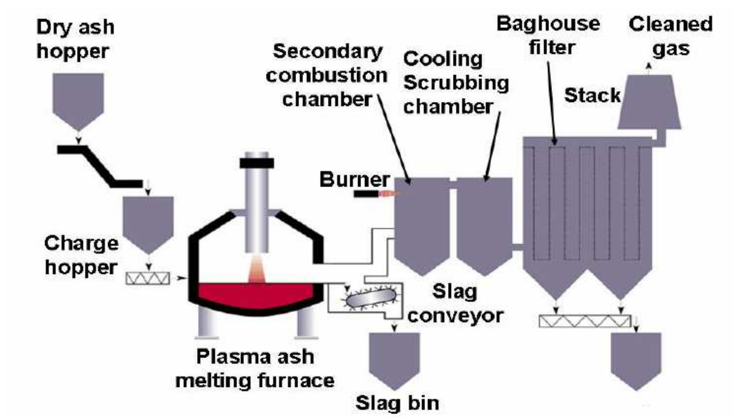
Thermal plasma based gasification has huge potential because all materials can be decomposed when brought in contact with plasma and high heat transfer rates to treated materials is possible. It exploits the thermochemical properties of plasma. The particle kinetic energy in the form of heat is used for decomposing biomass and presence of charged and excited species renders the environment highly reactive. Besides this, the high enthalpy and temperature of plasmas, compared to gases used in conventional methods, play an important role. Plasma process also offers better control of process temperature, higher process rates and optimum composition of produced syngas. Since energy for gasification is supplied from plasma rather than the energy from combustion, it offers more options in process chemistry and hence broad range of biomass feedstock can be gasified. Plasma gasification of biomass is a newly emerging application whose principal goal is to produce mainly a mixture of CO and H_2 with very less remainder. Unlike waste treatment where material decomposition is of prime importance, energy balance of the process is much more important in gasification.

At the process level, specific advantages of plasma gasification are (i) combustible gases are not produced (ii) temperature can easily be controlled (iii) shorter residence times can be achieved (iv) low thermal inertia and feedback control is obtainable (v) smaller plants can be installed. In the actual process, some oxygen is added to gasify all carbon present in the biomass material in the form of oxygen, air, steam or CO_2.

Only laboratory scale experiments have been performed till now and they have shown that optimal temperatures have to be around 1300 K. AC plasma torches with high flow rates and enthalpies, ~ 8 MJ/kg, have been used to produce syngas. In another experiment, dc plasma torches of ~ 160 kW power with gas/water stabilized arc have been used for gasification of wooden saw-dust in the presence of steam and small amount of argon. Composition of produced gas seems to depend weakly on material feeding rate and power but strongly on mass flow rate of oxygen in supplied gases. Numerical descriptions incorporating fluid dynamic model of plasma-material interaction, model of heat transfer to material, its heating and gasification as well as kinetics of chemical reactions in the reactor have also been proposed.

Hazardous waste treatment

With increasingly stricter environmental norms, lack of space and ecological negative impacts, ecological, social and political pressures on industry have led to the proposal of new waste treatment solutions & improvise the existing ones to reduce environmental impact and increase efficiency. Tests using `blown arc high power plasma torches' were carried out for the destruction of asbestos, ashes (from incinerators and gasifiers), low radioactive waste, chemical weapons, medical waste, organic chlorides etc. Special efforts have been made on the destruction of ashes and asbestos. Pioneering work has been done by Europlasma [5].



Generic commercial plasma treatment process for handling of ashes [5]

The efficiency of the plasma technology for ashes destruction was demonstrated by Europlasma by converting fly ashes into an inert material, with lifetime of over 200000 years, confining pollutants in the vitreous matrix. Dioxins and furans are also destroyed by the high temperature process (reaction temperature around 1400°C). All exhaust gases are mixed with the incinerator exhaust gases.

Asbestos, also a hazardous waste, can be vitrified by thermal plasma. A furnace can be equipped with several torches and furnace walls covered with specific refractory materials that can be changed. In the vitrification process, plasma torches are fed with air and used as heating devices to bring materials to their fusion temperature. Industrial units for ashes and asbestos vitrification are already under operation. However, new applications are under development with torches fed with other gases such as CO, CO_2, H_2, CH_4 mixtures.

It must be mentioned that a few plasma technologies may result in interesting processes such as nanoparticles synthesis, plasma assisted chemical vapour deposition for thermal barrier coatings etc. A new thermal plasma process called the hypersonic plasma particle deposition process, in which reactants are injected into the jet of a dc plasma torch and disassociated and the plasma is accelerated in a supersonic nozzle, has been used to produce narrow size distributions peaking at 20 nm. Thermal plasma CVD provides high fluxes of deposition precursors resulting in high deposition rates and large variety.

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Hot Dip Aluminized Coatings for Test Blanket Module

Mr.Nirav Jamnapara is a metallurgical engineer at FCIPT, working on developing hot dip aluminized coatings

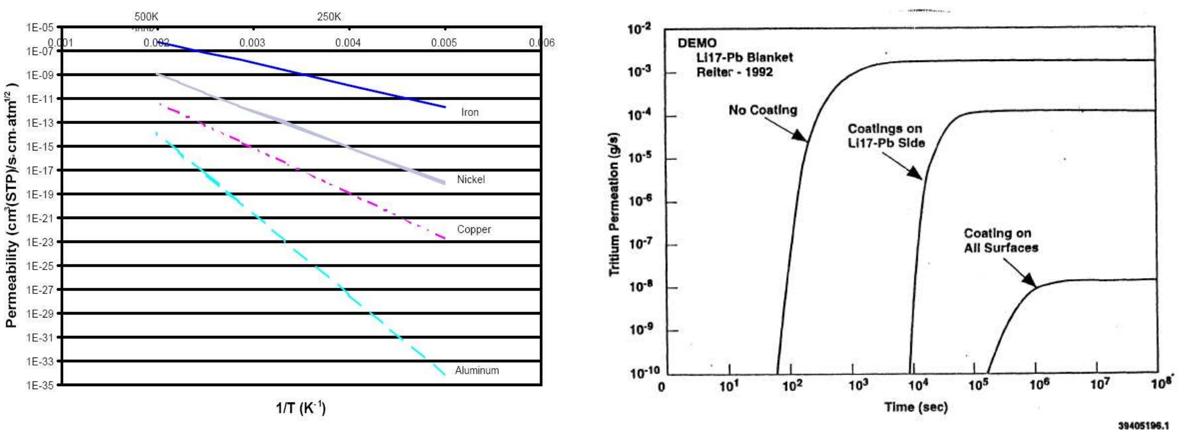
One of the key missions of the International Thermonuclear Experimental Reactor (ITER) which is being setup in Cadarache, France by collaboration between 7 partner countries viz. China, India, EU, U.S., Japan, Russia and Korea; is to validate the design concepts of tritium breeding blankets relevant to a power-producing reactor like DEMO. ITER should demonstrate the feasibility of the breeding blanket concepts that would in future, lead to tritium self-sufficiency and high grade heat extraction [1].

The main objective of Test Blanket Module (TBM) is to generate tritium (fuel for fusion reactor) from Lithium, by using high energy neutrons (14 MeV), and also to utilize Lithium as a coolant and thereby extract heat. Based on this, two types of breeders have been evolved namely 1) Solid Breeders where Li is in solid form (as Lithium Titanate pellets) and 2) Liquid Breeders where Li is in liquid form (as eutectic Pb-17Li). The Indian TBM concept includes both the types i.e. solid and liquid breeders. There are three major surface phenomena in the Indian TBM (which are also common in other liquid breeder blankets) are:

1. Permeation of Tritium through structural materials
2. Corrosion of FM Steels by flowing Pb-17Li eutectic
3. MHD Drag in the Pb-17Li flow channel

In order to tackle the above issues, the surfaces need to be modified with a coating which can resist the above three phenomena. As per the literature [2,3,4] reviewed for Helium Cooled Liquid Lithium (HCLL) and other such TBM concepts, aluminide coatings have been found reliable against the above phenomena. This aluminide coating is a graded coating with a top layer of Alumina adhered to an intermetallic aluminide layer. This graded coating profile is purposefully produced to prevent sudden co-efficient of thermal expansion (CTE) mismatch.

Various techniques have been explored worldwide to achieve aluminide coatings on Ferritic-Martensitic (FM) Steels such as Pack cementation, Hot Dip coating, Vaccum Plasma Spray (VPS), Chemical Vapour Deposition (CVD) etc. However, more weightage was given to the techniques capable of coating complex geometries. Hot Dipping has been recommended [4] due to its capability to coat complex geometries as well as its ability to provide homogenous coating with better tritium permeation resistance.



(a) (b)

Fig 2: (a) Permeability of H in various metallic coatings [3] (b) Calculated T permeation into coolant by Reiter [6]

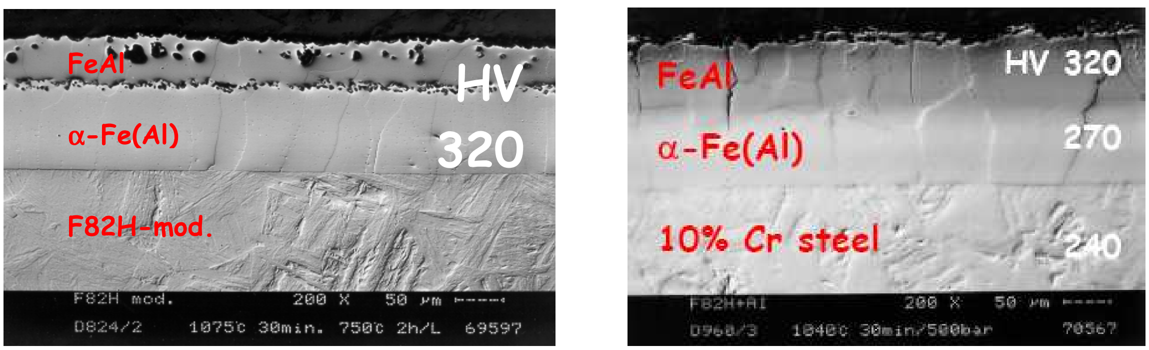
The hot dipping technique involves a dipping process followed by a diffusion technique. As per the work done at FZK [4,5] the hot dip coating process involves various steps as described in the Table 1. The process parameters as well as the purpose of the step have been identified.

Table 1: Details of process steps in HDA [4,5]

Process Step	**Specification**	**Purpose of this step**
Sample preparation	Tube / flat	Compliance to testing stds.
Surface activation	Aq. Flux coat	Activate surf. for Al adsorption
Hot Dipping in Al melt (Al-Si alloy)	@ 700 °C for 30 s, Argon environment	Al coating on steel
Diffusion Heat treatment (with surface oxidation)	1040 ± 50 °C	Form Fe-Al intermetallics & Al_2O_3 on surface.

Hot Isostatic Pressing (HIP)	1040 ± 50 °C + >250 Bar pressure	▪ Eliminate kirkendall pores ▪ convert brittle Fe_2Al_5 into ductile Fe-Al phase.

The hot dipping process is carried out at 700-750 °C for a predetermined time and subsequently the sample is held in mildly reducing environment [4,5]. Subsequent to dipping, the coated sample is diffusion annealed (at 1040 °C for 0.5 hr and 750 °C for 1 hr) [4,5] in oxidizing environment so that the aluminium diffuses in steel and forms iron aluminides. The oxidation also leads to the formation of thin alumina layer on the top. This alumina layer is crucial from the tritium permeation and Pb-17Li corrosion resistance points of view. However, major drawbacks of this technique are the formation of kirkendall pores (see Fig 3a) formed due to high temperature diffusion heat treatment and that this hot dipping treatment leads to formation of brittle intermetallic phases (Fe_2Al_5) which are undesired.



(a) (b)

Fig 3: (a) Microstructure of FM Steel after heat treatment (b) Microstructure of FM Steel after HIP treatment [5]

Konys *et. al.* [4,5] have reported that in order to remove the kirkendall pores and to transform the brittle phases into ductile (FeAl), the samples are exposed to Hot Isostatic Pressing (HIP) carried out at 1040 °C for 0.5 hr and 750 °C for 1 hr at a pressure of > 250 bar. The microstructure after HIPing is as indicated in Fig 3 (b) above which explains the removal of kirkendall pores.

The aluminized coating developed by the above process has been extensively tested for Hydrogen permeation and resistance to Pb-17Li corrosion. Since Tritium is a radioactive isotope of hydrogen, permeation studies with tritium needs sophisticated testing instruments with high level of safety. Hence many experiments of permeation testing have been done by hydrogen gas or hydrogen in Pb-17Li. The permeation is measured as a degree of improvement as compared to the permeation properties of bare FM Steels, i.e. Permeation Reduction Factor (PRF) and is calculated as the ratio of Permeation of hydrogen in bare FM steel to the permeation of hydrogen in aluminized or coated steels. From the corrosion perspective, it has been reported [7,8] that the aluminide coating of ~150 µm thick can withstand ~10,000 hrs of exposure to flowing Pb-17Li.

However, despite of this coating being the most qualified coating for the TBM surface engineering requirements, it still has certain drawbacks such as possibility of cracks due to inhomogeneous aluminium distribution along the case, especially segregation of aluminium melt due to gravitational effects. Moreover, the PRF values for Tritium permeation in Pb-Li are also yet to meet the targeted design value of 75. Efforts are also being made to reduce the thickness of this aluminide coating as it poses a threat in irradiation conditions.

Activities on development and optimization of an aluminide coating are being carried out at FCIPT, Gandhinagar with novel approaches such as growth of alumina layer in pulsed oxygen plasma environment for denser and adherent coatings, surface alloying for better phase stabilities and adherent alumina layer on top etc.; combined with the work done across the globe so as to achieve the targeted needs of the Indian TBM design.

Acknowledgement:
The above referred work on development of hot dip aluminized coatings is being carried out under the Test Blanket Module Programme of Institute for Plasma Research, Gandhinagar and the support is duly acknowledged.

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Plasma Textile Technology : World Status and Initiatives at FCIPT

Prof.P. B. Jhala is Advisor, Plasma Textile Applications, at FCIPT, pbjhala@ipr.res.in

INTRODUCTION

The textile industry is being transformed by technical developments throughout the manufacturing chain from fibre to finish product. New fibres and finishes have changed the way fabric and cloth look and feel. Casual wear, leisure wear and sports active wear has grown in importance in recent years and has put further demands for innovation on the fibre and finishing sector. The key to 21st century competitive advantage will be the development of textile products with increasing level of functionality. There are three basic appeals of functional textiles namely comfort, health and safety. In this field, Plasma Technology shows distinct advantages in imparting various functionalities in textiles.

Although plasma is being researched since 1920s, its broader industrial exploitation started only in the 1960s. The focus was on low-pressure plasma technology driven by the need of the microelectronics industry for ultrahigh performance batch processing. Operating at low pressure, however, restricted its move into mainstream industry needing roll-to-roll processing. This has led to the development of atmospheric pressure plasmas. The use of atmospheric pressure cold plasma is now well established as a versatile technology for modifying the surfaces of textiles. It produces no more than a surface reaction and it does not alter the bulk properties of textiles. The energetic species of cold plasma can break the covalent bonds of the fiber at its surface and etch or functionalize its surface. It is an environment friendly process and has an edge over chemical processes.

WORLD STATUS

In the textile field, significant research work has been going on since the early 1980s in many laboratories across the world dealing with low-pressure plasma treatments of a variety of fibrous materials showing very promising results regarding the improvements in various functional properties in plasma-treated textiles.

Lately, many EU-financed projects within the 4th, 5th and 6th Framework Programme such as Plasmatex (1997-2000), Plasmatech (2002-2005), Acteco (2005-2009) have had the objective of developing and demonstrating the feasibility of plasma-based industrial processes to meet the needs of the textile industry and offer tools for product development and innovation. As a part of EU Project Leapfrog CA, an extensive literature analysis and patent survey was carried out in 2005 in the area of plasmas and plasma-induced functionality of textiles. This survey has shown that hundreds of articles have been written on these subjects and a very large number of patents have been granted in the field of plasma treatment of fibres, polymers, fabrics, nonwovens, coated fabrics, filter media, composites, etc. for enhancing their functions and performances. It has also pointed out the potential use of plasma treatments of fibres, yarns and fabrics for the following types of functionalization.

(1) Anti-felting/shrink-resistance of woollen fabrics
(2) Hydrophilic enhancement for improving wetting and dyeing
(3) Hydrophilic enhancement for improving adhesive bonding
(4) Hydrophobic enhancement of water and oil-repellent textiles
(5) Facilitating the removal of sizing agents
(6) Scouring of cotton, viscose, polyester and nylon fabrics
(7) Anti-bacterial fabrics by silver particles deposition with the aid of plasma
(8) Prevention of readily occurring color variation in textiles
(9) Durable antistatic properties using PU-resin and plasma processing
(10) Electro-conductivity of textile yarns by surface plasma deposition

This shows that plasma technology, when developed at a commercially viable level, has strong potential to offer – in an attractive way – new functionalities in textiles. In recent years, considerable efforts have been made by many plasma technology suppliers to develop both low-pressure and atmospheric-pressure based plasma machinery and processes designed for industrial treatment of textiles and nonwovens to impart a broad range of functionalities. The standard and custom-designed plasma systems being offered in the European market are :

(1) Low-pressure Plasma Systems for In-line and Batch Treatment by Europlasma (Belgium), P2i (UK) and Mascioni (Italy)
(2) Atmospheric Pressure Plasma System for On-line Continuous Treatment by Dow Corning Plasma System (Ireland), Ahlbrandt (Germany), AcXys (France), APJeT (USA) and Tri-Star (USA).

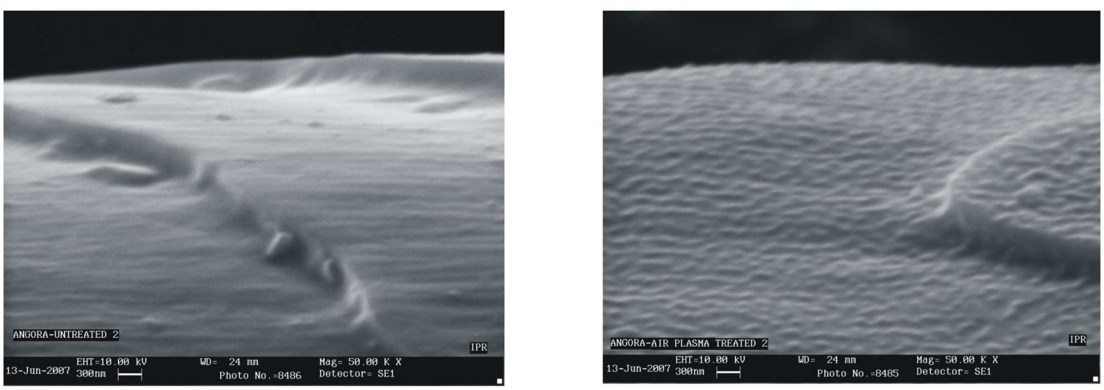
For the first time, in an International Textile Machinery Exhibition (ITMA), 2007 at Munich, four manufacturers were showcasing atmospheric pressure and low-pressure plasma processing systems for textile commercial applications namely Arioli (Italy), Grinp (Italy), HTP Unitex (Italy) and Mageba (Germany).

INDIAN STATUS

In the country, the textile educational and research institutes such as UDCT, Mumbai, IIT, Delhi, ATIRA, Ahmedabad, BTRA, Mumbai, CSTRI, Bangalore have been carrying out research work in plasma textile technology at the laboratory scale contributing to the knowledge base in the field.

Recently, FCIPT-Institute for Plasma Research (IPR) and National Institute of Design (NID) carried out a pioneering research work by way of not only developing an innovative Atmospheric Pressure Plasma Processing System for Angora Wool (APPAW) but also successfully installing and establishing it in the Angora Cottage Industry at Kullu for adding value and access to better markets at home and abroad. This plasma plant for surface modification of fibres, as shown in Fig.1, generates plasma at atmospheric pressure using air as plasma forming gas. A patent has already been filed for this novel technology. This is a cost-effective green process. Also, it is the first Atmospheric Pressure Plasma System for Textiles developed in the country, for demonstration.

Fig. 1: Photograph of Atmospheric Pressure Plasma Processing system for Angora Wool



Angora Fibre Before Plasma Treatment

Angora Fibre After Plasma Treatment

Fig. 2: Modification of Angora Fibre Surface

The plasma etching of Angora fibre surface at atmospheric pressure glow discharge is shown in Fig 2. Plasma treatment assists in increasing the friction and cohesion between the fibres. It forms a part of the movement on promotion of non-polluting techniques for mechanical processing of textile materials without any difficulties such as static, shedding, fibrosity. The plasma treatment caused a slight reduction in denier and increase in tenacity of Angora fibre while substantially increasing the friction between the fibres.

APPAW has been successfully installed and synchronized with Roller Worsted Card, for continuous plasma treatment of Angora wool in the web form, with the help of Weaving and Designing Training Centre of Central Wool Development Board and Shiva Weavers

Co-operative Society at Kullu. After plasma treatment of Angora fibres, it facilitated mill spinning as well as hand spinning of yarn without shedding; and later hand weaving of fabric without fibrosity. Products such as Stole, Shawl, Scarf, Cap, Sweater, Ponchos have been developed from plasma treated 100% Angora fibres. The dyeing of these products is done using Natural Dyes. The plasma treatment to Angora fibres also improves wettability and dye uptake, which are two additional advantages of plasma treatment.

FUTURE PLAN

The dissemination of Angora Plasma R&D work at national seminars and conferences and through the leading scientific and textile journals has generated a lot of interest amongst Indian textile technologists and researchers in the usage of plasma technology in textiles. Now, FCIPT is looking at various other potential plasma applications in textiles jointly with the textile educational and research institutes such as Wool Research Association (WRA), Central Silk Technological Research Institute (CSTRI), South India Textile Research Association (SITRA) as well as the textile industry in the country. Also, FCIPT along with TIFAC is working on formation of consortium of research and academic institutes, textile industry and machinery manufacturers for initiating National Plasma Textile Program.

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Development and installation of Carbon surface Activation using Atmospheric Pressure Plasma (CAAP) system

Dr. S.K. Gupta[*], Mr. R.S. Rane, Mr. N. Vaghela, Ms. K. Keena, and Mr. A.Viren

Water filter candle is the cheapest and most feasible solution for water treatment. The most commonly used water filter candles are made of activated carbon granules. Carbon is a natural substance and is derived from bituminous coal, lignite, wood, coconut shell etc. Activated carbon is carbon which has a slight electro-positive charge added to it, making it even more attractive to chemicals and impurities. As the water passes over the positively charged carbon surface, the negative ions of the contaminants are drawn to the surface of the carbon granules.

Most popular forms of activated carbon used in the treatment of point-of-use (POU) drinking water filters are granular activated carbon (GAC), extruded solid carbon block (CB) and powdered activated carbon (PAC). All activated carbon forms have a tremendous surface area resulting from its porous structure. For comparative purpose, a teaspoon of activated carbon has surface area the size of a football field. However the surface properties of the activated carbon are found to be hydrophobic, and the water that is getting filtered is the water that actually passes through the pores of the water filter candles. Due to its hydrophobic nature certain pressure is required to allow the water to pass through these pores. Generally for municipal water treatment plants, electric pumps are used to generate the desired pressure. In some cases, a water tank of few meters height is also capable to produce the necessary pressure. But when it comes to provide clean water to small villages where they lack both of these facilities, this method does not work. Due to these constraints it cannot be used in remote villages.

Figure 1 : Photograph of CAAP System

If the water absorbing property of the carbon powder can be improved, the above mentioned problem could be solved as the water doesn’t need to flow only through the pores of the water filter candles. FCIPT has taken up this challenging problem of converting the hydrophobic nature of the activated carbon into hydrophilic nature using plasma based technology, and at the same time maintain its activated state so that it can adsorb the chemicals and impurities. This would ensure that the self gravity pressure developed due to the weight of the water (to be filtered) is sufficient to get the water filtered. The aim of the present work was to improve the water absorption property of GAC, derived from coconut charcoal. We had decided upon developing a plasma etching system to achieve this objective, based on our previous experience. However conventional plasma etching is carried out in a vacuum vessel. But since it would be difficult to handle the powders in a low pressure environment, it was felt that an atmospheric plasma system would be a suitable choice. The main advantages of atmospheric pressure plasma system are the elimination of vacuum systems, reduction of costs, and the possibility to use continuous systems.

A well known configuration for atmospheric pressure plasma system treatments is the dielectric barrier discharge (DBD). In this case, one or both of the electrodes are covered with a dielectric layer in order to minimize electric-field intensity and to avoid arcing between the two electrodes. Barrier discharge is formed in a narrow gap between two parallel electrodes. With each half-cycle of the driving oscillation, the voltage applied across the electrodes exceeds breakdown voltage of gas and narrow discharge filaments are formed which initiate the conduction of electrons toward more positive electrode. As charge accumulates on the dielectric layer(s) at the end(s) of each filament, the voltage drop across the filament is reduced until it falls below the discharge-sustaining level, where upon the discharge is extinguished. The low charge mobility on the dielectric not only contributes to this self-arresting of filaments but also limits the lateral region over which the gap voltage is diminished, thereby allowing parallel filaments to form in close proximity to one another.

A DBD facility, using five sets of electrodes (the size of each electrode was 30 cm X 40 cm), was designed and developed at FCIPT. The photograph of the system is shown in figure 1. The GAC was passed through the narrow gap between the electrodes – continuously – using a conveyor belt mechanism and was exposed to the DBD discharge. During the initial trials, the improvement in the water absorbing property of GAC was demonstrated. However the field trials will be carried out the site. This complete system was successfully designed developed and commissioned at site in very short time period of 8 months.

Facilitation Centre for Industrial Plasma Technologies

Institute for Plasma Research,	**Phone**	(079) 23269000 / 23269002
B-15-17/P, Sector – 25,		23962000
GIDC Electronics Estate,	**Fax**	(079) 23269001/23962001
Gandhinagar, Gujarat – 382 044	**E-mail**	fcipt@ipr.res.in
INDIA	**Website**	www.plasmaindia.com

www.ipr.res.in/fcipt