Facilitation Centre for Industrial Plasma Technologies
Institute for Plasma Research

Plasma Processing Update

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Inside this Issue

Foreword by Editor

Welcome back! It has been a while since the last issue of Plasma Processing Update was published. While it is true that the Covid-19 pandemic has played havoc with the lives and robbed the livelihood of many, it could not break the human spirit. And scientists have revived an activity that they do best, research and development. New discoveries, new technologies, new systems, all for the benefit of society at large. This edition brings some exciting news on how water droplets become bouncing balls on super hydrophobic Teflon surfaces produced by ion irradiation, a plasma patterning system for water condensation experiments developed for Amity University by our colleagues; and a brief story of the ongoing plasma torch program at IPR. We also share some moments that were captured, at FCIPT, during the visit of Joint Secretary, R&D, DAE. We promise to keep bringing to you more exciting news on research, technology and plasma systems developed by IPR, more frequently. Keep reading!

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Highlights

- Plasma patterning system for water condensation experiments
- BRNS collaborative project - installed at Amity University, Noida
- Surface modification of substrates, superhydrophobicity

Team members

- Sooraj K.P.
- Vivek Pachchigar
- Mukesh Ranjan

System Focus :

Plasma patterning system developed under BRNS project for water condensation experiments at Amity University

A BRNS collaborative project has been carried out between IPR and Amity University, Noida; to develop a plasma based system for carrying out water condensation experiments from moist air using plasma patterned surfaces. Under this project, a high vacuum system with magnetron gun which can be pumped below 5.5×10^{-6} mbar pressure with the help of diffusion pump is developed and the image of the system is shown figure 1. This system will be used for producing super hydrophobic surfaces by bombardment of ions from DC discharge plasma. In this method, magnetron target acts as anode and sample holder is the cathode. Once the plasma is produced, the ions are accelerated towards the sample holder and strike the sample on its surface and sputter out atoms to produce nanopatterns/nanostrutures. These nanostructures increase the hydrophobicity of the surface and depending on the plasma parameters, superhydrophibic surfaces will be formed. Since super hydrophobic surfaces help water droplets roll freely and enhance the efficiency of water collection, they can be effectively used in water condensation applications.

The developed plasma patterning system has been installed at Amity University, Noida; and the testing and demonstration has been successfully carried out. The experiments for water condensation are in progress. Image of plasma treatment of sample, water droplet on super hydrophobic surface and water condensation on a prepared substrate are shown in figures 1(b), 1 (c), and 1(d) respectively.

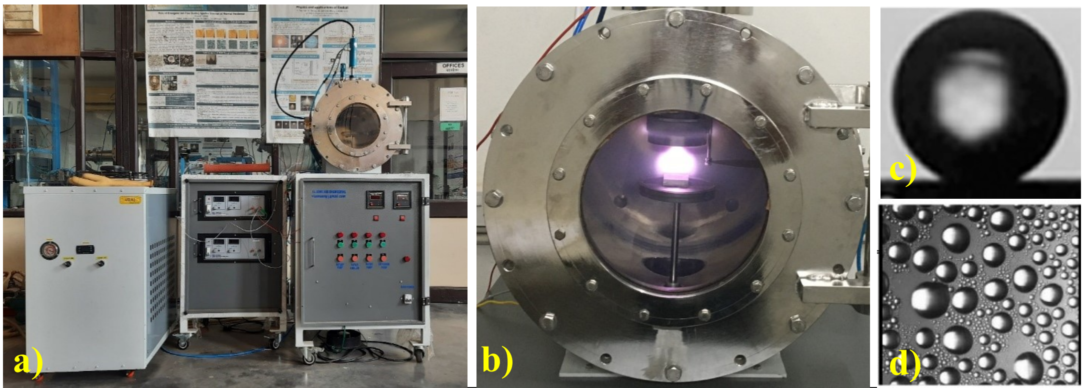
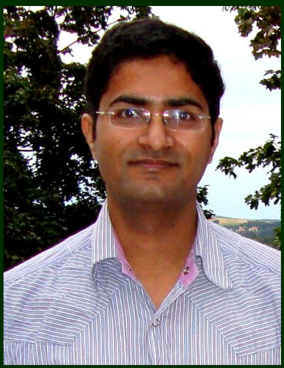


Figure 1: **(a)** Developed system, **(b)** plasma treatment of sample, **(c)** water droplet on plasma treated substrate and **(d)** water droplet condensation.



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Highlights

- Superhydrophobic PTFE surface for self-cleaning application
- Water droplets as bouncing balls
- Nanostructure formation after ion beam irradiation

Team members

- Vivek Pachchigar
- Sooraj K. P.

Research Focus :

Self-cleaning and bouncing behaviour of ion irradiation produced nanostructured superhydrophobic PTFE surfaces

In the present work, bouncing dynamics of impacting water droplet on low energy ion beam produced superhydrophobic PTFE surfaces was investigated for the self-cleaning applications. Ion beam with 300 eV and 800 eV energies was used for producing nanostructures on PTFE surfaces having the bouncing behaviour (Fig. 1).

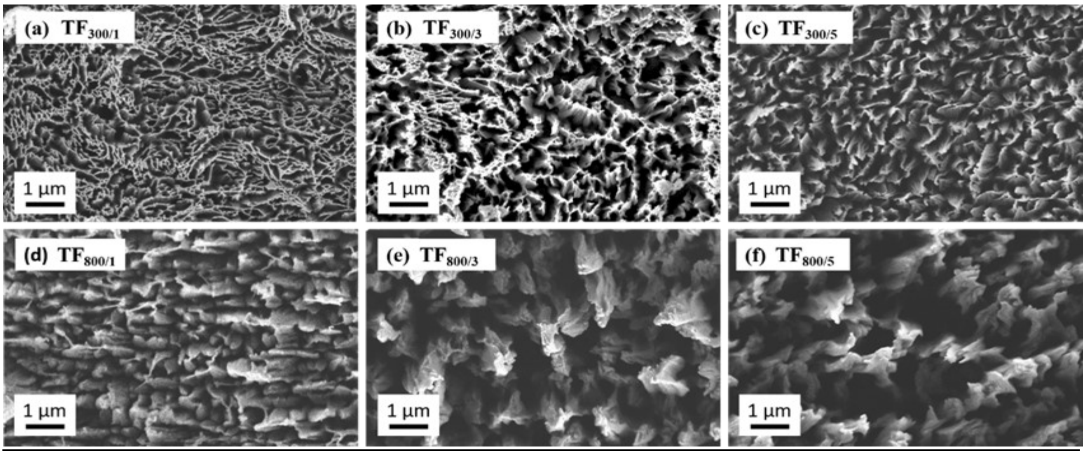

Figure 1: Surface morphology of ion beam irradiated PTFE surfaces at E_B = 300 eV ((a)-(c)) and E_B = 800 eV ((d)-(f)). Irradiation time (t_{ir}) = 1 min ((a), (d)); 3 min ((b), (e)) and 5 min ((c), (f)).

The irradiated PTFE surface became superhydrophobic with water contact angle of 156° just after few minutes of irradiation. The bouncing dynamics of water droplet was studied using high speed CCD camera and dynamic parameters like spreading factor (β), contact time (t_c), time of flight (t_a) and number of bounces were measured. The maximum spreading factor for the water droplet impact velocity of 0.5 m s^{-1} and 1.0 m s^{-1} was found to be 1.4 and 2.0, respectively for both 300 eV and 800 eV irradiated surfaces. The contact time of impacted droplet on 800 eV irradiated surface with 0.5 m s^{-1} velocity was found to be much lower (t_c=13.00 ms) than that of 300 eV ion irradiated surface (t_c=19.67 ms) (Fig. 2).

Figure 2(d) shows the temporal variation in β during impact on 800 eV irradiated PTFE surfaces at different irradiation time. Post impact bouncing number as high as 14 was found for 800 eV irradiated surface. Depending on ion energy and irradiation time the surface was converted from completely wetting to completely bouncing at low impact velocity of 0.5 m s^{-1}; and from completely bouncing to partially bouncing at 1.0 m s^{-1}.

The self-cleaning property on 800 eV irradiated surface was successfully demonstrated using carbon powder. When water droplet is impacting on pristine surface, it just mixes with the powder and stays on the surface (Fig. 3) without cleaning it. On the other hand, when water drop impacts on $TF_{800/5}$ surface, it rolls off from the surface with powder.

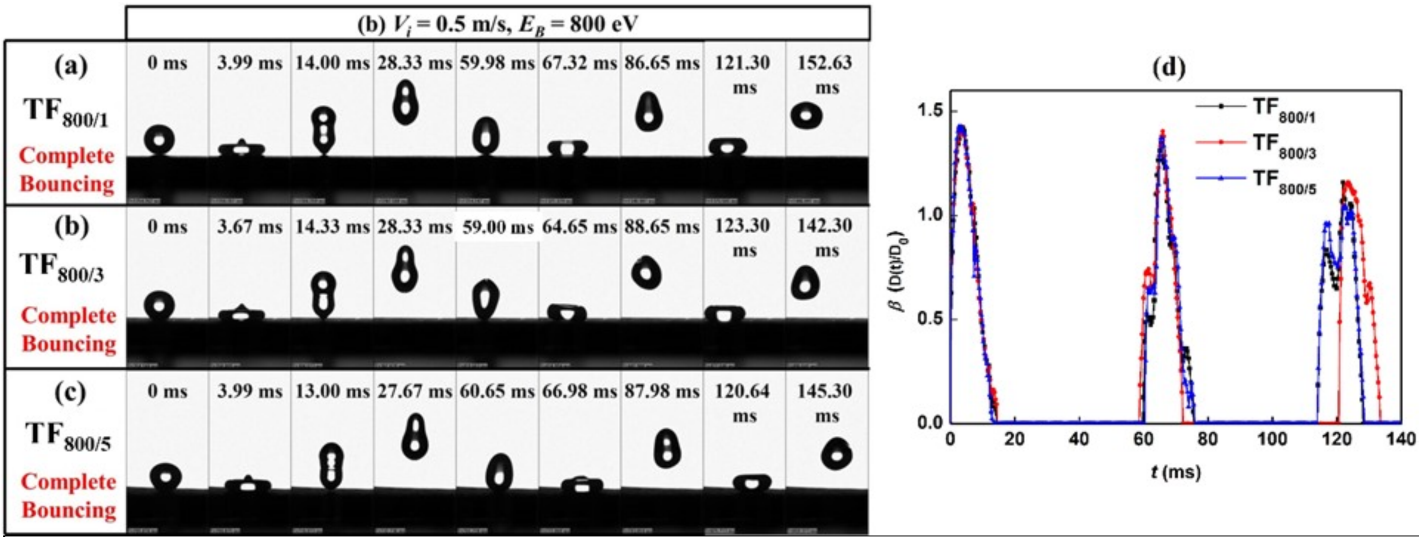

Figure 2: Sequences of water droplet impacting on 800 eV irradiated PTFE surfaces at V_0 = 0.5 m s^{-1}. The irradiation time varies as (a) t_{ir} = 1 min, (b) t_{ir} = 3 min and (c) t_{ir} = 5 min.

References:

[1] V. Pachchigar et. al., *Scientific Reports,* (2019), 9:8675

[2] V. Pachchigar et. al, *Surface and Coatings Technology,* (2021), 420, 127331

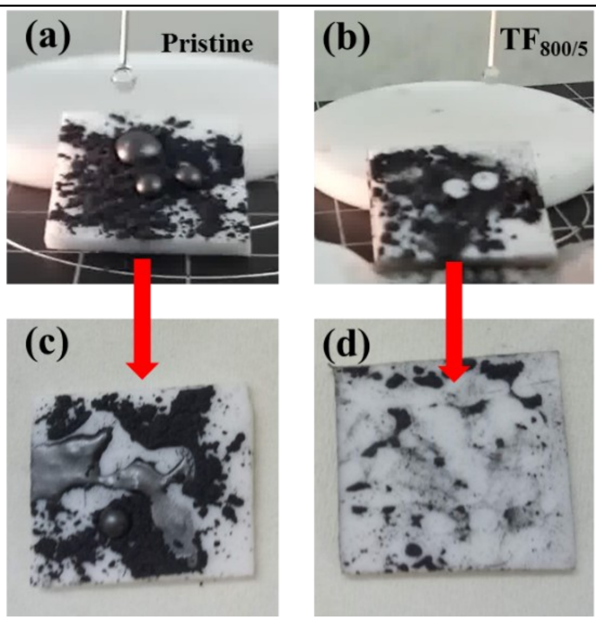

Figure 3: Self-cleaning test on (a) pristine PTFE and (b) $TF_{800/5}$ samples with carbon powder. Figure (c) and (d) shows images of surfaces after self-cleaning test.

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Highlights

- High Power (~100 kW), high efficiency Plasma Torches
- Very Low Pressure Plasma Spray facility
- Supersonic Plasma Plume

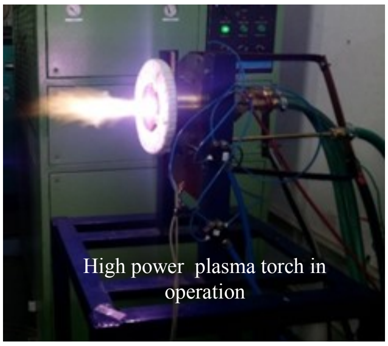
Team members

- Ram Krushna Mohanta
- Biswaranjan Sahoo
- Chirayu Patil

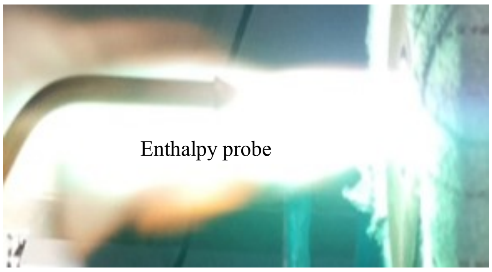
Technology Focus :

Plasma torch program at FCIPT

The plasma torch program at IPR dates back to the early 1990s. In the initial phase, research mainly involved developing plasma torches for different applications. With focus shifting to remedial of solid waste, especially bio-medical waste, the emphasis was on developing graphite based torches that did not require water cooling and were much more efficient, besides being easy to fabricate. This program matured into what we now know as plasma pyrolysis program. However, several technology areas still required the use of plasma torches without the use of graphite electrodes. The idea was to develop high power torches with non-expendable type electrodes and an environment devoid of pollutants other than those involved in the process itself. With this in mind, the plasma torch program was revived about a decade ago. The activities started with a deep understanding of dynamics of the plasma torches. This comprised of development of semi-empirical formulations, three dimensional computer models as well as fundamental studies. Understanding of the plasma dynamics was developed using a clever combination of several diagnostics such as electrical and magnetic techniques, fast imaging and spectroscopy. Many research papers were written and published by the group comprising of a scientist and research scholars. High power (~100 kW), high efficiency (~70 - 80%) torches and enthalpy probes were also developed.



High power plasma torch in operation

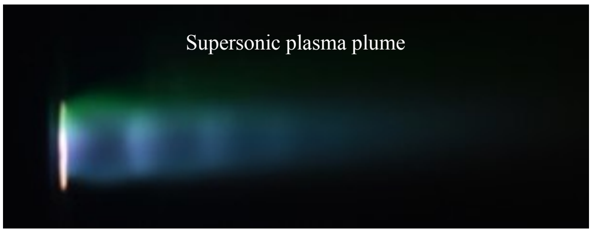


Enthalpy probe

With the understanding firmly in place, the focus shifted to applications. A major focus area currently is to develop the capability of depositing a wide spectrum of columnar structured coatings. Plasma spray processing is a major technique in materials engineering because it offers affordable and effective thin film and coating technology. However, demands of the rapid advances made in sectors like electronics, automotive, aerospace, biomedical etc. cannot be met by current technologies. Therefore, there is a need of a new technique for thermal spraying of specialized coatings at a rapid pace.

The technique presently being developed offers to bridge the gap between conventional plasma vapour deposition and atmospheric plasma spray by combining high deposition rates and cost-efficiency of thermal spraying and features of plasma vapour deposition to deposit wide spectrum of coatings, with the unique capability to deposit coatings on non-line-of-sight areas of substrates with complex geometries. This is a new technique and is being investigated by some other research laboratories across the world too.

The activities involve design and development of high power plasma torches for operation at very low pressures and identification of appropriate plasma parameter regime. Optimization of parameters, controlling the rate of feedstock introduction and vaporization and characterization of the coatings will follow.



References:

[1] Vidhi Goyal et al, Phys. Plasmas, Vol. 25, 073504 (2018)

[2] Yugesh, V. et al, Plasma Chem. Plasma Process., (2018) 38:759 - 770

[3] Yugesh V. et al, European Physical Journal D, 71:247 (2017)

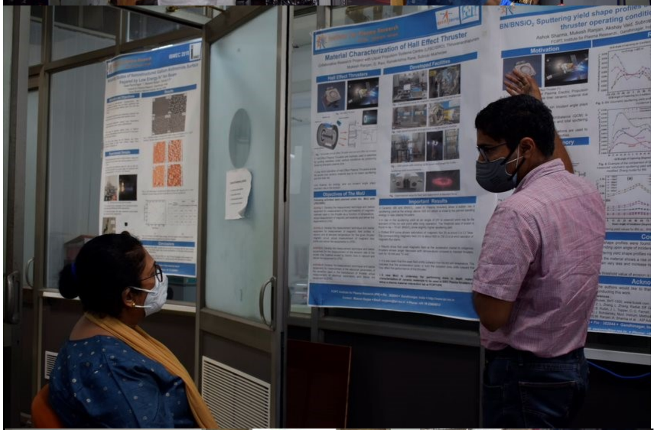
[4] Vidhi Goyal et al, Phys. Plasmas 24, 033506 (2017)

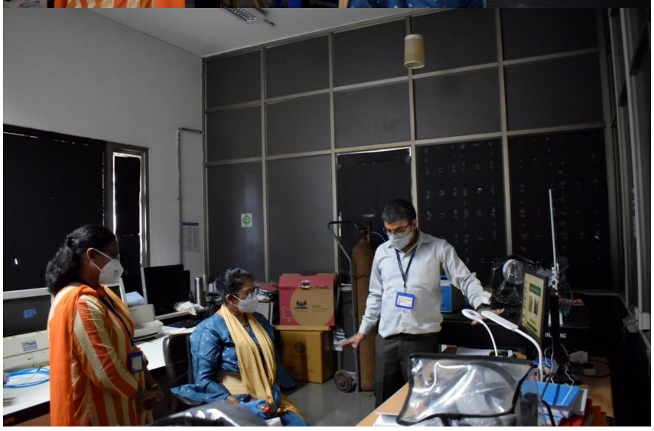
Past Events

Visit by Joint Secretary R&D, DAE

Smt. Shushma Taishete Joint Secretary R&D, Department of Atomic Energy visited FCIPT, on 28th of August 2021. She had an extensive interaction with scientists and researchers working on different plasma technologies for societal and industrial applications. Here are some glimpses of her visit:


PLASMA PROCESSING APPLICATION


Material Characterization of Hall Effect Thruster



Upcoming Events

One Day Meet

on

Plasma Processing of Nanomaterial and its Applications (PPNA-2021)

Date: 03rd Dec 2021

Venue

Online: Through Zoom platform

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