PLASMA PROCESSING UPDATE

A newsletter from the

Facilitation Centre for Industrial Plasma Technologies
Institute for Plasma Research

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Contents

Editor's Note

Techniques to produce metal nanoparticles with plasmonic properties have good applications in optics and electro-optics, due to the plasmonic resonant interaction of collective electron oscillation frequency with the incident light frequency. Over the years various techniques have been developed. In a new approach, metallic nanoparticles were grown using PVD methods on rippled patterns. The details are presented in the present issue by Dr. Mukesh Ranjan.

Diagnostics is one of the most important areas in the development of fusion devices. Bolometer is one such diagnostic tool meant for measuring the radiated power during the fusion reactions. An initiative was taken at FCIPT to develop coatings for bolometer applications and the details are discussed by Mr. P. A. Rayjada.

Editor : *Dr. S. Mukherjee*

Co-editor : *A. Satyaprasad*

Conference Presentations from FCIPT

Name of the Author	Topic	Date	Place	Conference
Mr. P. Vadivel Murugan	Plasma Pyrolysis Technology	20-21 January 2011	Lucknow	Awareness cum Training Workshop on Biomedical Waste Management
Dr. S. K. Nema	Plasma pyrolysis of various types of waste, Developments at FCIPT, Inst. For Plasma Research	29th January 2011	IISc - Bangalore	E-Waste Management Workshop
Dr. Mukesh Ranjan	Application of ion induced pattern substrate in plasmonics	6-10 February 2011	Bhubaneswar, India	International Conference on Ion-beam induced Nano-patterning of Materials (IINM-2011)
Dr. S. Mukherjee	Plasma Surface Engineering	7-28 February 2011	Guahati	SERC
Dr. P. M. Raole	Low-Temperature Plasma Processing and Characterization of Materials	17- 18 February 2011	S. P. University, India	International Symposium on Advanced Ceramics, Composites and Nanostructured Materials, ISACCNM-2011
Dr. S. Mukherjee	Development of Probe based Thruster Plume Diagnostic System for LPSC	23 -24 February 2011	LPSC, Bangalore	Invited Talk
Dr. S. Mukherjee	Inertial Electrostatic Confinement Fusion	7-9 March 2011	IPR, Gandhinagar	1st Indo-US workshop on Magnetic Fusion Research
Dr. S. Mukherjee	Plasma Surface Engineering	21st March 2011	NFRI, Daejeon, South Korea	Under Indo-Korean Collaboration Program
Dr. S. K. Nema	Thermal Plasma Technology for Safe Disposal of Infectious Biomedical waste and Energy Recovery from other Organic Waste	21st March 2011	NFRI, Daejeon, South Korea	Under Indo-Korean Collaboration Program
Dr. C. Balasubramanian	Plasma Process and Nanomaterials	1st April 2011	Shah - Schulman Center for Surface Science & Nanotechnolog, Nadiad, Gujarat	Guest Lecture

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*

Ripple Patterned Templates for Making Nanoparticle Arrays and Plasmon Resonance Tuning

Dr. Mukesh Ranjan and Dr. Stefan Facsko

1. Introduction

Metal nanoparticles and nanowires with sizes smaller or comparable to the wavelength of visible light have shown enormous potential for applications in optics and electro-optics. Resonant interaction of collective electron oscillation frequency of metal nanoparticles with incident light frequency is known as Localized Surface Plasmon Resonance (LSPR). It is associated with an enhanced near electric field at resonance frequency, which is localized at the nanoparticle and decays away from the nanoparticle/dielectric interface into the dielectric background. The unique property of LSPR and the accompanied local field enhancement opened new directions of research and has been utilised extensively in various plasmonic and nanophotonic technologies. For instance, surface plasmon polaritons can serve as a basis for building nanoscale photonic circuits in the sub-100 nm size regime [1]. Some of recent applications are plasmonic waveguides [2], plasmonic switching [3], near field applications such as SNOM [4], metamaterials [5], photovoltaic cells [6], and, single molecule [7], proteins and cancer tissue [8] detection by Surface Enhanced Raman Scattering (SERS).

Form a technological point of view the application of metal nanoparticles with plasmonic properties demands a fully controlled growth process. Currently available approaches to grow ordered particles can be divided in two categories, viz. top-down (lithographic methods) and bottom-up (self-assembling methods) mechanism. Lithographic methods for making nanoparticle arrays with inter-particle gap as small as 20 nm have a current limitation due to proximity effects. However, effects resulting from the local field enhancement are prominent for dimensions smaller than this. The plasmonic field coupling decays exponentially with inter-particle distance. Below 25 nm the coupling increases drastically and consequently a large plasmon resonant shift arises. The above mentioned examples are usually for lithographically produced particles, where the particle size is of the order of 100 nm, with a large inter-particle gap (~minimum 70 nm). Another serious drawback of electron beam lithography is the serial writing with small area coverage and thus a time consuming process. Self-assemble and self-organisation methods have been successfully demonstrated for instance by using faceted alumina, anodized alumina, or block co-polymers as templates. Several chemical methods have also been presented with limited success. There are various disadvantages in these approaches, such as very little control on nanoparticle size, inter-particle gap, array periodicity, and ordering. Therefore all these methods are lacking tunability of the optical properties of the metal nanoparticle film.

A new approach has been developed, recently, by Dr. Mukesh Ranjan (FCIPT/IPR, India) during his scientific collaboration with Dr. Stefan Facsko (HZDR, Dresden, Germany). In this approach ripple patterns induced by ion irradiation are used as templates followed by oblique incidence physical vapour deposition (PVD) to grow highly ordered nanoparticles and nanowires [9-12]. Knowledge base to produce rippled templates of different periodicity on a variety of substrate materials is already available. The scaling laws to tune the ripple periodicity from 20 nm to several µm have been investigated in detail for silicon (Si). Therefore this approach seems to be very promising to develop highly ordered nanoparticles and nanowires for plasmonic applications.

Ranjan et al. showed that ordered nanoparticles on such a ripple pattern substrate are optically anisotropic, i.e. different LSPR are observed along and across the ripples [9-12]. Later they investigated that this anisotropy is bi-axial in nature having different dielectric coefficients along x, y and z axes [11]. Silver nanowires grown on such pattern templates can have either metal or insulating type dielectric coefficients depending on the wire width [12]. High transmission is observed when the polarisation of the incident light is parallel to the nanowires whereas it is strongly reduced when the polarisation is perpendicular to the wires due to the localised plasmon resonance.

In the present article, it is demonstrated that low energy ion irradiation can produce ripple templates with periodicities down to 20 nm. By changing the ripple wavelength the LSPR can be tuned. With the present approach, the self-assembled nanoparticles with much shorter inter-particle gap (~ 5 nm) can be produced and can be aligned along the ripple length. Ripple pattern of narrow wavelength in the range of 20 nm to 50 nm were chosen as templates for the deposition, since field enhance effects are prominent in this dimension. Therefore, in this section only those ion energy scaling for ripple formation are shown which fulfil the above requirement.

2. Experimental

The periodic ripple templates are produced by ion beam irradiation from a Kaufman type ion source with 500 eV Argon ions (Ar^+) on Si (100) substrate at an angle of 67° with respect to the surface normal. The initial root mean square (rms) roughness of the Si surface is below 0.1 nm. The Si sample is maintained at a constant temperature of 15° C and at a working pressure of $2x10^{-4}$ mbar during Ar irradiation. At low fluence (~ 10^{16} cm^{-2}) shallow ripples appear. With the increasing fluence the ripple pattern grow and wavelength coarsening is observed resulting in increasing ripple wavelength with fluence. The wavelength can be tuned from 20 nm to around 45 nm at 500 eV ion energy by simply varying the fluence in the range from 10^{16} to 10^{19} cm^{-2}. The modulation (minimum to maximum) is roughly 2 nm for these ripple patterns produced by low energy ions.

The deposition of the Silver (Ag) atoms, on the patterned Si substrate, was carried out through a PVD technique using an e-beam evaporator. The ordering of the Ag nanoparticles depends critically on the angle of incidence and the direction of silver atoms with respect to the ripples, deposition rate and time, and substrate temperature [10]. At optimal conditions when the Ag atoms are deposited at grazing incidence and normal to the ripple orientation the nanoparticles self-align along the ripples. Their shape and size can be tuned by varying the growth parameters.

3. Results and Discussion

3.1 Surface characterization

AFM images of ripple patterns – prepared on Si (100) surfaces – with periodicity of 22, 28, 35, 41, 44 and 51 nm, respectively, along with their rms roughness values are shown in Fig. 1. The rms roughness increases with ripple periodicity. Ripples with periodicity in the range of 30-35 nm are found to be superior in terms of ordering compared to 20 nm (slightly disconnected ripples) and 45-50 nm (slight inhomogeneous) periodic ripple patterns. A higher lateral ordering of the 28 nm and 35 nm ripple patterns is reflected by a second order peak appearing in the Fast Fourier Transform (FFT) (inset of Fig. 1). Therefore in most of our experiments ripple patterns with a periodicity around 35 nm were use as a template. The quality of the ripple pattern directly affects the self-alignment of the nanoparticles.

During ion irradiation the Si surface is amorphized, gets oxidized, and a ~2-3 nm thick SiO2 layer is formed immediately after its exposure to atmosphere. Oxide layer formation is a favourable condition for both silver and other metal cluster formation due to larger surface free energy

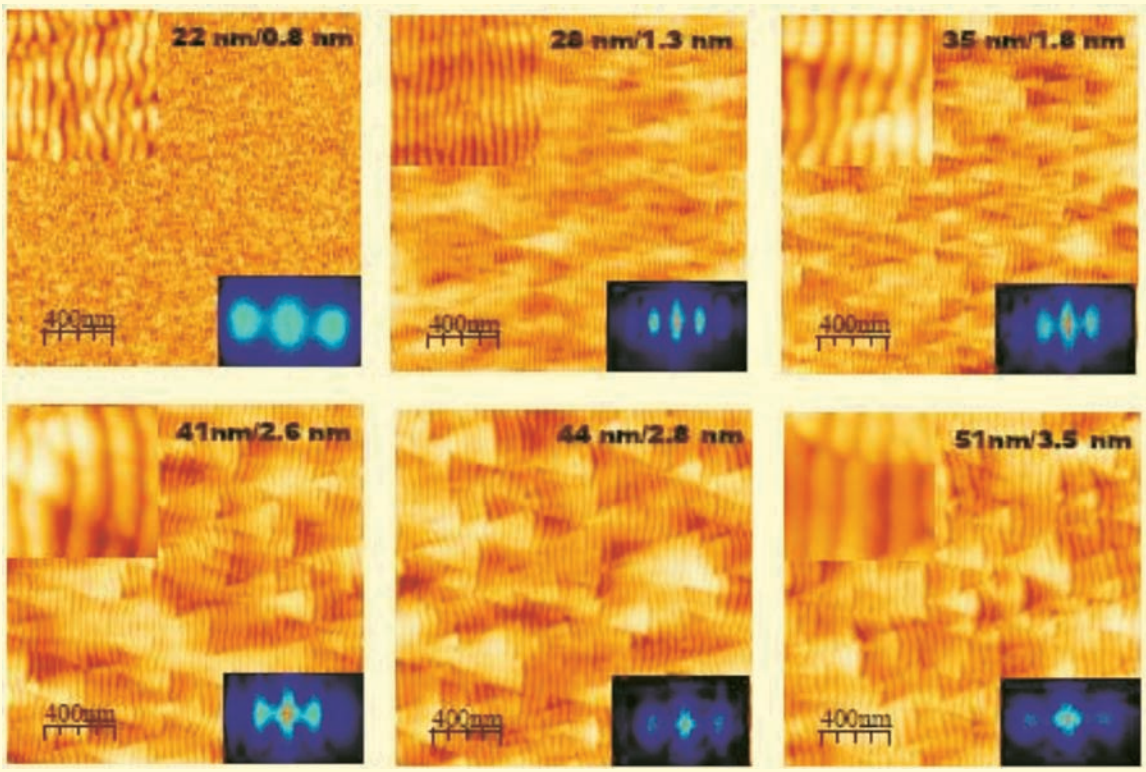

Fig. 1: *AFM images of ripple patterns with different periodicity produced by 500 eV Ar^+ ion irradiation at 67° incidence on Si substrate with fluences of 10^{16-19} cm^{-2}. The corresponding wavelength and roughness (rms) values are mentioned on each image. Zoomed portion and FFT shown in inset reflect the quality of ripples.*

difference and prevention of silicide formation. The length of ripple ridge varies for ripples of different wavelength. Hence nanoparticles of very small to larger sizes (< ridge size) can be aligned on rippled surface.

SEM images of silver nanoparticles grown on non-patterned and ripple patterned Si substrates are shown in Fig. 2(a) and Fig. 2(b), respectively. On non-patterned, flat substrates nanoparticles grow in a random order, whereas on rippled surfaces they align along the ripples. In the case of deposition at root temperature on flat and rippled substrate the nanoparticles are non-spherical. In addition, on the pre-patterned substrate they are randomly elongated along the ripple ridge portion (Fig. 2(b)). To perfectly align the nanoparticles along the ripple, annealing at moderate temperature of 300° C was performed. After annealing for 60 minutes the Ag nanoparticles attain their thermodynamically favoured spherical shape (Fig. 2(c)). Therefore small and bigger particles sitting in closer proximity along the ripple perform Ostwald ripening during the annealing process. So smaller particles vanish and bigger particles grow. In this way simply by changing the wavelength of the ripple pattern nanoparticles arrays of different wavelength can be obtained. In addition, by changing annealing time and temperature the inter particle gap can be tuned along the ripple. In this way nanoparticle arrays of 20, 30, 35 and 45 nm periodicity were prepared for optical measurements.

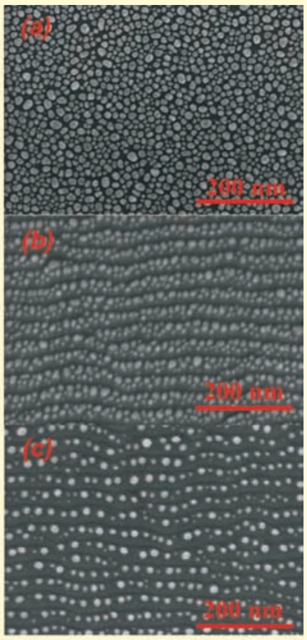

Fig. 2: *SEM images of Ag nanoparticles grown (a) on a flat Si substrate at room temperature, (b) on a ripple patterned substrate at room temperature; and (c) on a ripple patterned substrate followed by annealing at 300° C for 60 minutes.*

3.2 Plasmon Resonance Tuning

Optical reflection measurements in the spectral range of 300 nm to 700 nm were performed for both non-ordered and ordered nanoparticles by using linearly polarized light along and across the ripples at near normal incidence. In the case of non-ordered nanoparticles the plasmon resonance occurs at the same wavelength (Fig. 3(a)) for both polarisations, i.e. no direction dependent change in the LSPR is observed. Although the particles are close enough and their near field couples, the coupling is isotropic. The anisotropy due to the single particle shape is a minor effect and is averaged out for several particles in a far field measurement like reflection. In the case of ordered particles, however, a large red shift of the plasmon resonance appears for the excitation across the ripples, indicating a strong optical anisotropy (Fig. 3(b)). The reason for this anisotropy is attributed to different near field plasmonic coupling along and perpendicular to the ripple direction. Along the ripples particles are closely aligned at ~10 nm inter particle distance, while parallel to ripples they are separated by the ripple wavelength of ~35 nm.

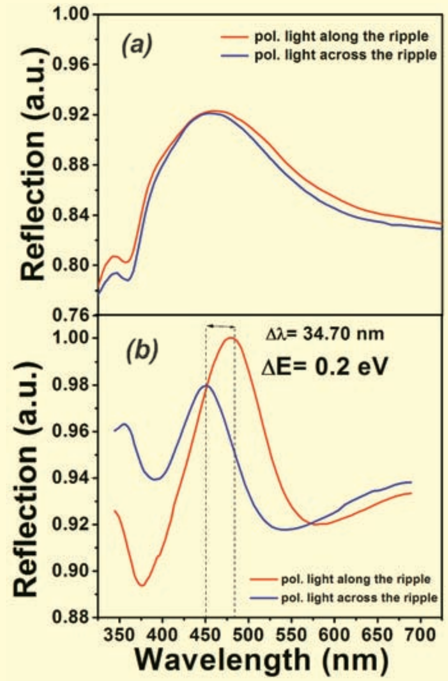

Fig. 3: *Reflection of light polarized along and across the ripple direction showing LSPR (a) of non-ordered particles on a flat Si surface shown in Fig. 2(a); and (b) of ordered particles shown in Fig. 2(c).*

Further, by comparing the figures 3(a) and 3(b) the following observations can be made. Particles of random shape and size show a broader distribution of the plasmon resonance, while annealed spherical particles produce a much sharper distribution. It can be concluded that the annealing process leads to a smaller size distribution of the aligned particles with a sharper plasmon resonance distribution.

The LSPR of nanoparticle arrays produced in the described way can be tuned over a wide range by changing the ripple pattern templates and the deposition parameters. It was mentioned previously that by varying the irradiation parameters, ripple patterns of different periodicities can be produced. On the other hand by varying the silver growth parameters, particles of different shape and aspect ratio can be produced along the ripples. These two factors provide a high flexibility to tune the plasmon resonance. An example of tuning the LSPR using self-aligned nanoparticles on pre-patterned ripple surface is shown in Fig. 4. Aligned particle chains of 20 nm, 30 nm, 35 nm, and 45 nm periodicities, were prepared for this purpose (SEM images not shown). Along the perpendicular direction to the ripples the inter particle distance is changing with the ripple periodicity. Therefore a blue shift from 446 nm (20 nm array) to 384 (45 nm array) in the LSPR position is observed (Fig. 4) due to the reduced inter particle distance. In this way LSPR can be tuned simply by changing the ripple wavelength.

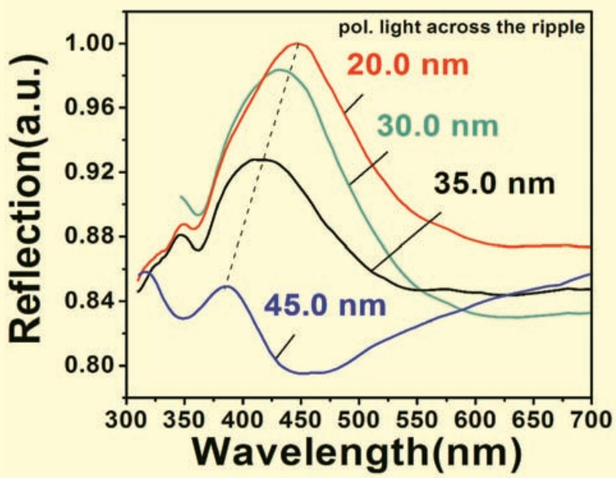

Fig. 4: *Reflection of light polarized across the ripples showing a LSPR which is red shifted with decreasing ripple wavelength from 45 nm to 20 nm.*

4. Conclusion

Ripple patterns produced by low energy ion irradiation are suitable templates for producing nanoparticle arrays with a high range of periodicities. With ion energy and fluence the wavelength of the ripple pattern can be tailored at the nanoscale. PVD growth of silver performed at optimised parameters leads to self-assembled nanoparticle arrays. Interparticle gap can be tuned by changing the annealing time and temperature. Such ordered nanoparticles are optically anisotropic due to different plasmonic field coupling along and across the ripples. LSPR can be tuned by changing the ripple period. Such templates can be explored to investigate the near field effects at much lower dimensions and can be explored to utilise as SERS based sensor.

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Development of Al-C Bi-layer Coatings on IR-transparent Substrates for Bolometer Applications in Fusion Devices

Mr. P. A. Rayjada

Introduction:

Detecting and monitoring various phenomena taking place in fusion plasma inside the magnetic fusion device using appropriate diagnostic techniques is vital for the realization of the fusion energy reactor. Moreover, the attention towards improvisation of such techniques is very high as the fusion experiments move towards longer time-scales, more intense neutron and gamma radiation and much bigger size. Measuring the total radiated power in such environment becomes challenging. Conventionally Bolometer with foil detector array providing electric signals has been used world over for this purpose. Bolometers are thermal infrared sensors that absorb electromagnetic radiation and thus increase their temperature. The resulting temperature increase is a function of the radiant energy striking the bolometer and is measured with e.g. the thermoelectric, pyroelectric, resistive or other temperature sensing principles. The signals are normally differentiated to get power from the time-integrated heat load on the foil and substructures. The major challenge is of making fast, robust, reliable, compact bolometers, responsive over the expected range in incident energies, convenient to calibrate, and economically viable for large number of channels for good spatial resolution using tomographic techniques.

Later on, Infrared based bolometers are developed using latest technology, which allows a high degree of radiation hardening, no wirings inside the vessel, low noise pick-up, compatibility with long-pulse operation and real-time response, and large number of channels to form a bolometric image. Such bolometers use segmented foil created by sandwiching a thin metal foil between heat sink plates suitably drilled to form pixel pattern into it (Fig. 1). As a result of plasma radiation falling on the metal foil pixel, its temperature will rise and will start radiating in IR range. The IR signal generated by each such pixel on the other side, is transmitted through proper IR transparent window and high resolution IR camera kept at safe distance from the vessel captures them to make a radiated power profile image. In order to improve the sensitivity, the foil has to be as thin as possible, made from a material with low thermal conductivity. Further improvement of sensitivity is realized by coating the back side of the foil with carbon paint to improve its IR emissivity. Moreover the choice of the foil material also depends on its opacity thickness for the expected energy of the plasma radiations. Low neutron-induced activity is emerging as yet other important criteria for the choice of material for the future devices. The masking plates are made of high thermal conductivity material as they need to act as heat sink to protect the foil from melting and also to avoid lateral heat flow spilling signal onto adjacent pixels. The temperature-map given by the IR camera along with the appropriate boundary conditions are used to estimate the flux falling on the foil by solving the heat conduction equation. This concept is already explored extensively on JT-60U and several other machines.

We have initiated some R & D in order to further simplify such IR imaging bolometer design. We work on developing bi-layer coating on IR-transparent substrate. Preliminery experiments are carried out on glass and CaF_2 substrates with high emissivity carbon and Aluminum bi-layer coatings. Though

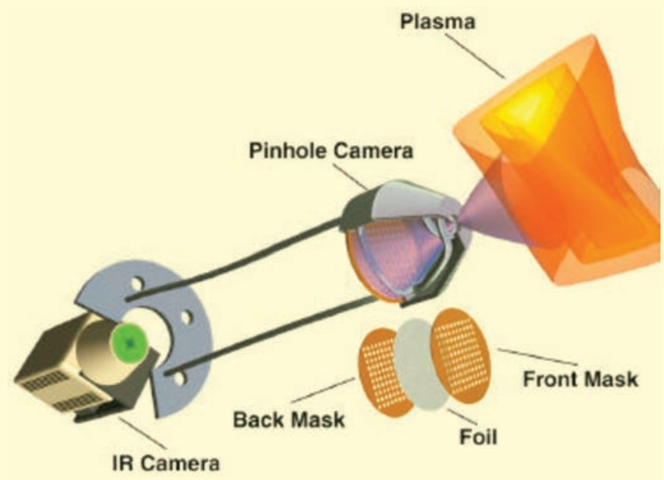

Fig. 1: *Schematic picture of thin foil IR imaging bolometer (Reproduced from Ref. 1)*

this arrangement may reduce the sensitivity to some extend due to physical contact of thick substrate with the sensor metal-carbon coating, it is crucially advantageous in space-saving and stability. On the other hand, latest high resolution IR-camera are increasingly sensitive to even minute temperature rise of the target and hence can come handy to cop with the reduced sensitivity.

We develop Aluminum-Carbon bilayer on glass as well as on CaF_2 using DC magnetron sputtering of Al and graphite cathodes (targets) by Argon plasma. Carbon film adhesion to glass is generally difficult especially with physical vapour deposition techniques, but the combination of glassy substrate with carbon film is vital for IR sensing applications. PVD carbon film is amorphous (a-C) in nature and peels off glass surface due to internal stresses and week bonding with the substrate. Our a-C film is extremely sensitive to process parameters. It has been observed as optically transparent or opaque, instantaneously peeling-off or stable for months, depending on the process parameters. Optically opaque and stable a-C film on glass and stress free, crystalline, stable Al layer over a-C film are developed using a narrow window of process. Characterization results using X-Ray Diffraction (XRD) and Scanning Electron Microscopy (SEM) are also presented.

Experimental :

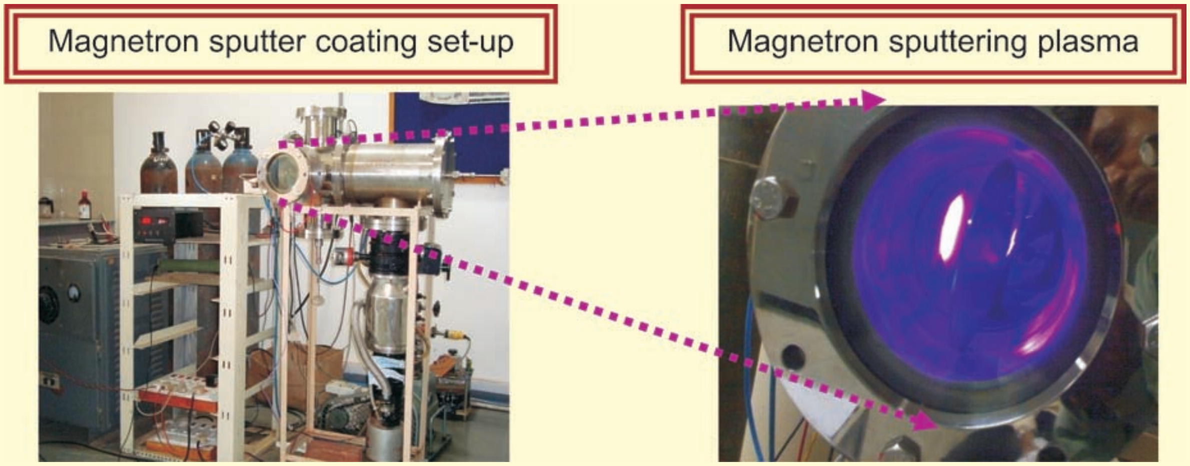

Fig. 2: *Experimental set-up showing plasma during sputtering process.*

Figure-2 shows the experimental set-up used to carry out the sputter depositions. Also shown is the view of plasma during a typical sputtering experiment. The substrate after thorough cleaning procedure is mounted inside it, facing the magnetron target at a distance of ~10 cm. The system uses Liquid N_2 trap along with oil-diffusion and rotary pump combination to get $1x10^{-6}$ mbar base vacuum. Subsequently, 99.9% pure Ar is purged through precise mass flow controller to increase the pressure to the order of $\sim10^{-3}$ mbar. At sufficient –ve voltage applied to the target with respect to the chamber, breakdown occurs and sputtering of the target by the Ar ions takes place. Typical operating voltage range for graphite and Al targets is 700-1000 V, where as current range is 450-1000 mA.

Results and Discussion:

The carbon coating is found to be extremely unstable upon exposure to atmosphere and starts peeling-off immediately after removal from the system. Hence, various attempts, such as roughening of the substrate, RF plasma etching of the substrate were made to improve its stability. Roughened substrates clearly showed long lasting stability without any other precautions. On the other hand, RF etching did improve the stability but it also started peeling off after a few days. However, this little improvement in the carbon film stability over mirror finished substrate is significant as it gives time to change it from carbon coating to Al coating mode. Interestingly, when such carbon films are immediately subjected to Al coating over it, the bi-layer as a whole becomes extremely stable. Fig 3 shows photographs of carbon coated and bi-layer coated glass slide.

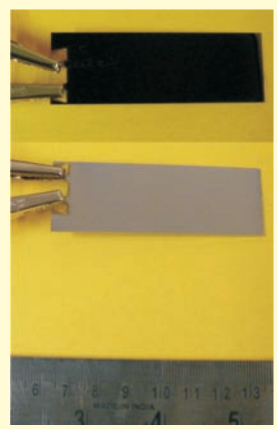

Fig. 3: *Perfectly optically opaque and uniform carbon coating (top) and over that shining aluminum coating (bottom).*

The analysis of black, visibly opaque, carbon film revealed that it is ~ 600-800 nm uniformly thick densely packed and amorphous film having emissivity greater than 0.95, which is ideal for the required application. The shining silver and visibly opaque Aluminum over layer is achieved in the thickness range of ~ 700 - 1800 nm, with cubic crystal structure. Fig. 4 and 5 shows the crystalline Aluminum and amorphous carbon XRD patterns and the SEM micrographs of an Al-C bi-layer coating respectively.

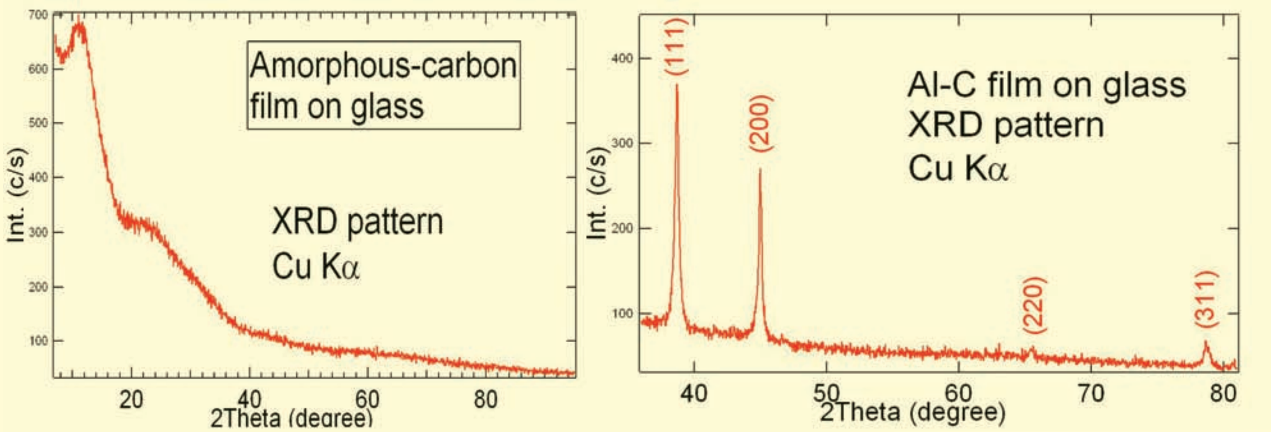

Fig. 4: *XRD patterns of Aluminum (left) on bi-layer and amorphous carbon film (right)*

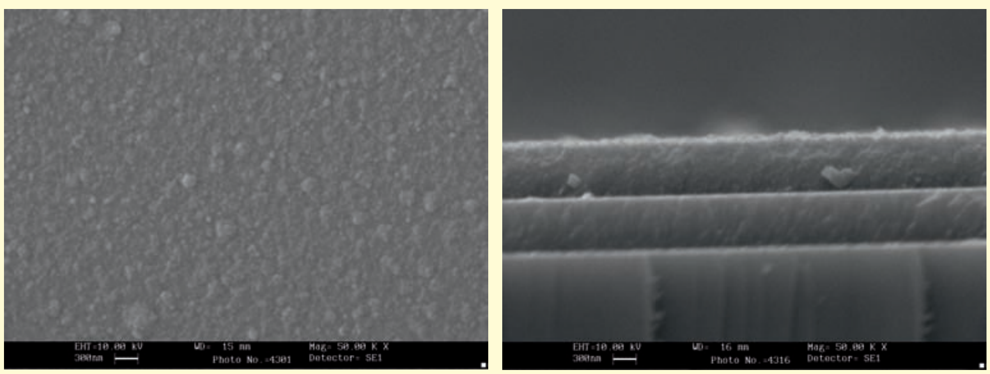

Fig. 5: *SEM micrograph of the surface and cross section of the bi-layer.*

Conclusions:

Amorphous carbon (a-C) PVD film with high opacity and stability on glass and CaF_2 substrate has been developed. A stress minimized, stable, reflective and shining cubic crystalline Al film is successfully coated over the a-C layer. The bilayer is tested for stability over exposure to atmosphere for more than 300 days and has shown no sign of deterioration.

Acknowledgement:

Apart from the author, Pratik Nayak, Santosh Pandya, N. L. Chauhan, N. P. Vaghela, Shwetang Pandya, J. Govindrajan and P. M. Raole have been the other active contributors to this work.

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OTHER NEWS

MoU with m/s Excel Industries

Phosphoric acid, in the presence of carbon (reducing agent), reduces into phosphorus and syngas at a temperature of around 900° C. Phosphorus is highly reactive with oxygen, and it converts into Phosphorus pent-oxide when it comes in contact with oxygen. Hence, recovery of Phosphorus from phosphoric acid not only needs high temperature, but reducing (oxygen starved) environment as well. Therefore, Plasma Pyrolysis seems to the suitable technology to provide the necessary conditions for the reduction reactions of phosphoric acid into phosphorus. In this regard a MoU was signed with m/s Excel Industries, Mumbai; for conducting feasibility study experiments to recover phosphorous from phosphoric acid using plasma pyrolysis technology, and also to see the possibility of recovering energy from the associated reactions.

Installation of a Plasma Pyrolysis system at Doon Hospital, Dehradun

A Plasma Pyrolysis System was installed and commissioned at Doon Hospital, Dehradun, in January 2011. The fabrication and installation of the system was carried out by M/s Bhagwati Pyrotech Pvt. Ltd. Along with FCIPT, IPR. This system is meant for disposing bio-medical waste and has a waste disposal capacity of 20 kg/hour. The photograph of the actual installed system is shown in figure below.

Photograph of the Plasma Pyrolysis system that was installed at Doon hospital, Dehradun

Installation of Twin Magnetron System at IIT – Kharagpur

FCIPT has designed and developed a twin-magnetron sputtering system, in which two different target materials could be simultaneously sputter deposited, and the electrical power to each of these targets could be controlled independently. This system could be used for depositing alloy coatings, multilayer coatings, and to carry out fundamental experiments in this area. The photograph of the system is shown below. It has been developed for IIT-Kharagpur, and has been successfully installed and commissioned in March 2011.

Photograph of the Twin-Magnetron System that was installed at IIT-Kharagpur

Installation of a Pulsed glow discharge plasma facility at Delhi University, Delhi

FCIPT, IPR has taken an initiative to promote the awareness of plasma science among Indian student community. Under this activity FCIPT has developed and successfully commissioned a pulsed glow discharge plasma facility at Department of Physics and Astrophysics of Delhi University, Delhi. The proposed facility will be used by the M. Tech and Ph.D. students of that region. This system has been designed in such a way that apart from performing basic plasma physics experiments, it can also be used for conducting surface plasma interaction experiments.

This experimental setup will encourage students to understand the applications of plasma technology in modification of surface properties (hardness, corrosion resistance) of metals (steel etc.) and dielectric properties of semiconductor material. There is a provision to tune and diagnose plasma parameters using Langmuir probe, spectrometer etc. From the student point of view, this system is user friendly and additional safety features with necessary interlocks are also provided. The photograph of the commissioned system is shown below.

Photograph of the Pulsed glow discharge plasma System

M. Tech. dissertation

An M.Tech. dissertation work was carried out by a student of mechanical engineering in partial fulfilment for the degree of Masters of Engineering. In the work titled “Development of a parametric finite element model of a plasma torch for simulation of thermal-fluid analysis with ANSYS”, a simplified parametric three-dimensional, steady state model of a plasma torch was developed using finite element techniques. The model consists of two parts, one involves full solid modeling using CATIA software and the other involves simplified modeling of key parts of the torch using FEM software ANSYS. The FEM model is parametric, viz. changes in geometry and dimensions of torch components such as anode, cathode, water cooling channels etc. and material properties and their effects can be taken into account just by changing an input file. The methodology consists of two main elements (i) CFD analysis, where temperature on the anode boundary is calculated using fluid analysis tool of ANSYS – FLOTRAN and (ii) Thermal analysis, where heat transfer between plasma gas, device walls and cooling channels is calculated using heat transfer analysis of ANSYS. Parametric approach enables easy model modifications and minimal file space requirements, make the program more user-friendly and can help reduce design cycle time scales for future designs of plasma torches. Design of a low power plasma torch operational at FCIPT was chosen for the above analysis. The model is able to predict some key operating conditions for which the torch runs successfully.

Ph.D. Thesis Submission

A Ph.D. Thesis was submitted to Devi Ahilya Viswavidyalaya, Indore on “Plasma Assisted Physical Vapor Deposition of Nano-structured Coatings”, by K. Kishorkumar under the guidance of Dr. S. Mukherjee; in the month of February 2011.

Facilitation Centre for Industrial Plasma Technologies

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