Plasma Processing Update

A Quarterly Newsletter from FCIPT, Institute for Plasma Research

Issue 98 April 2024

Newsletter Team : Satyaprasad A. Kushagra Nigam

INDEX

RESEARCH ARTICLE

Interaction of Atmospheric pressure plasma jet with Glioma tissues

Mr. Akshay Vaid
Scientific Officer
akshay@ipr.res.in

Team members

Mr. Akshay Vaid
Dr. Ramkrishna Rane
Mr. Anand Visani
Dr. Alphonsa Joseph
Mr. Yogesh Agarwaal
Mr. Jyotirmoy Banerjee

1. Introduction

APPJ is generated at room temperature. It contains numerous short-lived chemical species such as free radicals, ions, electrons and excited species as well as ultraviolet (UV) radiation and electric field [1]. Many authors have shown that APPJ induces cancer cell death in various human cell lines which includes brain [2], Hepatoma [3], breast [4] etc. APPJ induces apoptotic cell death in carcinoma cells without affecting normal cells [5]. Similarly APPJ shows specificity towards glioblastoma cells by killing cancer cells but not normal astrocytes [5]. Various studies that have been conducted previously prove that the mechanism of killing cells involves Reactive Oxygen and Nitrogen Species (RONS) [7]. Cancer cells are characterised by higher basal reactive oxygen species (ROS) levels and lower antioxidant capacities, and appear to be more susceptible to APPJ treatment [8].

2. Materials and methods

2.1 Samples

Thirty-eight samples were obtained from patients with gliomas and five non- tumorous samples obtained from patients with Drug-Resistant Epilepsy (DRE), who underwent resective surgery at the Department of Neurosurgery, AIIMS, New Delhi were included in this study. The study was carried out following recommendations of the Institutional Ethics Committee (IEC) of All India Institute for Medical Sciences (AIIMS), New Delhi, India (IEC-535/03.11.2017, RP-10/2017). A written informed consent was obtained from all the patients.

2.2 APPJ jet Device

The plasma jet device is developed by Institute for Plasma Research (IPR), and it’s schematic diagram is shown in Figure-1. A high voltage and high frequency (2 to 5 kV and 20 to 50 kHz) is given to APPJ through power supply that was developed in-house. Estimation of RONS is carried out using fluorescence method. Fluorescence was measured using a multimode microplate reader at 480 nm excitation (synergy HTX Biotek). Resected tissue samples were immediately transferred to carbogenated, ice-cold artificial cerebrospinal fluid (aCSF). Within 15 minutes of resection, slices (600 µm thick) were prepared using a vibrating blade microtome (VT1000s, Leica). These slices were treated with APPJ for 5, 10 or 15 min at 2.8kV at constant gas flow rate of 3 LPM.

3. Discussions

Our data suggests that a treatment duration of 5 min at 4 kV voltage is optimal in promoting significant RONS accumulation in resected tumor samples from LGG patients as shown in Figure-2

It has been observed that at the lower treatment duration, the levels of RONS are sufficiently low, while treatment durations of longer than 5 minutes did not lead to increase in RONS, on the contrary it damaged the sample. The penetration of RONS into deeper layers of tissue is crucial factor influencing the impact of APPJ on solid tissues. Existing studies have provided insights into the penetration capabilities of plasma, indicating that it can reach depths of upto 270 μm in human cervical tissue samples, with only a fraction of ROS and Reactive Nitrogen Species (RNS) able to penetrate through 500μm biological tissues [9].

In our study we observed significantly higher levels on intracellular RONS in plasma-treated slice which had a thickness of 600μm, when compared to un- treated slices as shown in Figure-3. The increase in RONS levels is attributed to the lower thickness of samples as APPJ can treat the samples more uniformly. This observation leads to the understanding that tissue thickness plays a vital role in APPJ penetration into the tissues. Thinner tumour samples appear to be more amenable to APPJ treatment, which suggests that the uniformity of thickness plays a significant role in enhancing RONS penetration. In our study, we observed that thinner slices have more RONS as compared to thicker tissues, but the level of penetration is not confirmed by it. To establish the exact depth of RONS penetration in brain

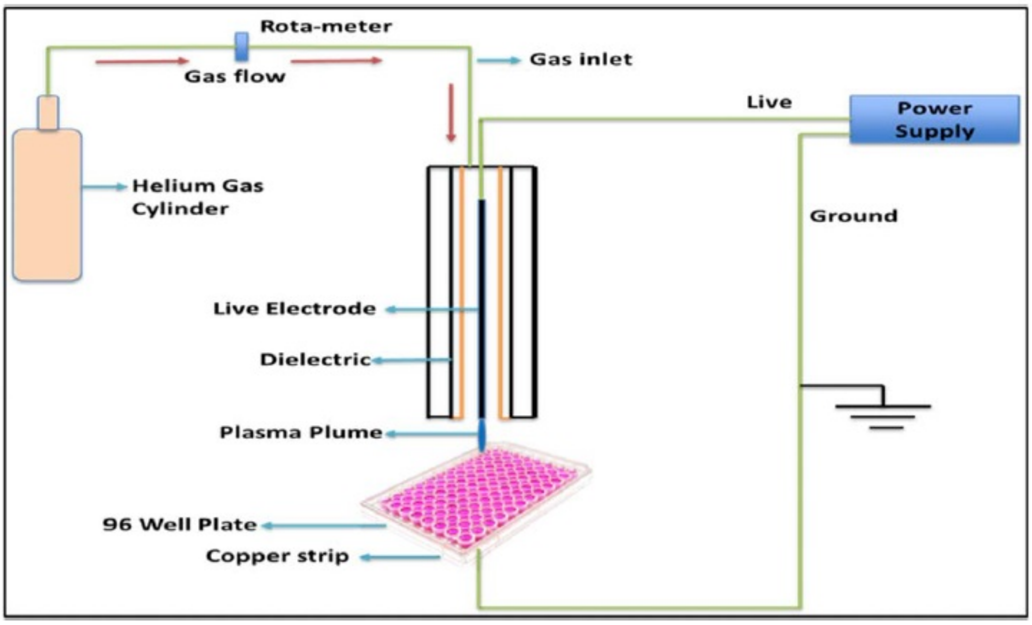

Figure 1: Schematic of APPJ

tissues, further studies are needed. Such investigations would provide a more comprehensive understanding of the practical implications of APPJ treatment for brain tumors, offering valuable insights for future clinical application.

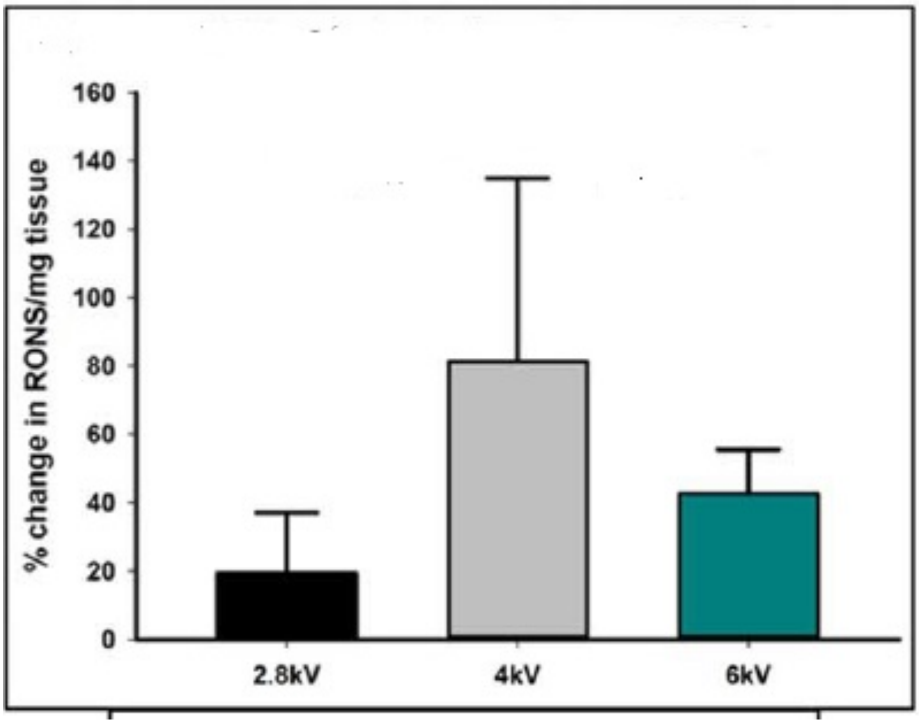

Figure 2: RONS production in glioma tissues on APPJ treatment at different voltages

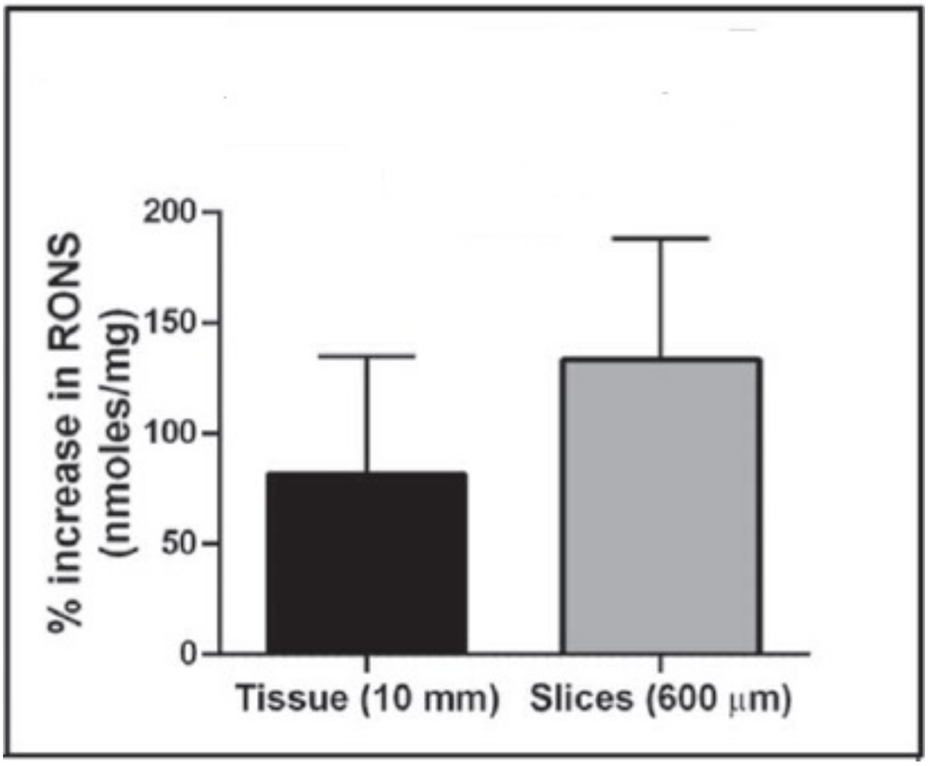

Figure 3: Percentage change in RONS levels in LGG tissue samples versus slice preparation on APPJ treatment

4. Conclusion

To summarise, our study demonstrates that APPJ treatment effectively elevates intracellular RONS level in resected brain samples obtained from LGG patients. APPJ proves to be more effective in thinner tumor slice preparations when compared to thicker samples, primarily due to its superior penetration capabilities. These findings hold promise for the potential application of APPJ as an adjunct therapy for the treatment of glioma, yet the additional research and clinical validation are required to fully unlock its therapeutic benefits.

References:

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[2] Zhang J, Du Q, Yang Y, Zhang J, Han R and Wang J 2023 Research progress and future trends of low temperature plasma applications in food industry: a review Molecules 28 4714.

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[9] Wenzel T et. al. 2019 Molecular effects and tissue penetration depth of phys- ical plasma in human mucosa analysed by contact and marker independent raman microspectroscopy ACS Appl. Mater. Interfaces 11 42885-95.

RESEARCH ARTICLE

Plasma Sterilization for Bacterial Inactivation: Studies on Probable Mechanisms and Biochemical Actions

Dr. Tejal Barkhade
Post Doctoral Fellow
tejal.barkhade@ipr.res.in

Team members

Dr. Tejal Barkhade

Mr. Kushagra Nigam

Dr. G. Ravi

Dr. S. K. Nema

Dr. Seema Rawat

Healthcare-Associated Infections (HAIs) spread through various equipment used during medical and surgical interventions in hospitals. Therefore, sterilization or disinfection of these equipment must be achieved before any such intervention [1]. Traditional methods of disinfection and sterilization are effective to a certain extent, but with the rise of multi-drug resistant pathogens, innovative approaches like plasma sterilization have become increasingly important. Plasma sterilization involves the use of plasma, which is the fourth state of matter (besides solid, liquid, and gas) and is generated by applying energy to a gas. This energized gas can effectively kill various microorganisms, including bacteria, viruses, and fungi. It's particularly advantageous because it can penetrate small crevices and intricate instruments, making it a potentially superior method for disinfecting complex medical equipment.

The plasma is rich in various reactive oxygen species (ROS) such as hydroxyl radicals ($^{\bullet}OH$), Ozone (O_3) and Hydrogen Peroxide (H_2O_2) which work as antibacterial agents due to their ability to oxidize the molecular compounds such as lipids, proteins, etc. present on the outer surface of cells [2]. The plasma further denatures and modifies the structure of essential biomolecules present inside the bacteria, thus affecting its cell functioning. The plasma treated bacterial cells display several effects such as membrane integrity loss, alterations in protein secondary and/or tertiary structures, disturbance in metabolic activity, and damage to Deoxyribonucleic acid (DNA) structure. These aspects of the studies are thoroughly examined and understood by utilising the spectroscopic and microscopic techniques and are discussed in this article. In the present study, a correlation between the biological processes and possible mechanisms involved in the inactivation of gram-positive *Staphylococcus aureus* and gram-negative *Salmonella abony* is established. CD spectroscopy has been used to analyse alteration in the secondary structure of protein due to plasma treatment. UV–visible spectroscopy is another well-known technique to analyse DNA concentration. Interesting results have emerged showing time-dependent destruction (swelling/shrinkage) of cells observed using FE-SEM. ATR-FTIR investigations have revealed several functional groups alteration. The key ROS radicals like $^{\bullet}OH$ and H_2O_2 generated on cell membrane due to plasma have been estimated using spectrofluorometer. These ROS species create oxidative stress in cell body, resulting in cell inactivation.

The plasma sterilization system as schematized in Fig. 1(a), consists of major components like vacuum compatible sterilization chamber, rotary vane pump (RVP), Pirani gauge, needle valve, vent valve, ozonizer and DC power supply. The sample loading door is sealed with the chamber using a vacuum gasket. A sample loading inner stainless steel basket and a tray are provided inside the chamber to load the bacteria sample. The broad view of plasma and bacterial suspension interactions inside the plasma chamber is shown in figure 1(b).

The estimation of ROS such as hydroxyl radicals ($^{\bullet}OH$) and hydrogen peroxide (H_2O_2) radicals generated in bacterial sample during plasma exposure is measured using Fluorescence-based spectroscopy. When the bacterial suspension is exposed to plasma, radical species are generated in the process and these radicals are diffused into the bacterial membrane. To confirm and estimate the presence of hydroxyl radicals on the bacterial membrane, bacterial cells were stained with a non-fluorescent terephthalic acid (TA) probe, after plasma treatment. Similarly, DCFH-DA is also a well-known probe for detecting intracellular H_2O_2. The graphs in figure 2 (a&b) show the fluorescence spectra obtained using TA probe for detection of $^{\bullet}OH$ radical on bacterial membrane of *S. aureus* and *S. abony* respectively. Interestingly, fluorescence spectra showed an increasing trend at 415 nm as plasma exposure time is increased, thus

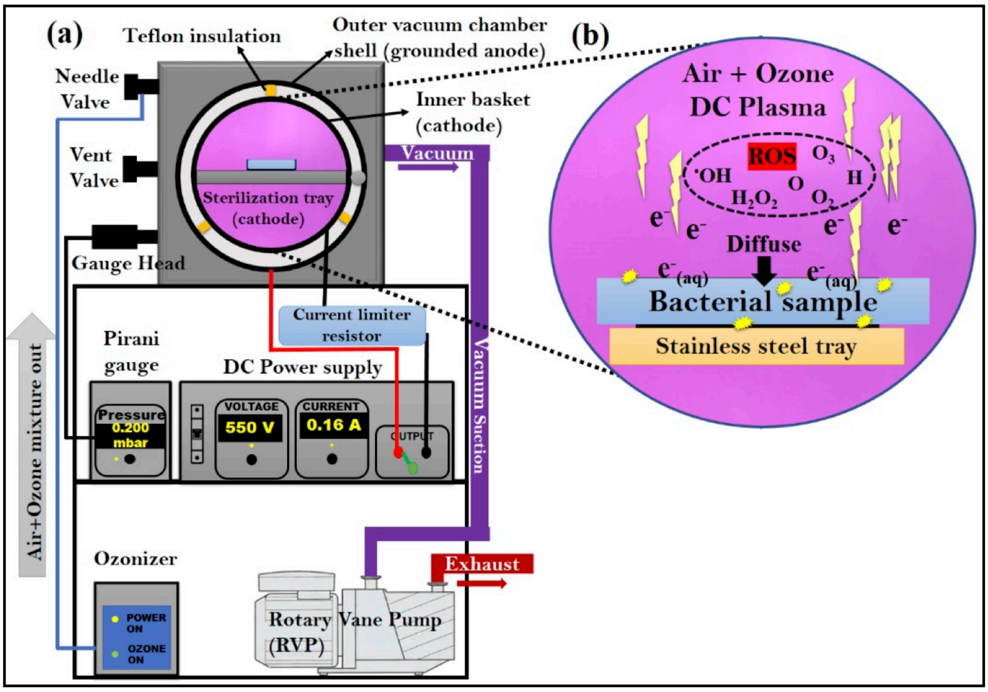

Figure 1: (a) Schematic diagram of Plasma sterilization system, and (b) Broad view of plasma-bacterial suspension interactions and ROS generation

indicating rising concentration of $^{\bullet}OH$ radical. Similarly, graphs in figure 2 (c&d) showed the generation of long-lived H_2O_2 estimated using DCFH-DA probe. The growing fluorescence spectra of both $^{\bullet}OH$ and H_2O_2 confirm the overproduction of reactive free radicals which creates oxidative stress in the inner environment of bacterial cell and leads to cell death or inactivation[2].

The morphological characteristics of *S. aureus* and *S.abony* bacteria before and after plasma treatment are depicted in figures 3 & 4(a-e),

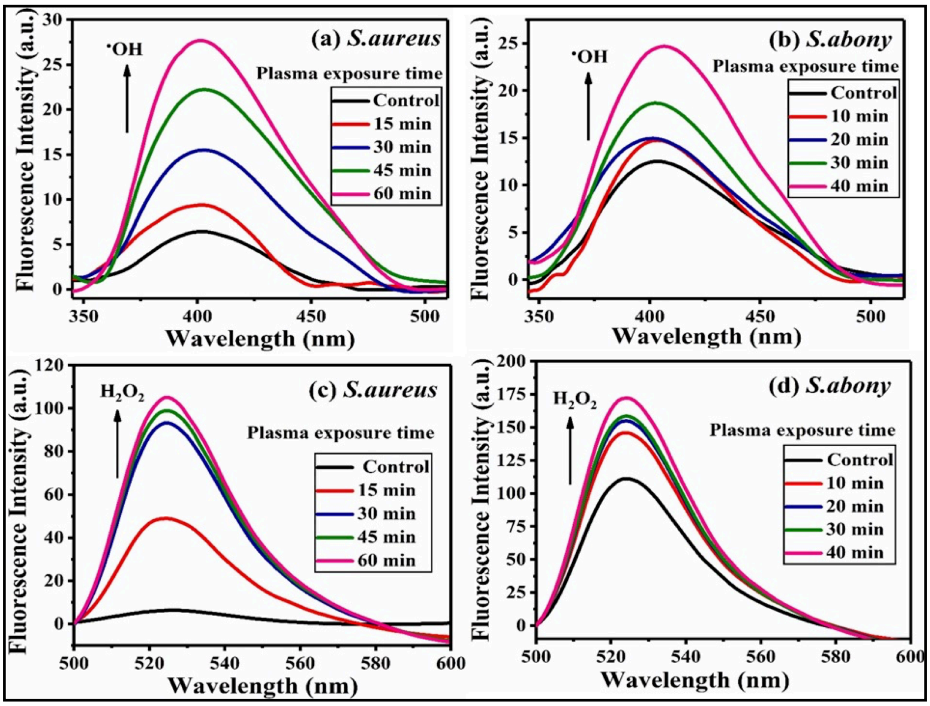

Figure 2: Fluorescence spectra of plasma-treated S. aureus and S. abony showing over-production of $^{\bullet}OH$ in (a) and (b), and H_2O_2 in (c) and (d), respectively

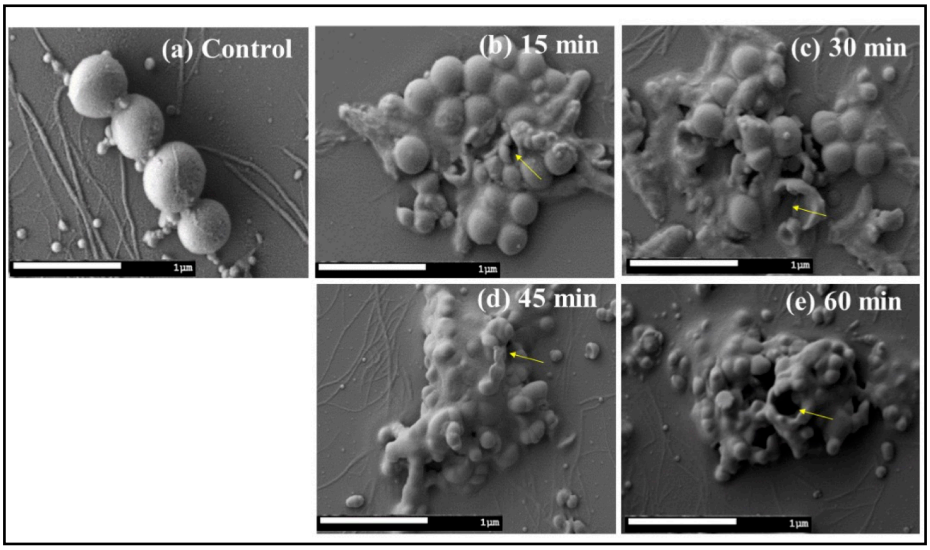

Figure 3: FE-SEM micrographs of S. aureus (a) control (untreated), plasma treatment for (b) 15 min, (c) 30 min, (d) 45 min, and (e) 60 min

respectively. Figure 3 (a) shows the untreated (control) micrograph of *S. aureus*. After the plasma treatment, the cocci-shaped *S. aureus* cells aggregate and form a cluster-like structure which can be seen in the pictures as marked by yellow arrows. Under the stressful conditions developed due to plasma exposure, multiple bacterial cells initiate the aggregation process to survive, as shown in figure 3(b-e). The uniform rod-shaped morphology was observed in untreated FE-SEM micrograph of gram-negative *S. abony* as shown in figure 4 (a). After the plasma treatment, bacterial morphology appeared less uniform, less distinct, and swollen. However, the intercellular materials appear to have leaked out after 20 min of plasma exposure. Here, we can infer that, the plasma exposure leads to dissimilar pathways of bacterial demise due to the difference in their cell wall structures. The micrographs (figure 3 b-e) of gram positive bacteria show gradual decrease in cell size (shrinkage), formation of irregular bulges (membrane-blebbing) and breaking of membrane into multiple apoptotic bodies, which are characteristics of apoptotic cell death. On the contrary micrographs of gram negative bacteria exhibit membrane swelling (figure 4b) and rupturing (figure 4c-e) leading to release of cell contents. This is the signature of necrotic cell death which is a cellular route of demise that occurs when the cells are exposed to extreme external conditions [2].

Conclusion

Thus, the above studies give an insight into the processes and pave way for development of plasma sterilization systems which would have the following advantages (i) DC plasma system overcomes this limitation by achieving sterilization over a large area (ii) no contamination probabilities (iii) no use of external toxic gases, and (iv) comparative inactivation mechanism through plasma on both group of bacteria i.e. gram positive and gram negative. It is concluded that the plasma system proves to be effective for sterilization by providing multiple pathways for bacterial killing.

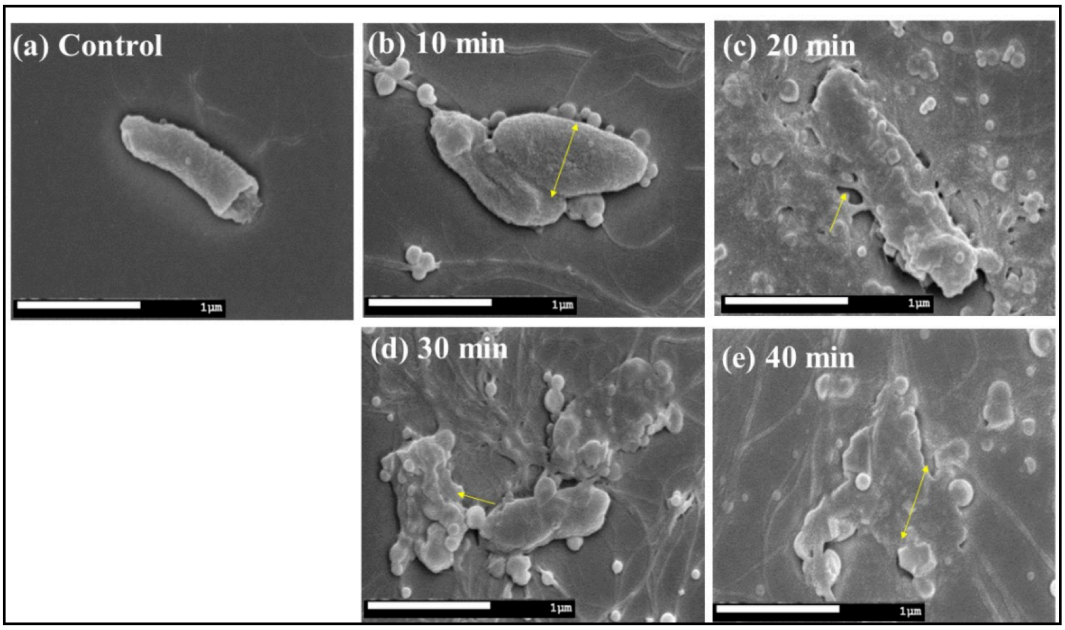

Figure 4: FE-SEM micrographs of S. abony (a) control (untreated), plasma treatment for (b) 10 min, (c) 20 min, (d) 30 min, and (e) 40 min

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2. T. Barkhade, K. Nigam, G. Ravi, S. Rawat, & S. K Nema. Plasma Sterilization for Bacterial Inactivation: Studies on Probable Mechanisms and Biochemical Actions, *Plasma Chemistry and Plasma Processing*, 44, 429-454, 2023.

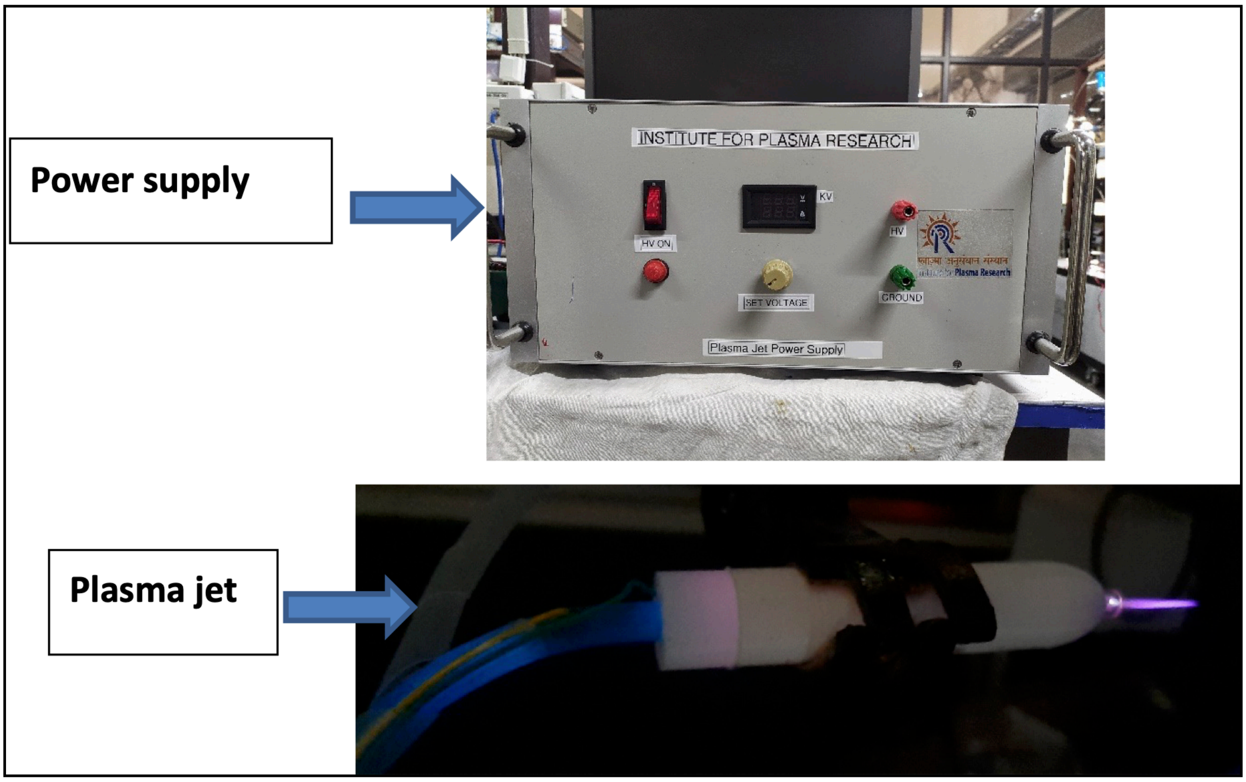
SYSTEM DELIVERY

Supply of Atmospheric Pressure Plasma Jet (APPJ) to Birla Institute of Technology, Mesra, Jaipur for educational and research purpose

The APPJ finds applications in various fields viz. polymeric surface modification, reactive chemistry, bacterial and biomolecule inactivation, wound healing and other biomedical applications etc. The research institutes, universities in India are working in the field of plasma application using APPJ.

In one of the externally funded projects, PSED division of IPR has developed and installed the plasma jet system at BIT-Mesra, Jaipur, which primarily will be used for studying characteristics of the plasma produced by the APPJ by using optical and electrical diagnostics. This plasma jet can be operated using helium and argon gas where plasma plume length will be 20-30 mm.

The following image shows the APPJ setup and a high-frequency power supply that was developed in-house at FCIPT, IPR.



The Atmospheric pressure plasma jet and power supply developed at FCIPT and installed at BIT, Mesra, Jaipur

ARRIVAL OF NEW SYSTEM AT FCIPT

Installation & Commissioning of a Plasma Carburizing System at FCIPT, IPR

In our everyday life, humans are surrounded by lots of industrial machines, which serve human life by producing good quality products in large quantities. The product quality and quantity both depend on the quality and capacity of the machines, which can be improved by improving the quality, and capacity of the machine. However, parts of the machine are designed very carefully to obtain the desired properties of the machine; there are several limitations like retaining toughness and hardness simultaneously.

Carburizing, is a process where carbon is diffused into the surface of a part or component (usually low-carbon steel) at a temperature well above the AC3 (the final critical temperature at which free ferrite is completely transformed into austenite during heating) where austenite is present and the diffusion rate of carbon in steel is reasonably high. The carbon content increases according to the diffusion rate at the chosen temperature (930 to 955°C) and the nature of the carbonaceous media used and later quenched with oil, water or high-pressure gas. In industries, five carburizing processes are available i.e. pack, liquid, gas, vacuum and plasma carburizing.

Institute for Plasma Research installed a High-Temperature Vacuum Furnace with a High-Pressure Gas Quenching System in December 2023 to develop a plasma carburizing process. The system can carburize ~ 500 kg load. The system comprises a working volume of 900 mm deep and 600 mm in height. The plasma carburizing process is an environment-friendly process. The process provides an even treatment of components with complex geometry. The plasma carburizing process delivers the

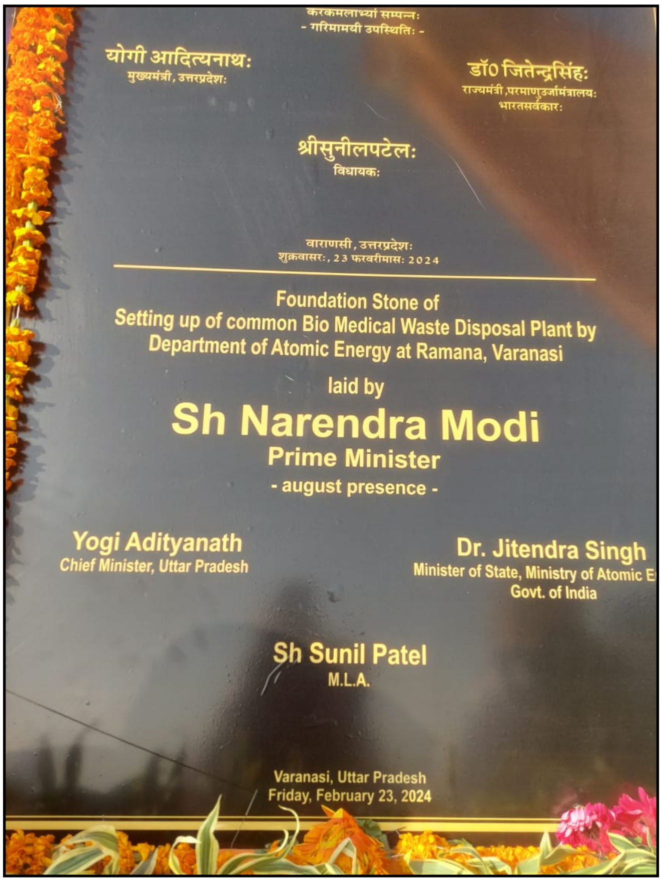
Plasma Carburizing system installed & commissioned at FCIPT, IPR component with minimum or no distortion compared to other processes. Plasma carburizing is suitable for material like EN36C, EN8, EN16, 17CrNiMo6, SAE8620, 20MnCr5, 20CrNi4, EN353 and EN354. Industries which can be benefited by plasma carburizng process are aerospace, automobile, manufacturing, rail and tool & die industries. The advantages of plasma carburizng are as follows.

- No Intergranular Oxidation
- Low distortion
- Repeatable
- Shorter cycle time
- No post grinding
- Uniform and high case depth
- High hardness of low carbon steels
- Environmentally friendly

IMPACT NEWS

Honourable Prime Minister laid the foundation stone of Setting up of Common Biomedical Waste Disposal Plant at Varanasi

On 23rd February 2024, Honourable Prime Minister Shri Narendra Modi laid foundation stone for setting up of common biomedical waste treatment facility (CBWTF) at Ramana, Varanasi. In this facility, a 5 tons per day (TPD) plasma pyrolysis plant (RAUDRA) - which is indigenously designed & developed by IPR - will be used for disposing yellow category biomedical waste. The essential equipment & machineries required for CBWTF to treat other categories of biomedical waste, as per CPCB norms, will also be part of this facility. The site development and shed construction is under progress through CPWD, Varanasi. This facility will cater to various hospitals and health care facilities located in and around Varanasi to treat and dispose their biomedical waste in environment friendly manner.



Foundation stone laid by Honourable Prime Minister Shri Narendra Modi

Dr. Shashank Chaturvedi (Director, IPR), Dr. S. K. Nema along with other officials during the stone laying ceremony

NEWS UPDATE

Inauguration of New Lab Building at FCIPT, IPR

Institute for Plasma Research (IPR) is developing a common biomedical waste treatment facility (CBWTF) of 5 Tons Per Day capacity for safe disposal of biomedical waste. This plasma pyrolysis system will be installed & commissioned at Varanasi, Uttarpradesh. However, this system will first be assembled & tested - using simulated medical waste - at FCIPT, IPR. After successful testing, it will be shifted to Varanasi. A new lab building was constructed for housing & testing of this facility at FCIPT campus of IPR.

Another facility of Plasma Nitriding for industrial components which would be jointly operated with Industries on a GOCO (Government Owned Contractor Operated) model, will also be housed in this new lab building. Further, this space will also be used for establishing a high capacity gasifier using an indigenously designed & developed plasma torch system of 320 kW capacity.

This new lab building was inaugurated by Dr. Shashank Chaturvedi, Director IPR, on 05th of January 2024. A few pictures of inauguration function shown below.

Dr. Shashank Chaturvedi, Director-IPR, inaugurating the new lab building

Dr. Subrato Mukherjee, Dean (Admin) - IPR,
breaking auspicious Shreephal

The new lab building

A few colleagues who have contributed in this project

Dr. Shashank Chaturvedi, Director-IPR, interacting with FCIPT staff

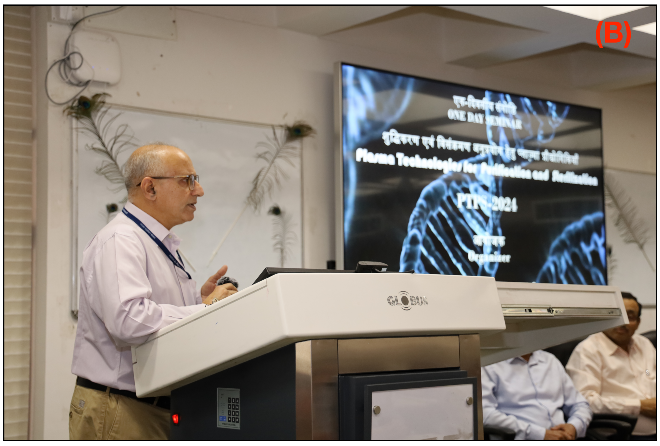
Group Photo

NEWS UPDATE

One day seminar at IPR, on ‘Plasma Technologies for Purification and Sterilization : PTPS2024’

A one-day seminar on “Plasma Technologies for Purifications and Sterilization” (PTPS2024) was organized at IPR on 1st March 2024. The seminar was graced by the chief guest Dr. Sunil Shukla, Director General, EDII (Entrepreneurship Development Institute of India). Professionals from industries, medical institutions, research organizations; students & academicians from academic institutes have participated in this event. Various plasma technologies developed by IPR, particularly in the area of purification and sterilization, were demonstrated for the delegates during FCIPT tour. In the end, a panel discussion was also conducted where in experts from different fields have discussed on the acceptance of promising plasma technologies by medical institutions within India through mandatory certifications and on how to approach for the same. The seminar was also in line with the “Make in India” program of Government of India in which the role of researchers in developing indigenous technologies is paramount.

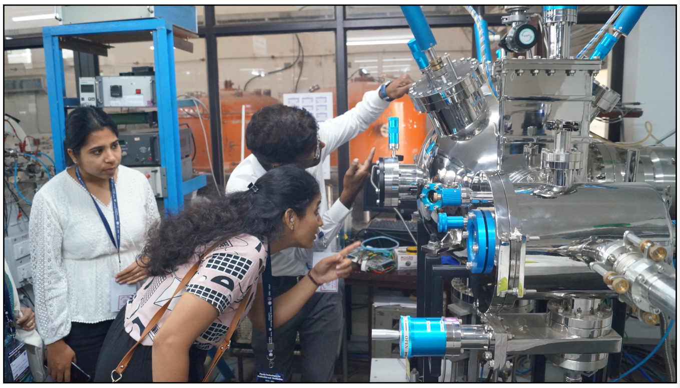
A few pictures of the event are shown below.



During inaugural session: (A) Lighting of the Lamp by dignitaries, (B) Welcome address by Dr. Shashank Chaturvedi, Director, IPR, (C) Chief Guest Dr. Sunil Shukla, Director General, EDII; addressing the participants, (D) Plenary talk by Dr. S. K. Nema

Participants of PTPS Seminar

Top L-R: *Dr. Kaushik Choudhury (CCAMP), Dr. Shital Butani (Nirma University), Shri Prateek Arora (Persapien Innovation); and* **Bottom L-R:** *Dr. R. Mahendran (NIFTEM), Ms. Purvi Dave (IPR), Mr. Kushagra Nigam (IPR) and Mr. Akshay Vaid (IPR) delivering the talks.*



Participants visiting various labs at FCIPT campus of IPR

During Panel discussion, at the end of Seminar

Dr. Vishal Jain, Convenor PTPS-2024, proposing Vote of Thanks

VISITS TO FCIPT

Visit of Smt. Sushma Taishete, Joint Secretary R&D, DAE

Smt. Sushma Taishete, Joint Secretary (R&D), DAE; has visited FCIPT, IPR on 13.03.2024.

Dr. S. K. Nema has given a presentation about latest work in progress at FCIPT, and about the technologies that are developed & are being developed at FCIPT. She has visited the new lab building that was inaugurated recently, at FCIPT; and also visited various labs in FCIPT.

A few pictures of her visit are shown below.

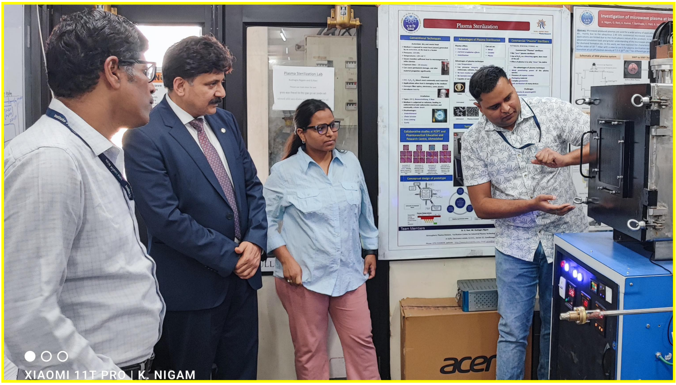
Joint Secretary (R&D), DAE; Smt. Sushma Taishete visiting various labs at FCIPT, and with FCIPT staff

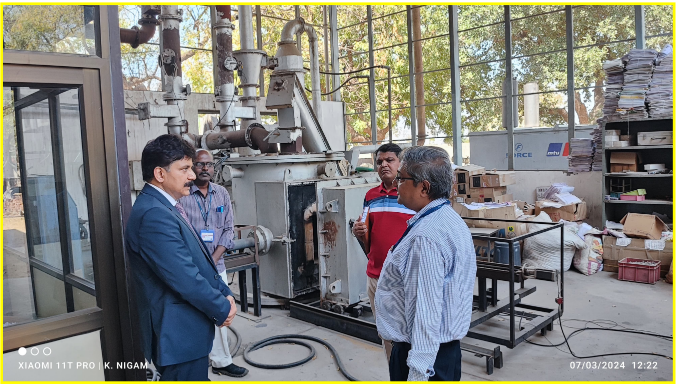
VISITS TO FCIPT

Visit of Prof. Sanjay Mathur, University of Cologne, Germany

Prof. Sanjay Mathur, Chair of Inorganic and Materials Chemistry, University of Cologne, Germany; has visited FCIPT on 07.03.2024. He has interacted with scientists and engineers at FCIPT, visited the labs and exchanged ideas.

A few pictures of her visit are shown below.





After a brief introductory meeting, Prof. Mathur has visited various labs at FCIPT

STUDENTS' NEWS

THESIS DEFENCE

Mr. Ram Krushna Mohanta DDFS Scholar successfully defended his Ph.D. thesis entitled "Investigation of Thermal Plasma Jet for Low - Pressure Plasma Spraying"

Dr. Ram Krushna Mohanta along with Doctoral committee members, Chairman Academic Committee and Thesis Examiner Prof. Kantesh Balani of IIT Kanpur

OTHER ACTIVITIES

SWACHCHATA PAKHWADA - 2024

As per the Government of India's guidelines, Swachhata Pakhwada is observed every year at IPR. This year, it was observed during 16th - 29th February 2024. As part of this celebration, various events and activities were organized. These included swachchata pledge, cleanliness drive, poster display, slogan writing competition, tree plantation drive, felicitation of safai karmachari etc.

Swachchata Pledge

Swachchata Pledge being taken by FCIPT staff, Security & house-keeping staff at FCIPT Campus

SWACHCHATA PAKHWADA - 2024

Felicitation of Swachchata warriors (safai karmachari)











As a part of Swachchata Pakhwada 2024, housekeeping staff and gardeners were felicitated for their contribution towards cleanliness of the campus, followed by tree plantation

SWACHCHATA PAKHWADA - 2024

Dr. Ramkrishna Rane has won the first prize in 'Swachchata Slogan Writing (English)' contest

At photo booth for swachchata promotion

OTHER ACTIVITIES

53rd NATIONAL SAFETY WEEK

As a part of 53rd National Safety Week, Fire Fighting Demonstration was organised in FCIPT campus on 06.03.2024.








Staff at FCIPT, being trained for fire-fighting

PATENTS / PUBLICATIONS / TALKS DELIVERED

Patents applied / granted

1. Atmospheric Pressure Plasma Jet for Bio-Medical Applications
   Akshay Vaid, Chirayu Patil, Adam Sanghariyat, Ramkrishna Rane, Abhijit Majumdar, Subroto Mukherjee
   Patent Granted. Patent Number: 497593 (11.01.2014)

2. System and Method for AiMethod for the realization of dense Isotropic h-Boron Nitride and its silica composite
   Remyamol Thekkayil, Mukesh Ranjan, Mappillatharayil Raman Ajith
   Patent Granted. Patent Number: 504606 (30.01.2024)

3. Low-Cost Process for the Preparation of Surface Enhanced Raman Spectroscopy (SERS) Substrate and SERS Substrate Prepared Thereby
   Mukesh Ranjan, Sebin Augustin, Mahesh Saini, Sooraj KP , Basanta Parida, SukiritiHans, Vivek Pachchigar
   Provisional Indian Patent App. No. :202321081756 (01/12/2023)

4. Plasma Sterilization System and Process to Sterilize Medical Components and Devices Using Microwave Source
   Kushagra Nigam, G. Ravi, S. K. Nema, Tejal Barkhade, Chirayu Patil and Biswaranjan Sahoo
   Provisional Indian Patent App. No. 202421018111 (13/03/2024)

Publications in peer reviewed journals

1. Investigation of facet evolution on Si surfaces bombarded with Xe ions
   S. Hans, Basanta Kumar Parida, S. Augustine, Vivek Pachchigar, S. K. P, and M. Ranjan
   Physica Scripta, Mar. 2024, doi: https://doi.org/10.1088/1402-4896/ad3153

2. Influence of in-situ substrate temperature on anisotropic behaviour of glancing angle grown nickel nanocolumns.
   Rajnarayan De, Sebin Augustine, B. Das, et al.
   Appl. Phys. A 130, 126 (2024). https://doi.org/10.1007/s00339-024-07300-5

3. Manifold enhancement in the near-field and SERS efficiency of all-sputter grown Ag-nanoparticles on Al-film based mirror structures
   M. Saini, Vivek Pachchigar, S. Augustine, Umesh Kumar Gaur, K.P. Sooraj, and M. Ranjan,
   Surfaces and Interfaces, vol. 41, pp. 103263–103263, Oct. 2023, doi: https://doi.org/10.1016/j.surfin.2023.103263

4. Graded oxide layer for high-performing nanosized synaptic emulator
   Sudheer, Rupam Mandal, Vivek Pachchigar, Sooraj KP, Biswarup Satpati, Tapobrata Som, and Mukesh Ranjan
   Applied Surface Science, vol. 639, pp. 158115–158115, Dec. 2023, doi: https://doi.org/10.1016/j.apsusc.2023.158115

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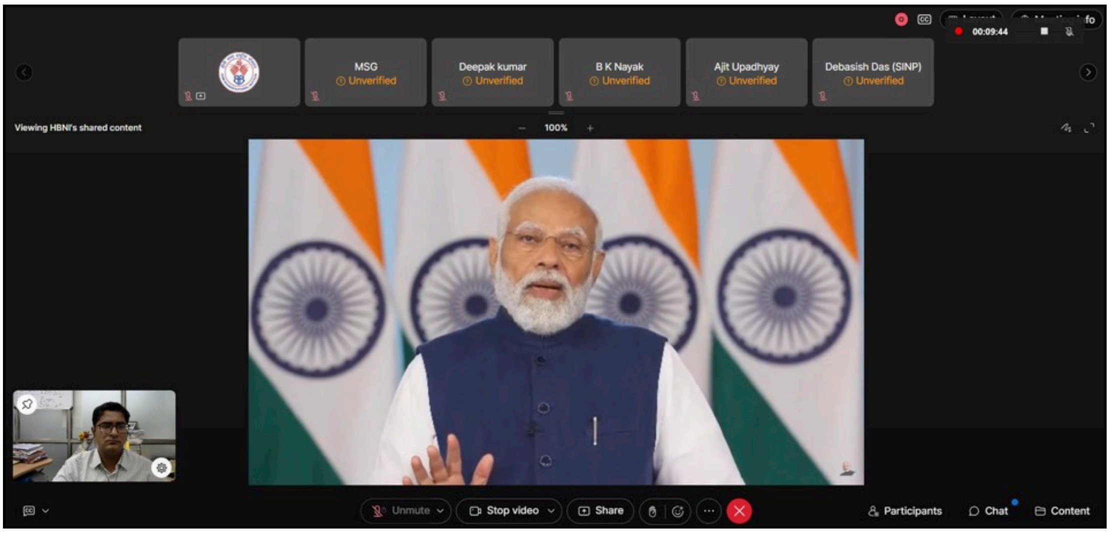
Talks delivered

1. **Mr. P.V. Murugan** delivered an invited talk during National Symposium, EcoViSun organized by Manipal University, Jaipur on "Thermal Plasma Technologies for Waste Management", 5th - 6th March 2024.

2. **Dr. Mukesh Ranjan** was invited as guest of honour during Annual Research & Innovation Conclave at Institute of Advance Research (IAR), Gandhinagar on 06.03.2024. After participating in Inaugural ceremony along with Director, Dean and registrar of IAR, Dr. Ranjan gave an invited talk on “Detection of food adulterants using plasmonic sensor”

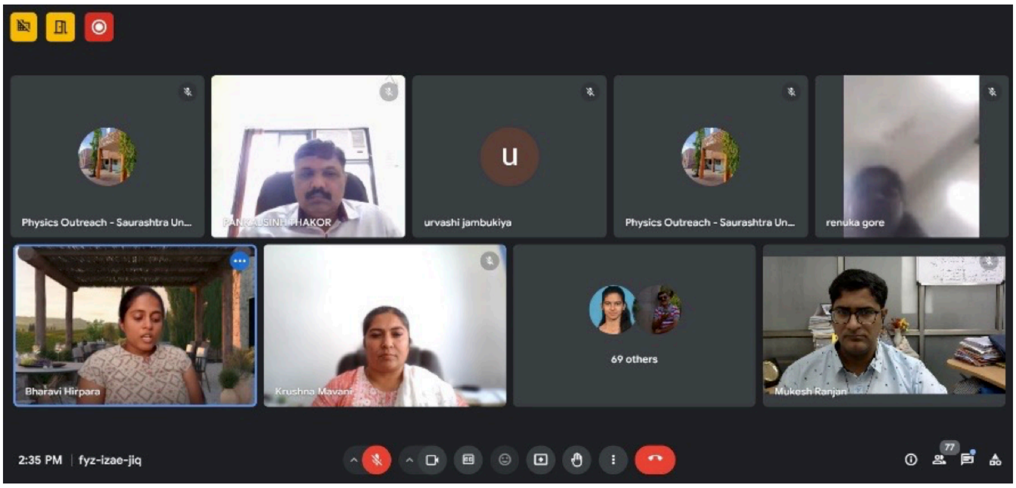
Dr. Mukesh Ranjan at IAR, Gandhinagar

3. **Dr. Mukesh Ranjan** was invited by registrar, Homi Bhabha National Institute (HBNI), DAE, Mumbai for delivering a talk about “Semiconductor processing using Plasma and Ion beam” during celebration of the event about **India’s Techade-Chips for Viksit Bharat**: **Breakthroughs in Semiconductor Research**, on 13-03-2024. Prime Minister Shri. Narendra Modi laid the foundation stone for the semiconductor chip fabrications labs at two places in Gujarat and Assam during this event.



Dr. Mukesh Ranjan attending the online event on India’s Techade-Chips for Vikasit Bharat

4. **Dr. Mukesh Ranjan** gave an online invited talk about "Harnessing Plasma For Societal Application" in National level series of conferences, "**Vigyan Yatra - 2024**". A Travel of Scientific Young Indian Minds towards Vikshit Bharat jointly organized by Department of Physics, Saurashtra University, Rajkot (Gujarat), Vigyan Gurjari (Gujarat Prant Unit of Vigyan Bharati - VIBHA) and Gujarat Council on Science & Technology (GUJCOST), Department of Science and Technology (DST), Government of Gujarat, Gandhinagar to be held online mode during March 04 – 15, 2024.



Dr. Mukesh Ranjan attending online event Vigyan Yatra - 2024

FACILITATION CENTER FOR INDUSTRIAL PLASMA TECHNOLOGIES (FCIPT)

Institute for Plasma Research

A-10/B

Industrial Estate

GIDC, Sector 25

Gandhinagar

Gujarat. 382016

079-23269003/11/29
079-23964039/38

ptts@ipr.res.in

ppu@ipr.res.in

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