PLASMA
PROCESSING UPDATE

A newsletter from the

Facilitation Centre for Industrial Plasma Technologies
Institute for Plasma Research

Issue 63 May – August 2011

Contents

Editor's Note

Failure of a hard coating under many tribological conditions is rarely promoted by conventional wear. Instead, the tribological failure is often caused by debonding of the coating from the substrate, fracture of the coating or even by subsurface fracture. Duplex coatings consisting of a plasma nitrided layer followed by plasma assisted physical vapour deposited hard coating have been developed in recent years to specifically improve the coating/substrate performance and therefore the lifetime of coated components by changing the substrate properties. Mrs. Alphonsa Joseph briefs on the effect of plasma nitriding on duplex coated AISI M2 steels.

Safe disposal of waste is an important issue. Any technique that disposes off the waste in an environment friendly manner and at the same time recovers energy from the same process would be of high demand. Thermal Plasma based technologies have been successfully used to achieve the same and the details are explained by Mr. P. V. Murugan.

Editor : *Dr. S. Mukherjee*
Co-editor : *A. Satyaprasad*

Conference Presentations from FCIPT

Name of the Author	*Topic*	*Date*	*Place*	*Conference*
Dr. P. M. Raole	Nanoscience and Nanotechnology- An Overview	5th May 2011	Charotar University of Science and Technology - Changa Changa 388 421 Gujarat, India	GUJCOST sponsored workshop on "Nanostructured Materials, Properties and future Research Areas in Mechanical Engineering"
Dr. S. B. Gupta	Aspects of Intense pulsed electric field induced effects for waste water treatment	23-27 May 2011	VJTI, Mumbai	School on Pulsed Power Technology [SPPT-2011]
Dr. G. Ravi	Plasma – A Stealth Tool	June 2011	ADA, Bangalore	Interactive Meeting on Stealth Technologies
Dr. Mukesh Ranjan	Tuning plasmon resonance using ion beam produced ripple patterns	26-30 June	Singapore	ICMAT2011
Dr. P.M.Raole	Nano-materials and Nanostructures in Fusion Research	14-17 August 2011	Cochin University of Science and Technology KOCHI-682 022, INDIA	Third International Conference on Frontiers in Nanoscience and Technology (Cochin nano-2011)

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 IPR with the Indian industries and commercially exploits its knowledgebase. FCIPT interacts closely with entrepreneurs through the phases of feasibility study, incubation, development, 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 worked or has been working on, include Plasma Surface Engineering, Plasma Pyrolysis/ Gasification/ Energy recovery, Plasma Diagnostics, Plasma based Nano Patterning and Nano Synthesis, Plasma based Thin film Deposition, Plasma Material Interaction, Plasma based High Heat-flux Source Development, Space Plasma and Stealth technologies, Textile Engineering, Solar Cell Development etc. The Centre has process development laboratories, jobshops and advanced material characterisation facilities like Scanning Electron Microscope, X-ray Diffractometer, 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. We would be very happy to have you write to us on ways of improving this service.

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

Effect of Plasma Nitriding on Duplex Coated AISI M2 Steel

Ms. Alphonsa Joseph

In this study, AISI M2 High Speed Steel (HSS) (0.86% C, 6.0% W, 5.0% Mo, 4.1% Cr, 1.9% V, 0.5% Co, in wt%) was selected as the substrate material because this steel is mostly used as cutting tool material. Since the cutting tools usually go unused due to chipping and plastic blunting, or by more continuous mechanisms such as abrasive, adhesive or continuous wear, it becomes necessary to modify the surface by some treatment. Both plasma nitriding and TiN coated AISI M2 steels are nowadays frequently used in metal cutting operations and increasingly replacing uncoated drills, taps, milling cutters etc. By combining the benefits of TiN coating and plasma nitriding, a further optimization of the wear resistance of TiN coatings can possibly be reached by the fact that the thick nitriding layer acts as a mechanical support for the TiN layer. An attempt has been made to first plasma nitride AISI M2 steel at 500°C for 24 hours with 80% nitrogen and 20% hydrogen gas mixture ratio prior to TiN coating. Plasma nitriding was then carried out on the duplex coated steel substrates. More emphasis was made to form TiN phase on AISI M2 steel by varying nitrogen gas flow rates during TiN coating. Variations of the microhardness, surface morphology, and structural phase changes have been investigated using a surface roughness tester, Vickers microhardness tester, scanning electron microscopy (SEM) and X-ray diffraction (XRD).

Disc shaped samples of 20 mm in diameter and 4 mm thick, made from AISI M2 High Speed Steel, were polished to mirror finish by standard metallography method and cleaned with acetone before processing. Plasma nitriding process and TiN coating deposition were done in separate systems.

In this study the TiN followed by plasma nitriding processed samples are denoted as TiN+PN. Similarly plasma nitrided, plasma nitriding followed by TiN deposition and Plasma nitriding process of TiN coated on plasma nitrided samples are denoted as PN, PN+TiN, PN + TiN +PN respectively. Also TiN coated with flow rates of 1, 2, 3, 4 and 5 sccm of nitrogen gas are denoted as TiN1, TiN2, TiN3, TiN4 and TiN5, respectively.

Surface roughness was measured in R_a using portable surface roughness tester (Mitutoyo SJ-201). Near surface hardness was investigated using Leitz make Vickers microhardness tester. Measurements were performed under the load of 10 grams, 15 grams, 25 grams, 50 grams and 100 grams, applied for 20 s on the mechanically polished and cleaned surfaces. Readings were taken from three distinct regions and the average value was finally considered. Scanning Electron Microscope (SEM) [LEO S-440i make] was used to observe the surface morphology after the treatments. Phase composition of the un-nitrided substrates and duplex coated nitrided layers were studied by X-ray diffraction (XRD) using a XRD3000PTS diffractometer with the Cu–Kα radiation (λ=1.5406 Å) in the Bragg–Brentano configuration operated at 40 KeV and 50 mA. XRD patterns were recorded with step size of 0.06° and step durations of 4 s at each step in the angular range of 30°–90°.

Plasma Nitriding of AISI M2 steel and its modification by TiN deposition followed by plasma nitriding process.

The surface hardness of plasma nitrided AISI M2 steel increased by a factor of 4 (845HV0.1). Cross-sectional

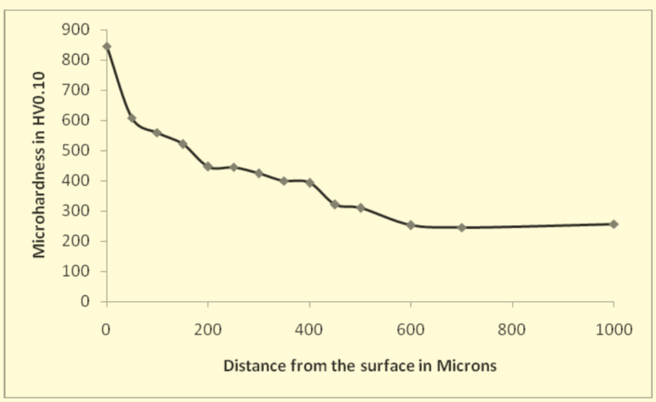


Fig. 1: *Cross-sectional hardness of plasma nitrided AISI M2 steel nitrided at 500°C at 5mbar pressure for 24 hours.*

microhardness profiles within the nitrided layers are shown in figure 1. The hardness is maximum on the outward surface and it decreases toward the sample core. This hardness profile can be associated with the nitrogen profile. Hardness increases due to the presence of compressive residual stresses in the nitrided layer. The case depth was estimated to be 500 microns.

Surface Appearance

The colour of samples after TiN deposition on plasma nitrided AISI M2 steel was uniform gold. The surface roughness of plasma nitrided samples was R_a = 0.06 µm. After TiN deposition the surface roughness (R_a) increased to 0.15 µm for TiN1 sample as shown in figure 2. It was highest for TiN deposited at 1sccm nitrogen flow rate. With increase in nitrogen gas flow rate, the TiN coatings surface roughness decreased due to lower deposition rates and low film thickness formation. This is also observed from the SEM microstructure of TiN coating on plasma nitrided AISI M2 steel shown in figure 3a.

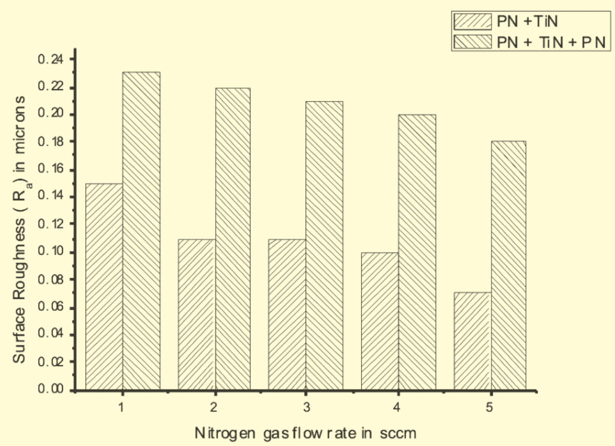
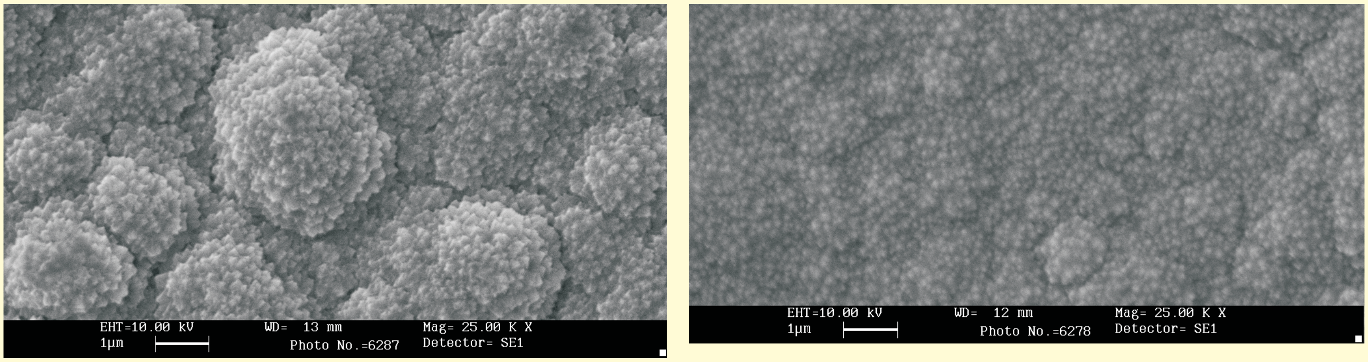
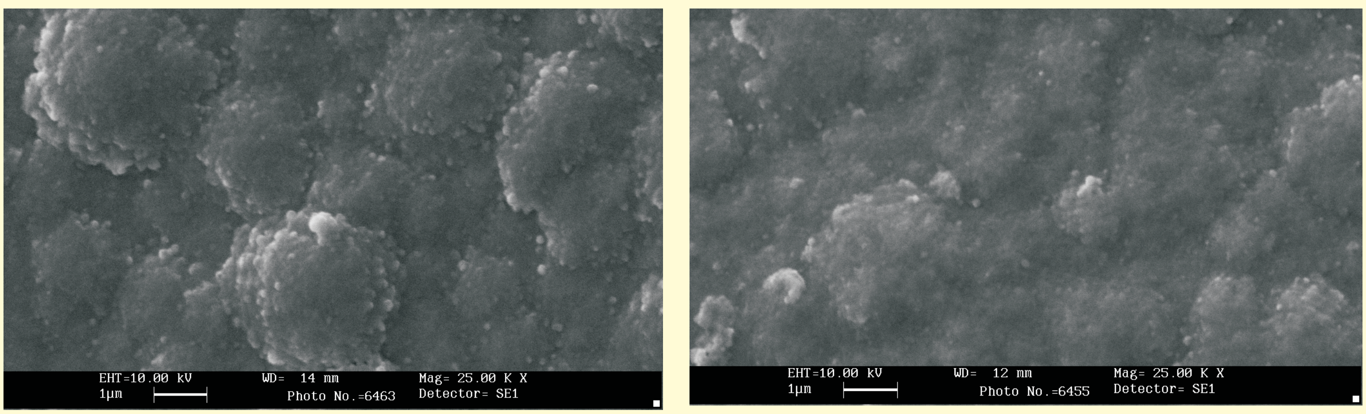


Fig. 2: *Change in surface roughness when coated with different nitrogen gas flow rates for duplex coated and duplex coated followed by plasma nitriding on AISI M2 steel substrates.*

After plasma nitriding on the TiN coated layer the gold color disappeared and the color of the sample was light grey. The surface roughness further increased due to nitrogen ion bombardment and heating compared to the only TiN coated samples. The surface roughness decreases for samples coated with higher nitrogen gas flow rates as shown in fig. 2 due to presence of thin TiN layer. The surface morphology of the duplex coated samples after plasma nitriding becomes inhomogeneous with void formation between the micro-particles on their surface as shown in figure 3b. Hence, plasma nitriding of the sample prior to coating influences the morphology of the coating structure.



PN+TiN1 (a) PN+ TiN3



PN+TiN1+PN (b) PN+TiN3+PN

Fig. 3: *Surface morphology of (a) duplex coated and (b) plasma nitriding on duplex coated AISI M2 steel with 1 and 3 sccm nitrogen flow rates. The surface morphology of the TiN PVD coatings deposited onto plasma nitrided AISI M2 steel is characterized by a significant inhomogeneity due the presence of multiple drop-shaped micro-particles on their surface.*

Surface hardness

The plasma nitrided AISM M2 steel, over which TiN was deposited at a N_2 flow of 1 sccm, has shown the highest hardness of 2060 HV0.01 with an error of ± 75HV; due to predominant presence of TiN phase and iron nitrides.

With increase in nitrogen flow rate the surface hardness of the deposited TiN layer decreased as compared to that obtained by 1sccm nitrogen flow rate. This is because of the thin TiN layer formed with increasing the nitrogen flow rate as observed previously. On plasma nitriding the PN+TiN coated AISI M2 samples the surface hardness decreased to 1702 HV0.01 for the TiN1sample as shown in figure 4. This is due to sputtering of the layer during plasma nitriding. Whereas, the surface hardness of TiN2, TiN3, TiN4 and TiN5 increased after plasma nitriding for 4 hours. The increase in surface hardness can be attributed to the high compressive stresses in the thin coated layer.

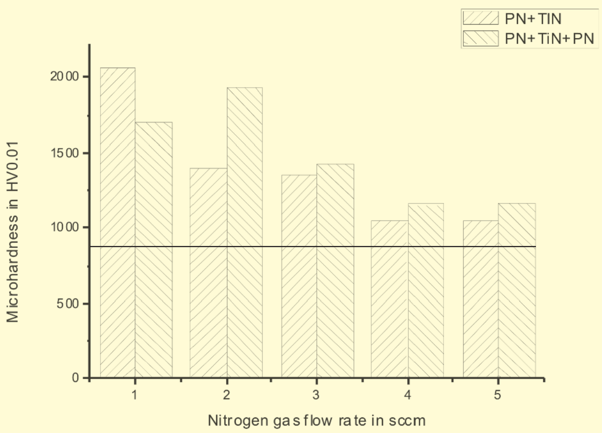


Fig. 4: *Surface microhardness of duplex coated with different nitrogen flow rates on AISI M2 and plasma nitriding of the duplex coated AISI M2 steels. Hardness was measured with 10 grams load. The horizontal line is the hardness of the plasma nitrided AISI M2 steel.*

XRD Analysis

According to figure 5 the XRD pattern of the plasma nitrided AISI M2 steel contains only γ -Fe_4N and ε-Fe_3N iron nitride phases due to the presence of white layer formed during plasma nitriding process. Since the plasma nitrided layer is very thick about 500 micron there is no presence of -Fe phase. TiN peaks at (111), (200), (220) (311) and (222) are formed during TiN deposition at all nitrogen gas flow rates. Whereas the intensity of iron nitride peaks decreases. The intensity of TiN and Fe_4N peak is higher for TiN1 samples due to higher film thickness. It is interesting to find that the Fe_3N peaks shift to the higher 2 theta values due to heating during TiN deposition. This is because the d value decreases due to nitrogen diffusing out of the compound layer. The reduced nitrogen concentration in the compound layer could also cause the formation of Fe_4N.

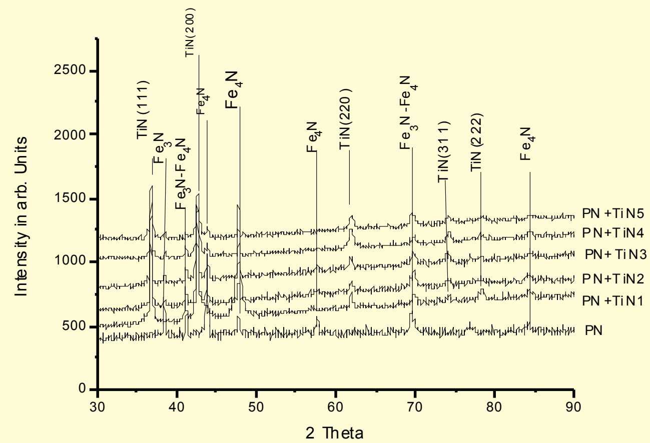


Fig. 5: *XRD pattern of duplex coated AISI M2 steel with different nitrogen flow rates. The intensity of Fe_4N increases whereas intensity of Fe_3N deceases. The Fe_4N peaks shift towards higher 2 theta values.*

After plasma nitriding the duplex coated layer the intensity of iron nitride peaks are higher compared to the duplex coated steel substrate as shown in figure 6. Also, TiN peaks are broader and shift towards higher angles indicating reducing compressive stresses. With increase in nitrogen content the intensity of TiN decreases. Also the shifts of TiN and Fe_3N and Fe_4N peaks are lower compared to duplex coated samples due to nitrogen ion bombardment and heating.

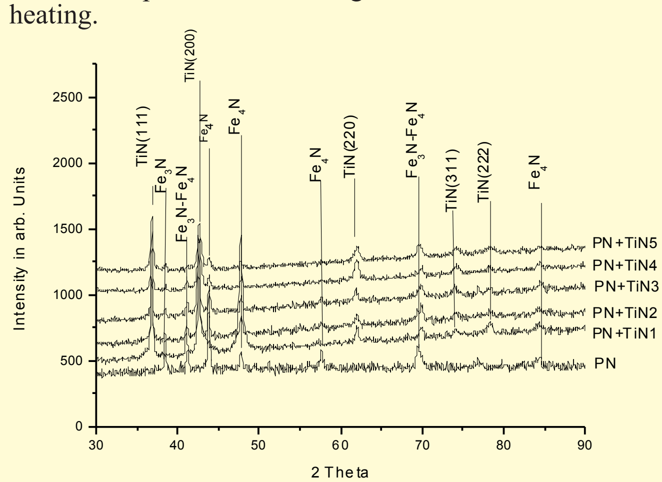


Fig. 6: *XRD-pattern of AISI M2 steel after PN and TiN deposition with different ratios of nitrogen. The iron nitride phases are predominant compared to the TiN phase after plasma nitriding.*

Crystallite size

The average crystallite size of TiN of duplex coated steel at (111) is 24.0 nm. With increasing nitrogen flow rate it increases to 35.0 nm. After plasma nitriding of duplex coated steel the average crystallite size of TiN is 22.5 nm. With increasing nitrogen flow the average crystallite size reduces to 20.0 nm. The reduction in crystallite size results in increase in microhardness. The average crystallite size of TiN is larger in duplex coating compared to the TiN phase formed during TiN deposition.

Conclusion

TiN layers deposited using higher flow rates of nitrogen resulted in thin film thickness due to low deposition rates. The higher coating thickness having rougher surface results in an increase in coating hardness. After plasma nitriding the TiN coated AISI M2 steel substrates, the crystallite size decreases due to nitrogen ion bombardment. The reason for reducing crystallite size can be attributed to defects generated on the surface resulting in increasing number of preferential nucleation sites. With increase in nitrogen flow rate the crystallite size decreases due to nitrogen ion bombardment on thin TiN layers and hence surface hardness increases. For duplex coated steel, the shifts of iron nitride peaks are low due to increase in intensity of iron nitrides and the intensity of TiN peak decreases.

References

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Spacecraft Plasma Interaction eXperiments (SPIX-II)

Dr. Suryakant B Gupta

The recent trend of placing more transponders in a single satellite has led to increased power requirements for Geosynchronous Earth Orbit (GEO) satellites. To fulfil this increased power need, the satellite bus voltage has to be increased beyond the present value of 42 V. Typically for a satellite rated more than 10 kW of power, the required bus voltage is about 100 V. Considering the growing demands of satellites for new applications, this power level is likely to increase further. In any satellite, the solar arrays are the only source of power.

It is known that the interaction of satellite with space plasma creates electrostatic discharges (ESD), or arcing on the solar array surface. This is a serious threat to the spacecraft because it may lead to disruption of entire satellite power. The problem is compounded by the fact that many of the mitigation techniques like grouting which function well in the beginning of the service life of the spacecraft, tend to become questionable at the end of its service life. A further complexity is brought about by the introduction of newer cells and cover glasses by manufacturers. In order to ensure the reliable operation of solar arrays in the orbit, the ground tests of solar arrays in the simulated conditions of space plasma environment is important. A consortium of JAXA (Japanese Space Agency), NASA (National Aeronautics and Space Administration), ONERA, (Office National d'Etudes et Recherches Aérospatiales), ESA (European Space Agency) is developing ISO standards which can provide methods for testing plasma interaction and electrostatic discharge on space solar array panels.

Considering the long term goal of Indian space program, ISRO and FCIPT, IPR envisaged to develop an indigenous ground test facility for Low Earth Orbit (LEO) environment (low energy: T_e= 0.1-10 eV, high density : n ~ 10^5-10^{12} cm^{-3}), and GEO environment (high energy: T_e = 1-10 keV, low density : n ~ 0.1-1cm^{-3}). The proposed test facility will be capable to experimentally simulate the charging processes of a solar array in both orbits. At FCIPT, in the last few years, arcing phenomena on solar arrays has been studied broadly in LEO like environment only. Objective of the present study is to design and develop a test facility which can meet the international standards for LEO and GEO like space environment. The photograph of the experimental reactor is shown in figure 7.

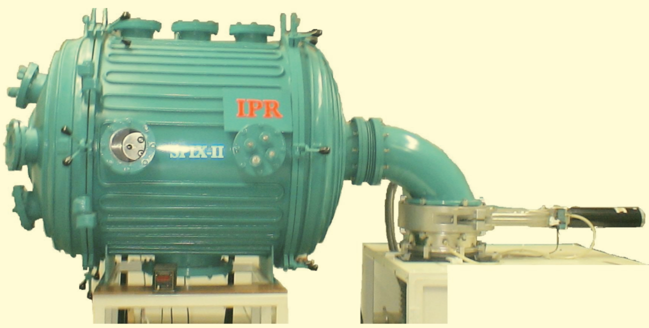

Fig. 7: *Photograph of the SPIX-II experimental reactor*

In order to simulate GEO conditions the solar array will be charged using an energetic electron beam irradiation, in a vacuum chamber which is maintained at an operating pressure lower than $1x10^{-5}$ mbar. The electron energy must be less than 10 keV so that the charging takes place mostly over the surface, and not below it. The vacuum chamber for GEO solar array test will be equipped with an appropriate instrument to determine the charging potential, such as a non-contacting surface potential probe, mounted on a 2-axis device. Whereas in the case of solar array test under LEO conditions, the solar array will be charged by a low energy plasma source (less than 10 eV), in a vacuum chamber at an operating pressure that guarantees the generation of a collision less plasma. The test facility will be equipped with a device that can record adequate images of the test coupon during the test so that ESD locations can be identified. Aim of this activity is to conduct experiments to gain a better physical understanding of ESD phenomena on solar arrays. It is expected that the outcome of this experiment will be helpful in preparing guidelines to choose solar array material, configuration and electrical design of the solar arrays.

Energy Recovery through Plasma Pyrolysis of High-calorific Value Waste

Mr. P. V. Murugan

Introduction

Waste disposal in a safe and economically viable manner has become a challenging task for several decades. Simply disposing the waste in an eco-friendly way is an expensive process, which cannot be afforded for long. The diversity of thermal processes used for waste treatment ranges from the exothermic combustion process through gasification to pyrolysis. The combustion/incineration is characterized by the usage of excess oxygen, thereby emitting waste gases with high organic content. The pyrolysis is an endothermic process with an external power source using no or very little oxygen. Gasification is an in between process that uses much less amount of oxygen.

Energy recovery from waste in the form of electricity or heat can bring down the process cost and can make the technology economically viable. One such technology, which can dispose various types of waste with energy recovery possibilities, is Plasma Pyrolysis/Gasification. In this plasma-based technology, plasma torch is the workhorse of the process and is used for converting the electrical energy into thermal energy in an efficient way.

Status in the world

Different types of waste that have been used for energy recovery using pyrolysis are..

- Municipal Solid Waste
- Low-grade Coal
- Rubber Waste
- Biomass

Around the world, many industries are into research and development of plasma-based technologies for waste disposal and energy recovery. Below, here is an overview of some of the activities of such industries and research institutes.

Municipal Solid Waste (MSW)

Plasma Waste Recycling Incorporation, a United States (US) based company, is working on a process named Plasma Waste Recycling (PWR) Process, which uses high-temperature thermal plasma to convert MSW to syngas, molten metal and vitreous slag without any ash formation. They also claim that emissions from this process are lower than emissions from the combustion of natural gas, and are easily within US Environment Protection Agency (EPA) standards. The products of this process are used very effectively. The syngas produced is used to generate electricity, which is sold to grid, the molten metal is cast as scrap steel and the slag is cast as building material aggregate or spun into mineral wool. The disposal reaction is controlled by the feed rate of the MSW into the reactor. The reaction is continuously monitored by sensing the temperature and composition of the syngas exiting the reactor, and the level of molten metal and slag in the reactor. Because the process involves extremely high temperatures in a sealed vessel under negative pressure, the process is non-combustive and there is no ash residue.

Low-grade Coal

In Korea, B. J. Lee et al. have successfully demonstrated a new Plasma Enhanced Gasifier (PE-IGCC). The salient features of the process are given below:

- Pulverized form of coal is used as the feed.
- Low-grade coal can also be used to generate energy, whereas the conventional gasifier demands high quality, high moisture and low lime content (<12%) coal.
- Microwave plasma torch has been employed in this process, which uses steam as plasma generating gas (Photograph of the torch is shown in figure 8).
- The operating temperature is greater than 3000ºC and the operating pressure is only one atmospheric pressure. This eliminates the requirement of high-pressure vessels as needed in the conventional gasifiers.
- Fast reaction speeds are achievable due to the presence of ionized and/or activated atoms in the thermal plasma.
- Preheating of the reactor is not essential, which saves the power consumption of the process.

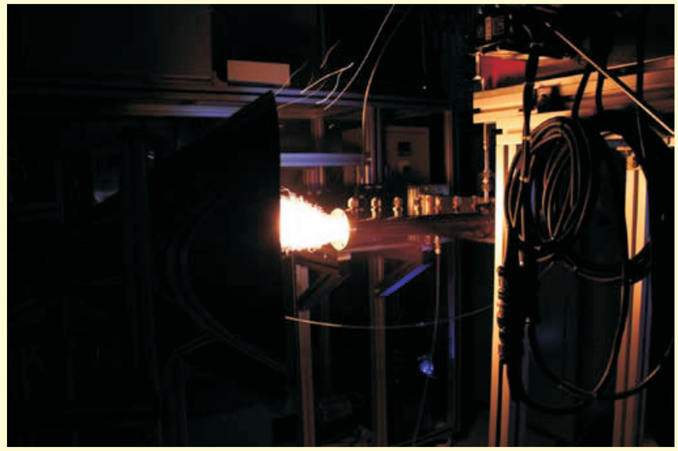

Fig. 8: *Microwave-Steam Plasma torch used for low-grade coal gasification (Courtesy: B. J. Lee's presentation at Indo-Korean Workshop, Bangalore)*

Rubber Waste

Waste tyre (Rubber) pyrolysis involves the thermal degradation in the absence of oxygen. The benefit of this application is the conversion of waste tyres into value-added products such as olefins, chemicals and surface-activated carbon. More than 30 major pyrolysis projects have been proposed, designed, patented, licensed, or built over the past decade, but none have yet been commercially successful. The primary barriers for this application are both economic and technical. The capital cost is high, and the products from pyrolysis do not have sufficient value and must compete with commodity materials. However, it is expected that technological innovations may break through this barrier in the near future. Developments of less costly techniques or processes for higher value added products would enable pyrolysis to become a profitable alternative for waste tyre recycling. Generally pyrolysis is known for low emissions to the environment.

General Process of Tyre Pyrolysis

Chipped tyres are heated to 600 – 800^{O} C in the absence of oxygen. Primary products are pyrolytic gas (pyro-gas) oils and char. The oils and char go through additional processes to manufacture secondary, value-added products. However there are some disadvantages associated with the conventional pyrolysis process and are given below.

- The oil obtained from the process is a mostly high aromatic carcinogenic compound.

- The purification of the high molecular weight substances is expensive, which induces the high process cost.
- Surface activated carbon obtained from the process is a valuable product, but there is no cost advantage compared to the alternative methods of surface carbon manufacturing.

Shortcomings of the conventional pyrolysis process can be overcome with the development of a suitable plasma pyrolysis process, where the ability of achieving high temperatures in the process chamber, with the help of plasma torch can minimize the conversion of waste into high molecular oils and can enhance the further conversion of high molecular substances into low molecular weight gases like CO, H_2, CH_4 etc. These small molecular gases have good market value, as they can be used in the power generation.

Biomass

Pyrolysis and gasification of the biomass have the advantage, over other processes, of producing syngas which makes the process more economical as it is a valuable commodity. Syngas is essentially a clean fuel with almost no ash left and much less toxic compounds, such as dioxins and furans, produced from further treatment after use. However, there are some problems that occur in conventional pyrolysis process, such as low gas productivity and the generation of heavy tarry compounds. These problems can be overcome via the use of thermal plasma pyrolysis, which offers some unique advantages for biomass conversion, such as providing a high temperature and heating rate, in comparison to conventional pyrolysis. Thermal plasma also offers the possibility of the decomposition of biomass by pure pyrolysis in the absence of oxygen. The high energy density and temperature associated with thermal plasmas and the corresponding fast reaction rates provide a potential solution for the problems that occur in conventional pyrolysis processes. The main advantages are a better control of the composition of the produced gas, higher heat capacity of the gas, reduction of unwanted contaminants, such as tar and CO_2, and higher hydrocarbons.

With reference to a study conducted at Department of Environmental Engineering, National I-Lan University, I-Lan 260, Taiwan, Graduate Institute of Environmental Engineering, National Taiwan University, Taipei, by Ching-Yuan Chang et al., the pyrolysis of biomass to produce syngas offers an alternative supply of energy other than fossil fuels. Because syngas contains essentially H_2 and CO, it has the potential for use as a high quality fuel. Moreover, after purification, it becomes an important source of H_2, which is anticipated to be used in fuel-cell technology.

Initiative at FCIPT

FCIPT has already developed a technology to pyrolyze various types of waste including medical waste, using thermal plasma. Plasma pyrolysis systems of 15 kg/hour capacity, have been installed at various places in the country. In one of the projects (funded by CFEES, DRDO) FCIPT has carried out the feasibility study of recovering energy from the pyrolysis of a mixture of plastic (30%) and cotton (70%) wastes. A non-transferred graphite torch was used for pyrolyzing this waste. During the plasma pyrolysis of this waste, the byproducts that we obtained were H_2, CO, and CH_4 (approximately 70% by volume all combined) and the rest comprised of higher hydrocarbons, N_2, CO_2 and soot particles. This gas mixture, after cleaning and filtering, was fed to a generator set which converts the chemical energy available in the gas into mechanical energy first and finally to electrical energy. At FCIPT, we have successfully demonstrated 12 kW power production by connecting the generator set to the plasma pyrolysis system which was pyrolyzing the above mentioned mixture of waste at 12 kg/hr rate. At FCIPT, efforts are being made to recover the energy from various types of organic waste stream by pyrolyzing and converting them into syngas and lower hydrocarbons in an economically viable and environment friendly manner.

Work Carried Out during Summer School Program

The summer school program (SSP), organized by IPR, is meant for final year M.Sc. and B.Tech. students. During this program, the students can learn about plasma and its applications in nuclear fusion and industries. As a part of this program, a few students have carried out their projects at FCIPT, and the work is briefly described below.

Synthesis of Nano ZnO

During the project duration, apart from learning the basics of Nanoscience as well as thermal plasma process of nanomaterial synthesis, experiments were carried out for synthesis of Zinc oxide nanoparticles using a thermal plasma torch. Tungsten rod was used as cathode and Zinc metal pieces were used as anode. The synthesized nanoparticles were characterized for their morphology, crystallinity and composition. Optical properties – namely luminescent properties – of ZnO synthesized at various operating parameters, were also studied.

The XRD, FTIR and EDAX indicated that the synthesized product is zinc oxide (ZnO) of *hcp* structure with no traceable impurities. The Scanning Electron Microscopy (SEM) images showed spherical particles of size ranging from few tens of nanometer to hundred nanometers. The average size was estimated to be ~35 nm. The UV luminescence spectra showed

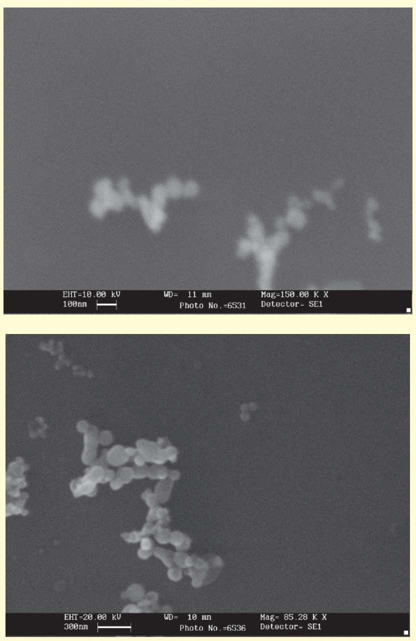

Fig.9: *SEM images of the ZnO nanoparticles*

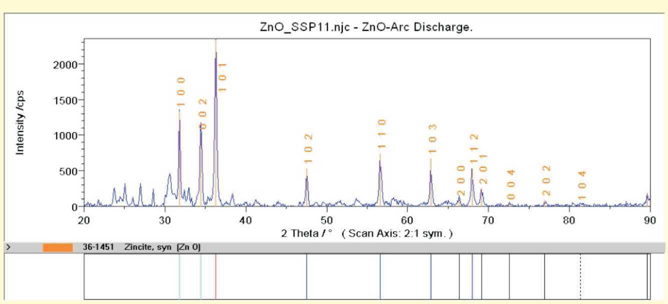

Fig.10: *XRD spectra of ZnO nanoparticles*

Surface Phase Transformation in SS304 due to Surface Preparation Techniques

In order to sustain harsh conditions of wear, tear and corrosion in various applications of stainless steel, diffusion hardening techniques are employed to alter its surface properties. Hence the diffusion of the species into top surface is considered a basic aspect determining the success of it and it must depend on the phase composition and microstructure of the surface. Hence, in this project, the surface phase transformations, in SS304, due to various surface preparation techniques has been investigated.

SS304 samples were prepared with different treatments such as mirror polishing, rough polishing, machining, grinding and electro polishing and combination of electro polishing and mirror polishing. They were then analysed for their surface roughness, the phases contained and microstructure using Stylus profilometer and X-ray diffraction methods.

It was observed from the relative powder XRD characteristic patterns (figure 11) that the amount of martensite formed in mechanically polished samples is more than in electro polished samples. This can be due to the stress-induced transformation happening during the mechanical polishing. Further it was observed that a trace amount of martensite is present even in electro polished samples though the reduction in full width at half maximum (FWHM) with time-span of electro polishing indicates significant removal of surface layers. Figure clearly shows martensite concentrated on the top surface in a machined surface of SS304 sample.

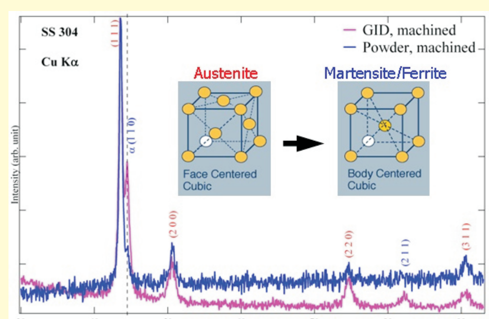

Fig. 11: *Machined SS304 sample in GIXRD and Powder mode*

This project was awarded the best project award (First Prize) in the combined category of Metallurgy and Mechanical Engineering.

OTHER NEWS

M. Tech. dissertation

A project titled "Studies and characterization of low-power plasma torch", was undertaken by Ms. Nasreen Banu – an M. Phil. Student (Physical Sciences) of Kanchi Mamunivar Centre for Post Graduate Studies (Autonomous), Puduchery University. A DC, non-transferred plasma torch was operated at low powers (~ 10 – 12 kW) under various experimental conditions to find stable and unstable operating regimes. Simple calorimetric techniques were used to find out regimes of maximum electro-thermal efficiency. Interesting correlation between efficiency and gas flow, applied external magnetic field, was found. The project was supervised by Dr. G. Ravi.

One more project, titled "A study of Sb:SnO_2 thin film process by co-evaporation of Sn and Sb in RF plasma", was undertaken by Ms. Dhivya Mariasoosai from K.M. Center for Post-graduate studies, Pondicherry University.

In order to study the effect of Sb (Antimony) doping, 'SnO_2 : Sb' thin films have been prepared by co-evaporation of Sn (Tin) and Sb using Plasma Assisted Thermal Evaporation (PATE) in oxygen (O_2) partial pressure at various doping levels from 4 at% to 25 at%. The influences of various Sb doping levels on the compositional, electrical, optical and structural properties have been investigated using various techniques, which have identified the role of Sb content in the film. Best electrical resistivity of 0.5 ohm-cm was obtained for SnO_2 : Sb with 4% Sb content in the films in comparison to optimized SnO_2 film (7 ohm-cm), confirming the usefulness of 'SnO_2 : Sb' (4 at %) films for device applications. The project was supervised by Mr. Chetan Jariwala.

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