Facilitation Centre for Industrial Plasma Technologies
Institute for Plasma Research

Plasma Processing Update

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Inside this Issue

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Highlights

- Non-toxic and eco-friendly technology
- Low temperature method for inactivation of harmful pathogens
- Potential applications in coping with pandemics

Research Focus

Cold Plasma, a possibility to inactivate viruses

Viruses are omnipresent and are microscopic infectious agents that can reproduce only inside a host cell. Once a virus has infected a host cell, it can replicate within that cell thousands of times [1]. They can be transmitted directly from one infected individual to another or indirectly via contaminated intermediates such as surfaces, objects, air, food, and water. The recent COVID-19 pandemic is caused by a novel virus called Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2). COVID-19 occurs by direct contact with infected people as well as by indirect contact with surfaces in the immediate environment or with objects used by the infected person. Therefore, inactivation of harmful viruses is crucial to curb spread of the disease.

Various virus inactivation methods are used to prevent the viral spread but are not environmentally friendly and produce toxic by-products. Hence, there is an urgent need to develop a technique that is safe to work, along with efficient virus inactivation. Several researchers have provided early evidence that COVID-19 patients might benefit from infusions of purified antibody-containing plasma from the blood of patients who have recovered from the disease. This is known as Convalescent Plasma Therapy [2]. The plasma referred here is blood plasma, as the name suggests. There exists another plasma which is the fourth state of matter consisting of a mixture of free electrons, ions and radicals, which is also used for the inactivation of microbes. Non-thermal plasma, also called as cold plasma or non-equilibrium plasma, is a type of plasma which is produced either at atmospheric pressure or lower pressures and has a temperature of about 30-60°C. Use of cold plasma could be a possible technique to inactivate microorganisms as it possesses UV radiation and reactive oxygen and/or nitrogen species (RONS) which have important antimicrobial properties. It has been reported that UV can damage nucleic acids, whereas RONS can oxidize nucleic acids, proteins, and lipids [3]. These inherent properties of cold plasma have motivated extensive studies for inactivation of various pathogenic microorganisms including viruses.

This technique has been shown to inactivate all types of bacteria as shown in Fig. 1 to a large extent but study on virus inactivation is still in its infancy [4].

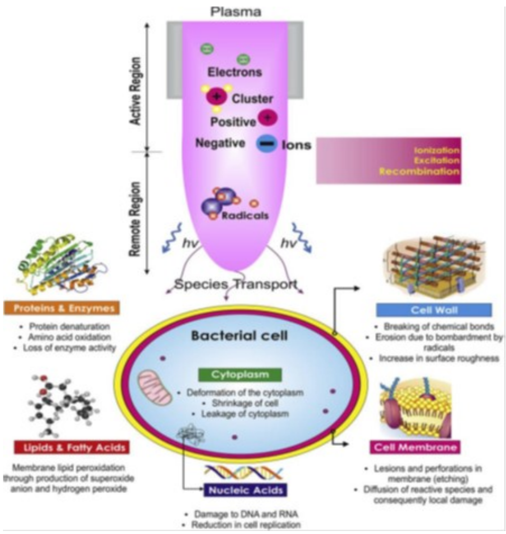

Figure 1: Action of Cold plasma on Bacterial cell (Misra and Jo, 2017) [4].

Effects of plasma on the inactivation of both enveloped and non-enveloped viruses have been studied by many researchers. Studies showed that nitrogen plasma generated by BLP-TES device (NGK Insulators Ltd., Nagoya, Japan) inactivated the enveloped viruses, such as the influenza virus and respiratory syncytial virus (RSV) as well as non-enveloped viruses, such as the adenovirus. Furthermore, a DBD plasma torch inactivated the non-enveloped virus, feline calicivirus [5,6]. Inactivation of viruses was achieved by a relatively short exposure to plasma. According to the U.S. Environmental Protection Agency (USEPA) "Guide Standard and Protocol for Testing Microbiological Water Purifiers," the minimum performance standards of the inactivation efficiency are a six-log reduction/ inactivation of bacteria, or a four-log reduction/inactivation of viruses [7]. Treatment using nitrogen gas plasma generated by BLP-TES showed an approximate two-log reduction in influenza virus titer after 1 min and four-log reduction of virus titer of adenovirus within 4 mins [8]. A 1 min treatment with the DBD plasma torch resulted in a greater than two-log reduction of virus titer for feline calicivirus [7].

The main mechanism responsible for inactivation is due to the formation of reactive oxygen species (ROS) and/or reactive nitrogen species (RNS) whereas UV irradiation and temperature changes are only minor contributors or have no effect. The mechanisms depend on the types of gases used to generate the plasma. In the case of nitrogen gas plasma, at least three major mechanisms (reactive chemical species, UV radiation exposure, and electric fields) are thought to contribute to the antimicrobial effects of plasma. In addition, inactivation mechanisms may vary depending on the target microorganism. Insufficient knowledge of plasma/virus interactions presents the biggest obstacle to expansion of this field. To understand these interactions, it is important to know the flux of reactive species (RONS or radiation) on the surface of the virus, the probability that a particular type of reactive species inactivates the virus, and synergetic effects between different reactive species for viral deactivation. None of these parameters are currently understood completely [9].

IPR has developed low pressure and portable plasma sterilization systems and carried out several experiments in association with PERD Centre, Ahmedabad, and Nirma Univeristy, Ahmedabad. Successful killing of various bacteria has been demonstrated. IPR has carried out in-vitro studies to disinfect bacterial microorganisms like Staphylococcus Aureus, Escherichia Coli, Salmonella Abony and Pseudomonas Aeruginosa and a 6 log reduction was obtained on exposure for few minutes to an hour. Cold plasma can present itself as a unique possibility to replace current chemical decontamination practices because it does not produce excessive waste and can efficiently inactivate viruses in or on different media and surfaces. Its usage will be of great advantage in coping with the current pandemics such as COVID-19, thus providing an ultimate decontamination tool.

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Highlights

- Stringent emission norms of pollution control boards and Ministry of Environment, Forest and Climate Change are forcing Indian thermal power companies to use green technologies
- Plasma assisted combustion has enormous potential to replace existing oil burners in thermal power plants

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- B.K. Patel
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Technology Focus

Plasma assisted coal ignition and combustion

Higher ash and moisture content in coal leads to poor combustion or ignition problems in the furnace. Initially the coal furnaces are pre-heated upto the ignition point of coal using oil fired burners which release particulate matter, NO_x etc. in the exhaust and pollute the environment. Thermal plasma being a reactive heat source can enhance coal combustion. In order to improve efficiency of coal burning and minimize harmful emissions by reducing fuel oil rate in thermal power plants, the large scale plasma technology of coal ignition and combustion are being developed in the world. Graphite-electrode based thermal plasma arc system developed at Institute for Plasma Research can be used as an alternative to oil-fired burners used for start up (pre-heating) of the furnace.

The technology works as follows. The Plasma device attached to cylindrical chamber is fed with pulverized coal-air mixture. Coal particles (50-100 µm) enter plasma zone and thermal shocks break down these particles into 5-10 µm and provide more surface area. Higher temperature & area of coal particles promotes partial gasification (volatiles evaporate). Gasified mixture is then combusted efficiently which produces a long plume. The remaining pulverized coal burners (connected to the furnace) are gradually started after reaching the required thermal parameters of the furnace (close to ignition temperature of the coal i.e. 360 °C). The air plasma flame is a source of heat and additional oxidation. It provides a high temperature medium enriched with radicals, where the fuel mixture is heated, volatile components of coal are extracted, and carbon is partially gasified which can then be ignited easily [1-4].

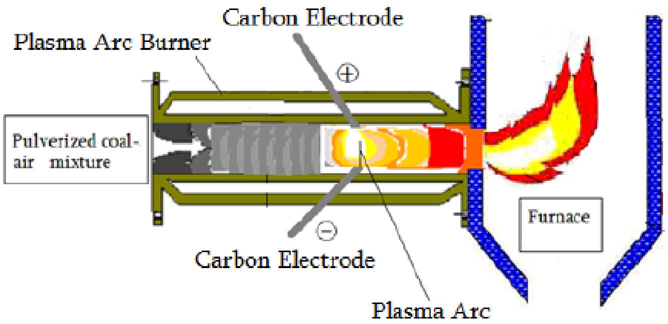

Figure 1: Working principle of plasma assisted coal burning [1]

Advantages of Plasma Assisted Coal Burning:

- Improves efficiency of coal combustion.
- Oil free burner for furnace start-up.
- Pulverized coal preheated by plasma in burner increases reactivity.
- Reduces NO_x emissions
- Reduces unburnt carbon particles (coal fines) in furnace by 40-50% due to high temperature accelerated oxidation reactions.

Gases formed	Volume
CO	28.5%
H_2	8.0 %
CH_4	1.5%
C_6H_6	0.5%
CO_2	2.0%
N_2	59.5%
NO_x	24 ppm

Table 1: Gases formed in plasma assisted ignition [1]

Considering the above mentioned advantages it is quite clear that plasma assisted coal combustion has a great potential in thermal power plants. It provides nearly emission free combustion of pulverized coal and can replace oil burners. IPR has developed a prototype setup to initiate preliminary studies on plasma assisted ignition and combustion of coal.

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Highlights

- Langmuir Probe System and Paschen's Curve System.

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System Focus

Installation of Basic Plasma Experiment System at Saurashtra University

FCIPT/IPR has successfully completed a collaboration agreement with Saurashtra University, Rajkot titled "Development & Demonstration of Experimental Plasma Systems". Under this agreement a basic experimental plasma system for performing Paschen's curve and Langmuir probe diagnostics experiments for graduate and postgraduate level students was developed and installed at Department of Nanoscience and Advance Materials, Saurashtra University. From IPR, Dr. Mukesh Ranjan (PSED, IPR), Mr. Akshay Vaid (PSED, IPR), Mr. Sooraj K P (PSED, IPR) and Ms. Pramila (Electronics Group, IPR) contributed for the work agreement. Faculties and students from Saurashtra University attended the training program. As an outreach activity after installation and training, Dr. Mukesh Ranjan gave a talk about plasma in our day to day life.

Past Events

International Conference on Advances in Plasma Science & Technology (ICAPST-2020)

FCIPT scientists and research fellows participated in the International Conference on Advances in Plasma Science & Technology (ICAPST-2020) organized by Department of Physics Sri Shakthi Institute of Engineering and Technology, Coimbatore, India. The conference was focused on plasma processing of materials using both non-thermal and thermal plasmas. The participants were Dr. Alphonsa Joseph, Dr. Mukesh Ranjan, Dr. C. Balasubramanian, Dr. G. Ravi, Dr. Arkaprava Das, Mr. Ram Krushna Mohanta, Mr. Satyaprakash Kandada and Ms. Sukriti Hans. Here are some glimpses:

Mr. Ram Krushna Mohanta, Research scholar presenting his work

Dr. Alphonsa Joseph presenting the momento to a speaker in the session she chaired

Dr. G. Ravi, giving an invited talk

Dr. C. Balasubramanian giving an invited talk

"Plasma for a safe future"

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