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Institute for Plasma Research

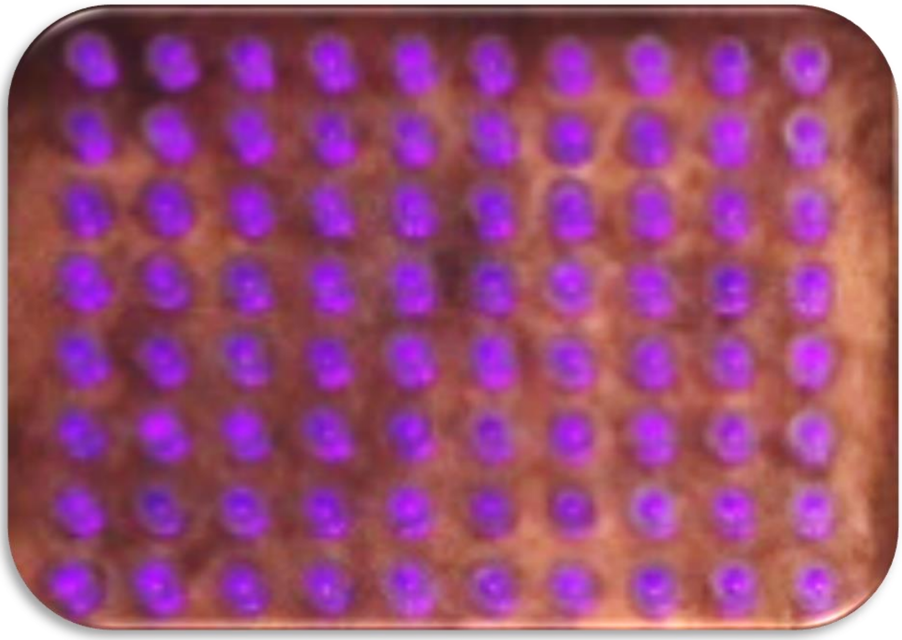
PLASMA PROCESSING UPDATE

Issue 103

EDITORIAL TEAM

Contents:

Atmospheric Pressure Plasma Array Device



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Cold atmospheric helium plasma for imparting antibacterial effect in hand sanitizer

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Background:

CAP (Cold Atmospheric Plasma) has found its many applications in bio-medical field. It is generated using dielectric barrier discharge (DBD) principal at atmospheric pressure. It consists of electrons, ions, neutrals and long and short lived reactive species such as reactive oxygen species (ROS) consisting of hydroxyl radicals, superoxide anion, singlet oxygen and hydrogen peroxide and reactive nitrogen species (RNS) consisting of nitric oxide (NO), peroxynitrite (ONOO-) and NOx. Recently CAP has found significant application in sterilization due to its ability to inactivate a wide range of microorganisms including bacteria, viruses, fungi and spores in short treatment times.

The study was performed to evaluate the disinfecting effects of helium generated cold atmospheric plasma (He-CAP) against bacteria for hand sanitization. Antibacterial effects of Helium operated cold atmospheric plasma (He-CAP) jet were evaluated on gram positive staphylococcus aureus and gram negative pseudomonas aeruginosa.

Experimental Details:

The bacterial strains were isolated from the finger dab cultures collected from the hands of human volunteers. Thereafter phenotypic classification of isolated strains was done. The identification of selected bacterial strains was done as per the Bergey's Manual of Determinative bacteriology [1]. Isolated strains were transferred to LB broth and incubated at 37°C at 24 hrs in a bacteriological incubator. The concentration of bacterial cultures was kept uniform throughout the study by comparing the culture density with 0.5 McFarland standard at 600 nm wavelength using a UV spectrophotometer (Shimadzu 2600).

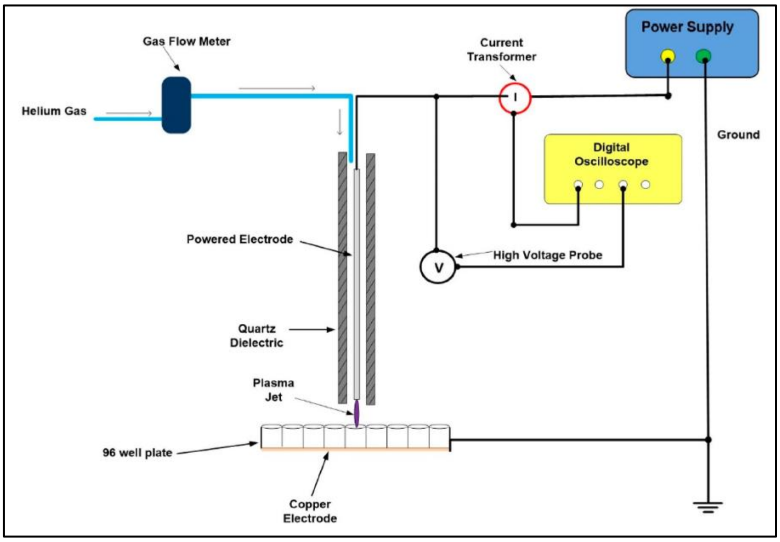

Figure 1: *Schematic representation of experimental set up used for He-CAP generation.*

Bactericidal effects were observed at 5 LPM flow rate having time of exposure of 5 min at voltage of 2 kV (p-p). Schematic representation of experimental set up is shown in Figure 1. The distance between plasma jet and bacterial strains are kept at 10 mm. After plasma treatment, the morphology of bacterial strains was observed under scanning electron microscope as per the standard protocol [2]. Cell membrane integrity after plasma treatment was determined by measuring the content of nucleic acid and proteins as per the standard protocol [3].

Results and discussions:

In the study, not only the effect of He-CAP on the bacterial strains were studied but also other parameters like electrical characterization during the treatment as well as the temperature of the plasma plume were measured and analyzed. These results are detailed in the sections below.

Temperature of plasma plume:

Temperature of the plasma plume is an important factor to characterize the plasma jet especially for human skin treatment applications. Therefore temperature of the plasma gas was measured using a square copper strip of mass 0.04 g attached to a J-type thermocouple. Figure 2 shows the temperature variation with respect to time. The temperature measured is around 36°C.

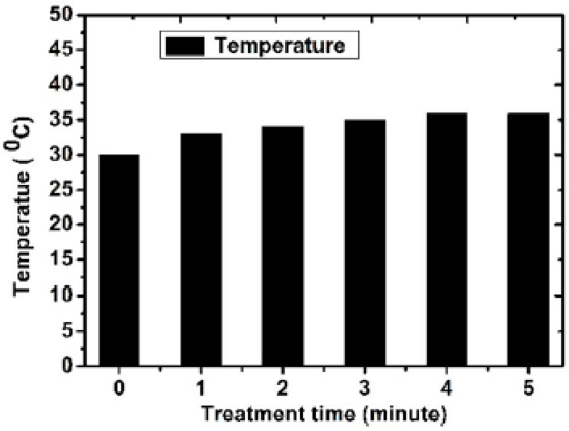

Figure 2: *Plasma gas temperature variation with time.*

Efficiency of He-CAP jet towards micro-organisms:

Colony forming units (CFU) of S. aureus and P.aeruginosa for three different plasma exposure times were studied. It shows that as the time of treatment increases the CFU count goes down. Figure 3 shows the survived bacterial CFU. Figure 4 shows the SEM images of the control and He-CAP jet treated micro-organisms.

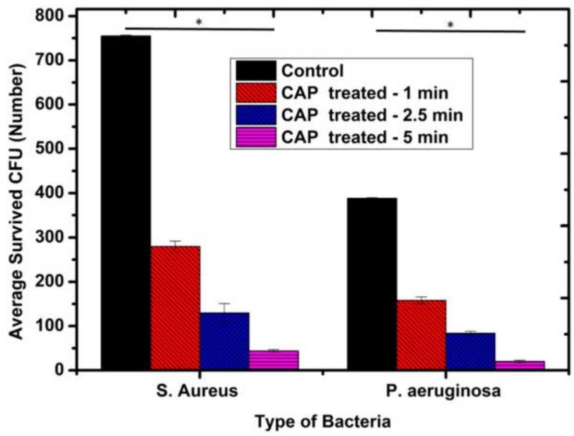

Figure 3: *Survived bacterial CFU at different plasma.*

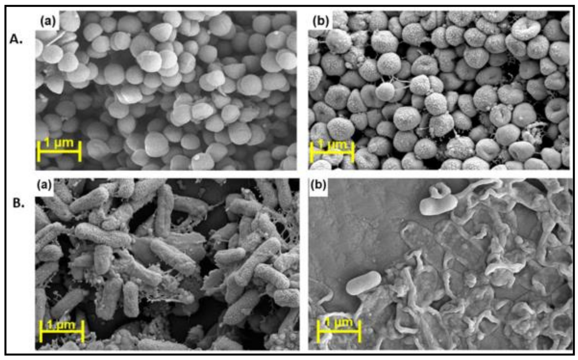

Figure 4: *SEM images of (A) S.aureous and (B) P. aeruginosa where (a) control (b) CAP treated.*

Study of bacterial cell membrane integrity:

Figure 5 shows the nucleic acid and protein concentrations in control and plasma treatment bacterial cultures. The increased concentration of both nucleic acid and protein after treatment with plasma suggests damage to the cell and nuclear membranes, leading to the leakage of cytosolic and nuclear proteins. The observation of bacterial morphology after He-CAP jet treatment is done using scanning electron microscopy. It is observed that cell death is induced through cell membrane disruption and cytosolic leakage in the plasma treated organisms.

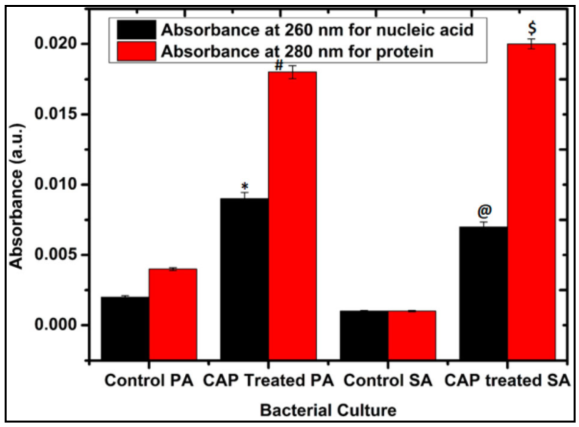

Figure 5: *Nucleic acid (DNA) and protein concentrations of S. aureus and P. aeruginosa.*

Conclusion:

In conclusion, it was observed that He-CAP jet has promising antimicrobial effects against gram-positive and gram–negative bacteria. The in-depth mechanism of interaction with the bacteria needs to be investigated in order to understand the interaction of He-CAP Jet with biological matter. This has the potential application as a hand sanitizer.

References:

[1] Bergey DH, et al. Bergey's manual of determinative bacteriology. Baltimore: Williams & Wilkins (1994).

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Effect of microwave plasma on bacterial cell structure, viability and membrane integrity

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Background:

Plasma-mediated bacterial inactivation holds great promise over conventional techniques such as heat, chemical disinfectants, and radiation, because of plasma's unique composition, consisting of ions, electrons, and neutral particles which enables generation of reactive species capable of neutralizing a wide array of micro-organisms [1, 2]. The generation of reactive oxygen and nitrogen species (•OH, H_2O_2, O, O_3 and NO) exerts a lethal effect on the bacterial cell, creating oxidative stress, disrupting membrane and inflicting DNA damage [3]. However, there is still a lack of understanding on the effects of plasma at the molecular and genetic level. How different process parameters and the specific actions of various species involved in the process influence the overall outcome is the subject of this study. In FCIPT we have carried out a systematic study with an objective to understand antibacterial action of plasma and subsequently to develop plasma based sterilization process.

Among various plasma sources, microwave plasma stands out as a highly efficient and promising technology due to its near-instantaneous generation time, non-invasive nature and comparatively higher plasma densities (~ 10^{10} to 10^{11} per cc), which contribute to faster bacterial inactivation. Ozone also plays a significant role in plasma sterilization by enhancing the antimicrobial effects through several mechanisms. When ozone reacts with other chemical species, such as H_2O_2, it generates reactive •OH. These highly reactive molecules can further attack bacterial cells and the combination of ozone and plasma generates a synergistic effect for improving sterilization process.

Experimental Setup and Methodology:

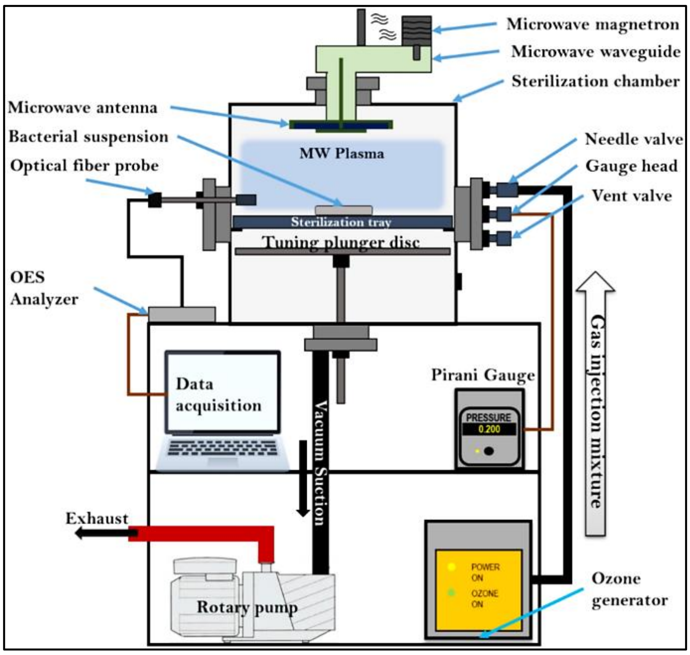


Figure 1: *Schematic of non-thermal microwave plasma system.*

The experimental setup (Figure 1) consists of a 2.45 GHz microwave (MW) source coupled to a vacuum chamber that is used to produce plasma at sub-atmospheric pressure of 0.3–0.5 mbar with an air-ozone mixture. Other components include an antenna, ozonizer, pressure gauges and arrangement to house the samples. Different techniques such as fluorescence spectro-fluorometry, field emission scanning electron microscopy, confocal microscopy and flow cytometer were used to study cell structures, their viability and membrane integrity. Two bacterial species, the Gram positive Staphylococcus aureus (S. aureus) and Gram negative Salmonella abony (S. abony) were chosen and studied.

All reagents like Propidium iodide, 3,3′-Diethyloxacarbocyanine iodide, DMSO as well as analytical reagent like acetone and isopropyl alcohol were procured from Sigma Aldrich. For bacterial cultivation, standard nutrient agar (M001) and nutrient broth (M002) from HiMedia Laboratories were used. All culture media intended for microbiological analysis underwent autoclaving for 30 min at 15 psi and 121 °C. Bacterial strains, including Staphylococcus aureus (NCIM 2079) and Salmonella abony (NCIM 2257), were procured from the National Collection of Industrial Microorganisms (NCIM) at the National Chemical Laboratory in Pune, India. In this study, the term ‘control’ refers to an untreated bacterial suspension, maintained without exposure to plasma or ozone. This control helps as a reference to assess the effects of plasma treatment.

Outcome of Study:

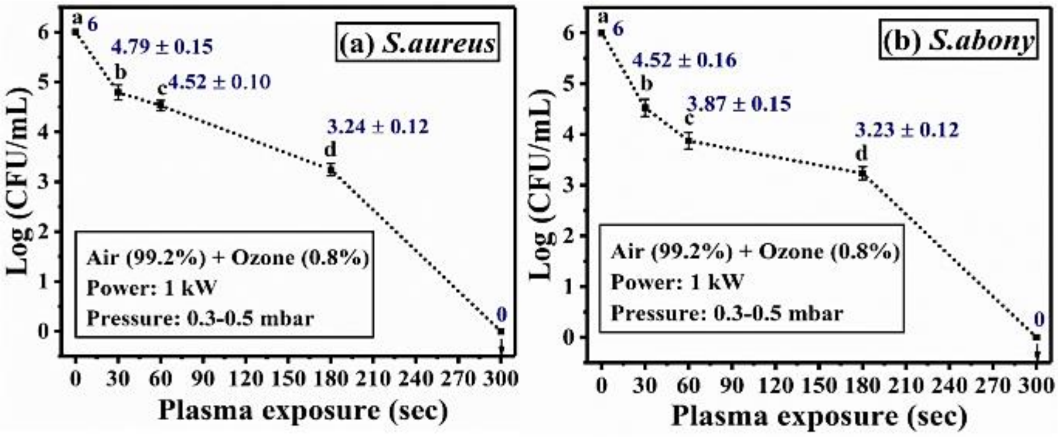


Figure 2: *The reduction curves showing a 6 Log (CFU/mL) decrease for (a) S. aureus and (b) S. abony are presented*.

Optical characterization of plasma revealed the appearance of hydrogen Balmer transition lines indicating the presence of hydrogen comprising species that are stable and long lived peroxide (e.g. H_2O_2). The hydroxyl radicals (•OH) and other reactive oxygen species such as O II, O III and O IV indicate that they might induce various cytotoxic and genotoxic effects on the cells, resulting in cellular damage. When the colony forming units (CFU) of the bacteria were counted, it shows that it is indeed so. 6-log reduction of CFU was achieved within 5 – 6 mins of treatment time (Figure 2). Gram negative species with a thinner cell wall are inactivated more rapidly than Gram positive bacteria, particularly during the early exposure periods (30 and 60 s). This is because Gram-negative S. abony has a thinner outer membrane and also consists of porins that facilitates the diffusion of reactive plasma generated species. This makes them more vulnerable that leads to fast cell damage in the initial phases. In contrast, Gram-positive S. aureus has a thicker outer layer which acts as a physical barrier and delays the diffusion of reactive species. Confocal imaging was used to analyze the dead cells. The count of red fluorescent cells was used as a practical indicator of bacterial cell damage through single staining with a dye called propidium iodide that binds to the DNA of dead cells in the medium (as shown in Figure 3A and 3B). Higher accumulation of the dye was observed in S. aureus compared to S. abony after plasma treatment due to differences in their outer cell wall structures and membrane compositions. This is also reflected in the CFU results.

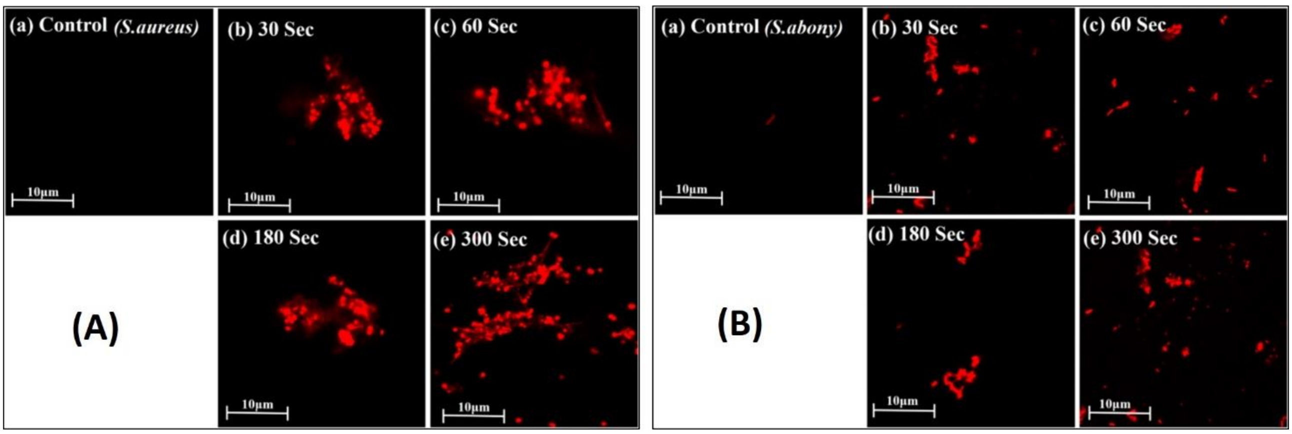


Figure 3: *Confocal microscope results showing red fluorescent dead bacteria (A) S. aureus and (B) S. abony (dye penetration).*

The surface morphological characteristics of both S. aureus and S. abony were then investigated using FE-SEM. The morphology of S. aureus (Figure 4a), usually characterized by regularly round-shaped cells with smooth surfaces, changes upon exposure to plasma. A notable aggregation of cells occurs followed by the initiation of membrane rupture and eventually severe cellular damage due to prolonged exposure to plasma. This alteration in morphology is likely due to localized membrane damage and destruction of the thick cell wall typical of Gram-positive bacteria. Ultimately it leads to opening of the cell and leakage of its contents such as cytoplasm, nucleic acids and proteins ensued and eventually cell death. On the other hand, the regularly rod-shaped bacteria (S. abony, Figure 4b) underwent a transformation into irregular shapes, dented, and wrinkled, with noticeable increases in surface roughness apparent after 30 s of treatment. The outer membrane is compromised due to oxidative stress caused by reactive molecules passing through the porins. Cellular expansion occurred, resulting in swelling and compromised membrane integrity, which facilitated the leakage of intracellular material present in S. abony.

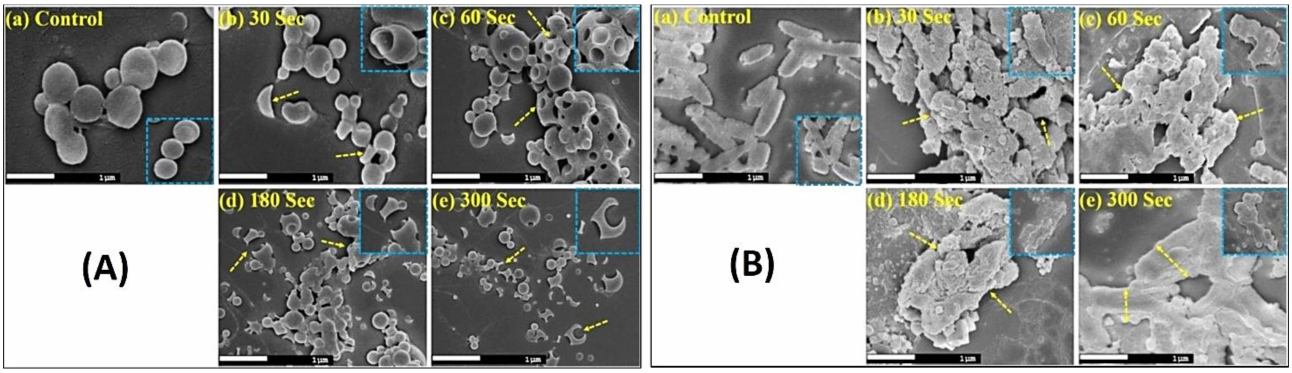


Figure 4: *FE-SEM micrographs illustrate the surface morphologies of (A) S. aureus and (B) S. abony.*

Delving deeper into the processes, the membrane potential was assessed using fluorescent probes and a spectro-fluorophotometer. The dye exhibited greater fluorescence intensity in both S. aureus and S. abony, indicative of membrane depolarization, i.e. making the inside of the cell less negative compared to its surroundings. Typically, in healthy cells, dye becomes more concentrated in intact membranes maintaining a membrane potential. Whether the plasma had any impact on the DNA was analysed using another method called UV absorbance spectroscopy. Gradual leakage of DNA was found from both S. aureus and S. abony. This leakage was also confirmed by ATR-FTIR analysis. Complete details of the study are given in published literature of our team [4].

Summary and Conclusions:

In summary, the high plasma density from the microwave source was found to significantly contribute to the 6-log reduction of S. aureus and S. abony, as demonstrated by the conventional colony count method. The study suggests that bacterial inactivation likely occurs due to the diffusion of highly and intense amount of reactive oxygen species, such as •OH and H_2O_2, which create oxidative stress within the bacterial cells. To gain a deeper understanding of the bacterial cell death and inactivation mechanisms, various spectroscopic and microscopic methods were employed. Notable findings included (i) outer layer and membrane damage (ii) leakage of inner cellular contents, (iii) membrane depolarization and change in membrane potential, (iv) decrease in viable cell counts, (v) morphological changes. Overall, our studies have demonstrated the excellent antibacterial activity of non-thermal microwave plasma against S. aureus and S. abony.

Future research on the potential of plasma sterilization needs to focus on its effectiveness, scalability, and application in the healthcare sector. Studies could further explore the optimization of plasma parameters for cost-effective rapid sterilization of medical and surgical instruments, biofilm removal, and surface decontamination in hospitals ensuring a safer, healthier future for all.

Patent:

An Indian Patent "*Plasma Sterilization System and Process to Sterilize Medical Components and Devices using Microwave Source*" has been filed with App. No. 202421018111 (2024).

References:

[1] Lerouge, S., Wertheimer, M. R. & Yahia, L. H. *"Plasma sterilization: A review of parameters, mechanisms, and limitations",* Plasmas Polym. 6, 175–188 (2001).

[2] Moisan, M. et al. *"Plasma sterilization. Methods and mechanisms",* Pure Appl. Chem. 74*(3),* 349–358 (2002).

[3] Barkhade, T., Nigam, K., Ravi, G., Rawat, S. & Nema, S. K., *"Plasma sterilization for bacterial inactivation: Studies on probable mechanisms and biochemical actions",* Plasma Chem. Plasma Process. 44(1), 429–454 (2024).

[4] Tejal Barkhade, Kushagra Nigam, Ganesh Ravi, Seema Rawat, Sudhir Kumar Nema*, "Investigating the effects of microwave plasma on bacterial cell structures, viability, and membrane integrity",* Scientific Reports 15, 1805 (2025).

Incubation Agreements with Startups

AIC-IPR Plasmatech Innovation Foundation (AIC-PLASMATECH, IPR's technology incubator) is delighted to announce a significant step forward in our mission to nurture deep-tech innovation. Recently, AIC-PLASMATECH have formally executed two Incubation Agreements and two Technology Transfer Agreements with startups working in the field of plasma-based technologies. These startups were selected following a rigorous evaluation process and are now on board to receive comprehensive support through our incubation ecosystem — including technical mentoring, access to infrastructure, business development assistance, and networking opportunities.

Coldray Plasma Labs:

"Coldray Plasma Labs" is a medtech startup focused on developing a compact, low-temperature plasma jet device aimed at promoting faster wound healing, with a special emphasis on chronic wounds and diabetic ulcers. This innovative technology leverages the unique properties of cold atmospheric plasma — including antimicrobial action, stimulation of cell regeneration, and improved blood microcirculation — to offer a non-invasive approach. With diabetic wounds being a major global healthcare concern, this plasma-based solution holds the potential to significantly reduce healing time, lower the risk of infections, and enhance the quality of life for patients. The startup was incubated on 9th April 2025 followed by execution of a technology knowhow and license agreement on 25th April, 2025. The startup company will now be able to make a prototype device for demonstration and further regulatory clearances.

Incubation agreement execution with Coldray Plasma Labs

Pedocrown Dental Private Limited:

"*Pedocrown Dental Private Limited*" is a dentistry startup founded by dentists Dr. Yash Bafna and Dr. Madhulika Bafna. The startup (Pedocrown) is developing a cost-effective, plasma activated water based solution (PAW-G) for the preservation of natural teeth that are avulsed due to accidents or injuries. The solution aims to significantly enhance the viability of dental tissues, thereby increasing the chances of successful re-implantation. This innovation holds particular promise in emergency care and trauma scenarios, offering a practical and accessible alternative to existing preservation methods, especially in resource-constrained settings. By combining plasma science with dental health, the startup is paving the way for improved clinical outcomes and patient care.

Incubation agreement execution with Pedocrown team

Ecoplaswa Technology Private Limited:

"*Ecoplaswa Technology Private Limited*", an agritech startup founded by Ms. Sowmya R. S. is incubated at AIC-IPR Plasmatech Innovation Foundation and into the development of Activated Plasma Water based products for Dairy and agricultural applications. Agreement for transfer of knowhow and license for Plasma Activated Water generation device has been executed between AIC-IPR Plasmatech Innovation Foundation and *Ecoplaswa Technologies Private Limited* on 25th April 2025 enabling the startup to now start manufacturing the prototype.

Execution of technology knowhow and license agreement with Ecoplasmwa

These collaborations underscore our commitment to fostering deep-tech entrepreneurship and supporting technologies that have a tangible societal impact. With plasma science at the core of their innovation, we are excited to see how these startups progress during their incubation journey.

Conference Participations and FCIPT Visits

1. **Dr. Nirav Jamnapara** delivered an invited talk about **“Perspectives for students and Startups"** organized by New Age Makers Institute of Technology (NAMTECH) (an educational initiative of Arcellor Mittal and Nippon Steel) at IIT Gandhinagar campus. The talk showcased an overview about plasmas, activities of IPR and fusion technologies followed by Plasmapreneurship ideas involving the spin-off potential of plasma technologies for industry and society. The talk was attended by over 50+ students and more than 12 professionals including faculties and industry representatives. A number of students expressed their interest to pursue academic projects with IPR on topics of mutual interest supporting IPR's objective on advancing fusion technology. A number of students also expressed their keen interest about the incubation possibilities at IPR's Atal Incubation Centre which was appropriately addressed by the speaker.

2. **Dr. Suryakant B. Gupta** delivered an invited talk titled “**An overview of Advanced Instrumentation and Pulsed Power Technology for Various Plasma Applications**”, 11th International Conference on Frontiers of Plasma Physics and Technology (FPPT-11) May 5-9, 2025, Dubrovnik, Croatia.

3. **Dr. Suryakant B. Gupta** delivered an invited talk titled “**ESD and its detrimental effects on spacecraft charging and arc mitigation techniques**” 7th Latin American Workshop on Plasma Physics held in Santiago, Chile from Jan 20-23, 2025.

4. **Mr. Amba Sankar** presented a poster titled “**Fe-Doped $NiCo_2O_4$ Composites Treated with N_2 Plasma as Bifunctional Electrocatalyst for Water Electrolysis**” at the *2nd Global Forum – International Conference on Industrial Plasma Processes and Diagnostics (IPPD 2025)*, organized by IIT Delhi from during May 18-20, 2025.

5. **Dr. Debashrita Mahana** delivered a talk titled "**Optimizing Electrolytic Conditions for Enhanced Hydrogen Production via Dual Cathodic Plasma Electrolysis**" at the *2nd Global Forum – International Conference on Industrial Plasma Processes and Diagnostics (IPPD 2025)*, organized by IIT Delhi from, May 18-20, 2025.

6. IIT Delhi Organized the 2nd Global Forum and International Conference on Industrial Plasma Processes and Diagnostics 2025 (IPPD 2025) from May 18-20, 2025. **Dr. Mukesh Ranjan** delivered an invited talk titled "**Plasma Surface Engineering for Sensing and Wettability Application"** and also chaired the session about Fundamentals of Plasmas, Energy Conversion, Environment Technologies, Plasma Processes and Role of Diagnostics.

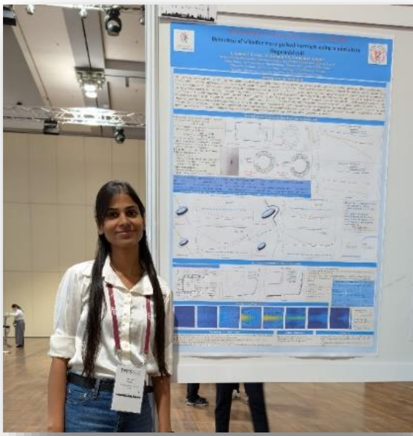
7. Dr. Ramkrishna Rane delivered an invited talk titled "**Low-pressure plasma surface modification of polymeric material for various biomedical application**" at 2nd Global Forum and International Conference on Industrial Plasma Processes and Diagnostics 2025 (IPPD 2025), May 18-20, 2025.

8. Dr. Mukesh Ranjan delivered an invited talk titled "**Harnessing Plasma for Societal Application**" at IIIT Vadodara, Gandhinagar campus. Students, faculties and Director IIIT Prof. Dharmendra Singh attended the talk.

9. IIT Gandhinagar arranged a day-long Industry Open House **CoLab 2025** event 2025. The event envisions fostering new dialogues between researchers and industrial professionals to understand market trends and find avenues for building sustainable partnerships. **Dr. Mukesh Ranjan** participated in the discussion on the theme **"The New Space-Defense Paradigm: Technology, Security, and Beyond".** Dr. Kishore Nath, Project Director-VEDA, Advanced Systems Laboratory, DRDO and Dr. Lokesh Srivastava (Deputy Project Director, ASL - DRDO), Dr. Senthil Kumar (Dy Director SAC) and Dr. Deepak Mishra (Group Director SAC) along with IIT faculties participated in the discussion.

10. Dr. Mukesh Ranjan delivered an invited talk titled "**Reducing Carbon foot prints utilising plasma processing**" at National Workshop on Shaping the Future with Nanotechnology: Energy Storage and CO_2 Utilization" at St. Xavier's College, Ahmedabad, 29-30/03/25.

11. **Ms. Ambesh Kumari** presented the poster titled "**Detection of whistler wave pulsed currents using a miniature Rogowski coil** " and at IEEE PPPS 2025 conference during June 15-20, 2025, Berlin, Germany.



12. **Mr. Kunal Trivedi** presented the poster titled "**Feasibility studies of surface treatment amd multilayer TiAlN/TiN coatings on Zircaloy-4 clad tube for Accident Tolerant Fuel (ATF) design using a PVD technique**" at IEEE PPPS 2025 conference during June 15-20, 2025, Berlin, Germany.

13. IP Utsav organized by Ministry of Education Innovation Cell (MEI) from 21-26 April 2025. IPR coordinator of HBNI Institute Innovation Council (HIIC) members at IPR **Dr. Mukesh Ranjan** (Innovation ambassadors), Dr. Sudhirsinh J Vala (Innovation ambassadors) coordinated the IP Utsav activity. Various talks about Design registration, copyright, trademark, patententing, commercialisation etc. were arranged both at IPR , FCIPT and CPP campus. Students, Dean Academic, Academic committee members, HBNI faculties and Posdoc participated in the event.

14. **Dr. Suryakant B. Gupta** delivered an invited talk titled "**Emerging role of Plasma Technology in Multidisciplinary Research**" Samvaad at Silver Oak University Ahmedabad 5th Dec 2024.

15. **Dr. Suryakant B. Gupta** delivered an invited talk titled "**Indigenously developed Pulsed power sources for Nonequilibrium Plasma Applications**", "DAE-BRNS 1st National Conference on "Pulsed Power Science, Technology & Applications" (PPSTA-2024) during Sep 12-14, 2024 at BARCF Facility, Atchutapuram, Visakhapatnam.

16. **Dr. Mukesh Ranjan** delivered a talk titled "**Surface Enhanced Raman Scattering for health and medical science**" at Gandhinagar Science college.

17. Dr. Mukesh Ranjan gave the talk about Industrial Plasma Applications and **Dr. Amreen Hussain** and **Ms. Nisha Chandwani** coordinated for the lab visit at FCIPT for the IPR summer school students.

18. IPR employees who joined in past three years had participated in orientation program. As a part of this program, they visited FCIPT Campus.

19. IPR is working on a MoU with VSSC/IPR about Anode Liner Material Erosion Studies for the indigenous development of Anode liner material and it's testing under various plasma thruster operating conditions. Under this MoU a low energy ion beam facility is developed at FCIPT/IPR for performing ion erosion experiments. After performing detailed experimental studies in past few years and feedback given to ISRO, Anode liner material is developed, process patented and technology is given to LPSC/ISRO. The work is recently appreciated at the occasion of Innovation day celebration at ISRO. Dr. Asir Packiaraj. Director, ISRO Propulsion complex (IPRC), Mahendragiri and Dr. Mohan, Director LPSC felicitated the team VSSC (Dr. Remya and Dr. Ajith) and IPR (**Dr. Mukesh Ranjan**) on the occasion of Innovation day for the anode liner material technology development and patenting it. Congratulations to team IPR and Team VSSC.

Journal Publications & IPR Research /Technical Reports

[1] **Synergistic effect of Argon plasma treatment and HDTMS coating for making superhydrophobic jute fabric**
Rohit Sharma, Prashant Kumar Barnwal, Poonam Chauhan, K.P. Sooraj, Mukesh Ranjan, *Fibers and Polymers* (**2025**).

[2] **Engineered surfaces and cation tuning in hybrid perovskites for sustainable paper-based memristors for AI and brain-inspired computation**
Mansi Patel, Jeny Gosai, Manish Khemnani, Bhawana Andola, YogeshKumar Srivastava, Tarundeep Kaur Lamba, Mukesh Ranjan, Ankur Solanki, *Applied Materials Today* 44 (**2025**) 102784.

[3] **Cold plasma-mediated kapok fibre/epoxy composites for printed circuit board applications**
Ramya Ranjan, Dileep, M. Ranjan, *Polymer Composite* (**2025**)1.

[4] **Low Energy Ion-Implanted Nanometer-Thick Metal Oxide Memristor for Random Number Generation at the Nanoscale**
Sudheer, Mandal Rupam, Hasina Dilruba, Alam Mollick, Safiul Mandal, Aparajita, Ranjan Mukesh, Som Tapobrata, *ACS Applied Nano Materials* 8(**2025**)6327.

[5] **Microwave-assisted rapid synthesis of non-stoichiometric tungsten oxide doped borosilicate glasses for NIR shielding application**
G S Amgith, Nidhi Pathak, Ritu Kumari Pilania, Sooraj KP, Mukesh Ranjan, Charu Lata Dube, *Ceramic International* 51(**2025**)24470.

[6] **Exploring the role of nitrogen doping in tuning the band gap and electrical properties of sol–gel synthesized anatase titanium dioxide nanoparticles**
Gagandeep Kaur , Puneet Negi , RuhitJyoti Konwar, Hemaunt Kumar, Nisha Devi, M. Ranjan , K.P. Sooraj , Himitri T rivedi , Bhargav Rajyaguru, N.P. Barde, N.A. Shah , P.S. Solanki et al., *Optical Material* 162 (**2025**) 116851.

[7] **The macromolecular transition of kapok fibre by RF plasma treatment investigated by SAXS/WAXD and their correlation with electrical properties of the fibre-reinforced composites**
Remya Ranjan Das, Basanta Kumar Parida, Mukesh Ranjan, T. Umasankar Patro, Dillip Kumar Bisoyi, *Journal of Applied Polymer Science* 142 (**2025**) e56954.

[8] **Green Technologies from Plasmas**
R. Babu, R. Bahl, B. R. Kumar, C Balasubramanian, N. Chandwani P. K. Chattopadhyay, J. Chowdhury, P. Dave, A. Gahlaut, S. Gupta, A. A. Hussain, V. Jain, N. Jamnapara, G. Jhala, A. Joseph, K. Kalaria, B. Khodiyar, P. Kumar, R. Kumar, S. Kumar, M. Kumar, M Mariammal, S. K Nema, P. V Murugan, R. Rane, V. Rathore, N. Singh, N. Vaghela, A. Vaid, R. P. Yadav, *Transaction of the Indian National Academy of Engineering*, INAE-D-24-00348 (**2025**).

[9] **Investigating the effects of microwave plasma on bacterial cell structures, viability, and membrane integrity**
Tejal Barkhade, Kushagra Nigam, G. Ravi, Seema Rawat & S. K. Nema, *Scientific Reports*, 15 (**2025**) 18052.

[10] **Influence of plasma-forming gas and plasma source driving frequency on surface properties of silicone catheters for reducing bacterial adhesion**, DAVE Purvi, C Balasubramanian, Chirayu Patil, RANE Ramakrishna, K NEMA Sudhir, *Plasma Science and Technology* 27 (7) (**2025**) 075504.

[11] **The efficacy of helium generated cold atmospheric plasma for skin disinfection**
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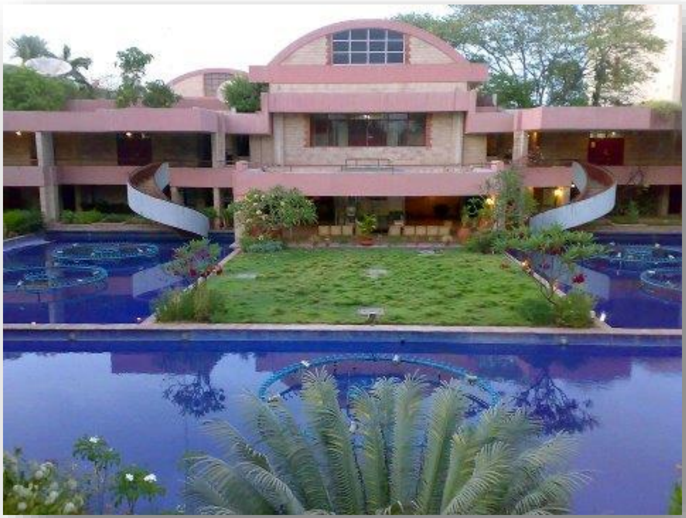
AIC-PLASMATECH

The Department of Atomic Energy (DAE), through its units and aided institutes, has been transferring and deploying several advanced technologies for the betterment of society. In support of the Government of India's initiatives on *Atma Nirbhar Bharat* and Start-up India, the DAE proactively launched incubation centres at BARC Mumbai, IGCAR Kalpakkam, RRCAT Indore, IPR Gandhinagar, and VECC Kolkata. This step aims to make the expertise, sophisticated infrastructure, and technologies of DAE available to industries and society at large. Additionally, the DAE initiated the recognition of such incubation centres with the Atal Innovation Mission, NITI Aayog, New Delhi, as '*Atal Incubation Centres*'.

Based on this initiative, the Institute for Plasma Research established an Atal Incubation Centre as a special purpose vehicle under Section 8 of the Companies Act 2013 in December 2023, with 100% ownership by DAE. The Atal Incubation Centre, popularly known as '*AIC-Plasmatech*' and '*Plasmatech Innovation Foundation*,'

AIC-PLASMATECH OFFER

The Atal Incubation Centre (AIC Plasmatech) offers not only office space to startups but also essential mentoring by IPR's scientists, along with access to cutting-edge technologies and infrastructure. Additionally, it provides business mentoring from experts and external mentors, as well as support in areas such as intellectual property/patenting, marketing, and branding.



Plasma Sterilizer System

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