Fighting COVID-19 with Non-Thermal Plasma Technology

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Abstract

Plasma with its exotic and reactive properties has a great potential towards developing plasma-based technologies to combat COVID-19 virus effectively. Non-Thermal Plasma (NTP) can be created in air/gas/gas mixture at atmospheric or reduced pressures as a very efficient source of active species. Different NTP generation techniques are already established for different applications. The ability of NTP to disrupt the infectiousness of a virus was demonstrated many years back and this technique has been successfully used for cleaning the air, sterilization of microorganisms contaminated surfaces, and potential applications against foodborne microorganisms in food processing & preservation since then. At present, with no vaccine for the COVID-19 pandemic, use of NTP, which have already been proved to inactivate several airborne viruses, scientists are exploring the possibility of whether it could also work against the Novel Coronavirus. The challenges of using non-thermal plasma in the context of the current pandemic may prove difficult because immediate approval for the use of NTP technology, designing and developing devices for treatment as per human needs remain major short-term barriers. However, efforts should continue to develop NTP based technology to combat Coronavirus for long term benefit of mankind.

Keywords: Coronavirus, Non-Thermal Plasmas, Disinfestations, Plasma Reactor.

Introduction

Plasma, the fourth state of matter is well known for its inherited exotic properties and characteristics due to the presence of electron and ions along with neutral particles maintaining their independent identities as well as exhibiting a collective behavior. Without any exaggeration one can specify plasma as that "plasma has its own mind" and it can behave accordingly under different situations. Plasma is said to exist in its various forms: thermal/non-thermal, hot/cold, fully ionized/partially ionized and equilibrium/non-equilibrium. Plasma is no more only a naturally existing state of matter but can be easily produced artificially in laboratories[1,2]. Even with the ease of its instantaneous production, its successful confinement for a significant time has eluded fusion process and has given way to many spin off applications of plasma. Without going into details of various forms of plasma and its different applications, we are here concerned about non-thermal version of plasma and its possible application in fighting Coronavirus. It is important to make it clear that the use of non-thermal plasma to combat corona virus is totally different than much talked "Plasma Therapy" in which antibodies from blood plasma of COVID-19 cured human are given to the Corona patient.

Non-Thermal Plasma

When the electron temperature is much higher than the temperature of heavy species (ions and neutrals) of the plasma, it is said to be in thermodynamic equilibrium state and is termed as Non-Thermal Plasma, also called as cold or non-equilibrium plasma. Moreover,

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this is a partially ionized state with low specific heat and does not transfer much heat from plasma to surroundings. Non-thermal plasma can be created in air or in another gas or a gas mixture at atmospheric or reduced pressure, and is a very efficient source of active species (radicals, excited species, charged particles, photons emission from UV to IR wavelength range, etc.)[3]. Cold plasmas are created in the laboratories by sending high speed electrons through gases like helium and air. These electrons hit the atoms and molecules with so much energy that they pull off the outermost electrons of the atoms and molecules in the gas, creating a soupy mixture of free electrons and free ions. Non-Thermal Plasmas for removal of hazardous pollutants have been produced by an electron beam and electrical discharge methods[4,5]. In an electron beam method, the electrons are accelerated by high voltage in the vacuum region before being injected into a gas-processing chamber through a thin foil window. The energy of electron beam is directly used for dissociation and ionization of the background gas. During ionization, a shower of ionization electrons is generated, which further produce a large volume of plasma. In the electrical discharge method, the objective gas is fed into plasma directly, which generates energetic electron and radicals and Non-Thermal Plasma are produced in atmospheric pressure using AC/DC or pulsed power sources. However, the Dielectric Barrier Discharge (DBD) method using AC high voltage source and pulsed power have been developed particularly to this day [6]. A kind of common Non-Thermal Plasma is the mercury-vapor gas within a fluorescent lamp.

Treating Viruses with Non-Thermal Plasma

Plasma is a state of matter in which high enough energy levels cause electrons to be knocked out of their orbits and enter a free state. Unsurprisingly, these radical electrons can be damaging to DNA and RNA. The ability of Non-Thermal Plasma to disrupt the infectiousness of a virus was first demonstrated by a group of Chinese researchers in 2015 [6]. Therefore, plasma research is focused on using Non-Thermal Plasma as a means to inactivate airborne viruses and such plasma has shown to achieve greater than 99% inactivation of an airborne viral surrogate (MS2 phage). Scientists have also proved that Non-Thermal Plasma could also inactivate the Porcine Reproductive and Respiratory Syndrome virus (PRRSv). According to scientists, the exact mechanism by which the plasma deactivates the viruses is still being explored, but more than 99 percent of viruses are inactivated as compared with before-and-after plasma treatment [7]. As the ability of these viruses to infect cells was substantially reduced, the overall amount of viral genetic material was hardly affected, which suggests that Non-Thermal Plasma with just the right intensity may be altering the proteins on the surface of the viruses. Scientists have shown previously that Coronaviruses are destroyed on copper alloy surfaces; therefore, copper as an antiviral agent can be deposited by plasma on textiles or face masks to prolong their sterility [6]. During this study, it was found that human Coronavirus 229E was rapidly inactivated on a range of copper alloys (within a few minutes for simulated fingertip contamination) and Cu/Zn combinations were very effective with lower copper concentration.

Fighting the COVID-19 with Plasma

Since there is no vaccine for the pandemic, our only protection against the Coronavirus at present is social distancing, face covering, and self-quarantine. When Non-Thermal Plasma has been proven to inactivate several airborne viruses, scientists are exploring the possibility whether it could work against the Novel Coronavirus [8,9]. As it became increasingly clear that the Novel Coronavirus is airborne, and was detected in the air vents of hospitals, people are looking out for the applicability of Non-Thermal Plasma technology to fight Coronavirus. Despite the need for more ways to combat Coronavirus, the challenges of using Non-Thermal Plasma in the context of the current pandemic may prove too cumbersome because immediate approval for the use of Non-Thermal Plasma technology, designing, developing and producing devices for treatment as per the human settings remain major short-term barriers. One possibility of curbing the spread of COVID-19 is the use of a Non-Thermal Plasma reactor that leaves airborne virus unable to infect host organisms, including people. Oxidation of viruses with plasma disables their mechanism of entering cells. Non-Thermal Plasma reactors will be useful to fight COVID-19, where people are concentrated in enclosed spaces. Scientists will need to better understand these variables before Non-Thermal Plasma reactors can be used in a big way to help fight the spread of COVID-19. There are several theories of how Non-Thermal Plasmas kill bacteria, but airborne viruses aren't "alive" like bacteria and therefore can't be "killed" in the same way. Also, understanding of Non-Thermal Plasma sterilization is mostly based on sterilizing contaminated surfaces using minutes-long plasma exposures, much longer than the sub-second exposures [10]. With the use of plasma disinfection, however, the viruses themselves remained largely unchanged

with their DNA, which means that the plasma didn't destroy the virus but rather altered its ability to infect.

The recent pandemic has greatly stressed supply chains, treatment modalities, and medical resources. Cold plasma air filter based on the technology to neutralize Coronavirus in the air is being advocated to combat COVID-19. Cold Atmospheric Plasma (CAP) has been used for a wide range of applications in biomedical engineering due to its many components including electrons, charged particles, Reactive Oxygen Species (ROS), Reactive Nitrogen Species (RNS), free radicals, ultraviolet (UV) photons, molecules, electromagnetic fields, physical forces, and electric fields. Viral pandemics, such as COVID-19, highlight the need for alternative virus inactivation methods to replace, complement, or upgrade existing procedures. Viruses can infect all cell-based organisms, from bacteria to humans, animals, and plants, and Cold Plasma (CP) has entered this field as a novel, efficient, and clean solution for virus inactivation. CP can be used as an environmentally friendly tool for virus inactivation as it can inactivate different human, animal, and plant viruses in various matrices. When using CP for virus inactivation, it is important to set the correct parameters and to choose treatment durations that allow particles to interact with the contaminated material. Reactive oxygen and/or nitrogen species have been shown to be responsible for virus inactivation through effects on proteins and/or nucleic acids. The development of more accurate methods will provide information on which plasma particles are crucial in each environment/situation, and how exactly they affect viruses. Studies indicate the advantages of highly deployable CAP devices for both sanitation and treatment of COVID-19. We hope that this timely research will help engage the broader community of engineers that wish to help the medical community with this pandemic and to prevent and treat future outbreaks.

Working of Non-Thermal Plasma Reactor

As public health research reveals how the virus can persist and be transmitted through air in indoor environments, it will become increasingly important for engineers to develop air sterilization technology that can neutralize or remove it. Plasma treatment technology uses electric pulses to excite the particles in the air, creating a molecular maelstrom can be wielded to blast apart chemical contaminants and bacteria. Non-Thermal or Cold Plasma does not generate heat, so it's safer to handle - and much easier to control. The filter uses a grid of wires, called a dielectric barrier grating discharge system, to generate the electrical pulses necessary to produce a screen of plasma. Inside the Non-Thermal Plasma reactor (Figure 1), borosilicate glass beads are packed into a cylindrical shape, or bed. Forcing air through the grid theoretically enables deactivation of viral particles. To gauge the effectiveness of Non-Thermal Plasmas, researchers pumped virus particles into flowing air as it enters a reactor. The viruses flow with the air through the spaces between the beads, and that's where they're inactivated. In the void spaces, the plasma is produced as the applied voltage increases until sparking gets initiated and the bacteria in the air stream are attacked by unstable molecular fragments called radicals until the virus has diminished its ability to infect cells.

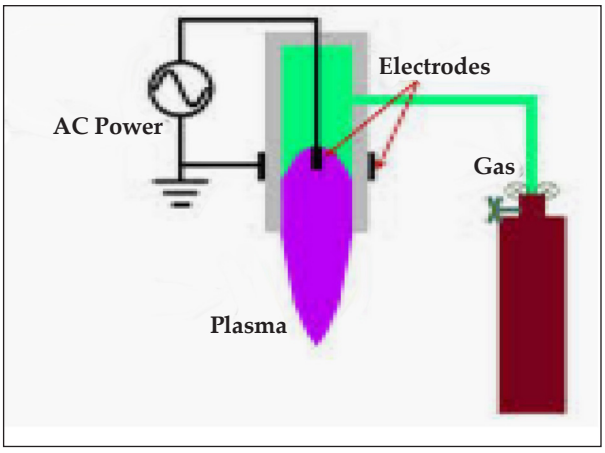

Fig.1: Non-thermal plasma reactor *(Credit: preprints.org)*

Final Words

Nations around the globe are struggling to contain the Novel Coronavirus (COVID-19) and this research represents a step towards next generation collective protection technologies that can sterilize air supplied to inhabited enclosed environments. Scientists envision the technology as an eventual replacement for the surgical mask and it could provide complementary protection during the long development cycle required for vaccines. Moreover, the disinfectant effect of Non-Thermal Plasmas is not dependent on viral strain so it doesn't involve months or years of development as required to develop specific vaccines for each novel or emerging viral disease. Filters have long been used to remove particles, including viruses and bacteria, from the air we breathe. Particle filters are key components of building and aircraft ventilation systems. Unfortunately, viruses are much smaller than the smallest particles that are typically captured by those filters reliably. In comparison to surgical masks and ultraviolet radiations, use of Non-Thermal Plasma technology could provide a more efficient way of ster-

ilizing air than filtration or inactivation, alone. Thus, a technology like Non-Thermal Plasma reactor can be a good breakthrough in near future that will help humans to combat COVID-19 infections.

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