SAPP XXV

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Edited by G. D. Megersa, E. Maťaš, J. Országh, P. Papp, Š. Matejčík

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Symposium organised by Department of Experimental Physics, Faculty of Mathematics, Physics and Informatics, Comenius University in Bratislava and Society for Plasma Research and Applications in hotel SOREA TRIGAN***.

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INDOOR AIR CLEANING BY NON-THERMAL PLASMA AND PHOTOCATALYSIS

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Indoor air contains many harmful compounds (chemical pollutants, pathogenic aerosols, tobacco smoke, etc.). We use non-thermal atmospheric plasma in a dielectric barrier discharge configuration and UV-induced photocatalysis for the treatment of polluted indoor air. The main advantage of using these two technologies is their capability to destroy and mineralize pollutants to inert gases, contrary to traditional filters that just trap them. We target to decompose chemical pollutants and pathogenic bio-aerosols, at high gas flow rates (>300 L/min) for a real scale use, which is the main challenge of this study.

1. Introduction

Indoor air contains many harmful components (chemical pollutants, bacteria, pathogenic aerosols, tobacco smoke, etc.) that can cause respiratory, cardiovascular, and oncological diseases under long-term exposure. Hospital-acquired infections are also spread through air contaminants [1]. Finding an innovative technology that would efficiently remove all kinds of airborne pollutants without producing harmful by-products and with a low energy cost would be not only a major advance for public health but would also help prevent the spread of airborne pathogens such as in the case of the recent COVID-19 pandemic. The goal of this work is to assess the efficacy of non-thermal plasma (NTP) dielectric barrier discharge combined with UV-A induced photocatalysis for the removal of volatile organic compounds (VOCs) and inactivation of aerosol-borne bacteria at a high gas flow rate. NTP and photocatalysis have proven their capabilities to decompose or inactivate a broad range of harmful compounds present in indoor air. Moreover, combining these two techniques may offer a very effective hybrid air decontamination device, as studies suggest a synergetic effect [2].

2. Experiment

We designed an indoor air decontamination device that combines a Dielectric Barrier Discharge (DBD) for the NTP generation (Fig. 1), and a TiO_2 coating which is activated on-demand by UV-A LEDs. The device uses a very short residence time of the pollutant in the reactor: the gas flow rate was set above 300 L/min and uses a single-pass method to determine the pollutant reduction.

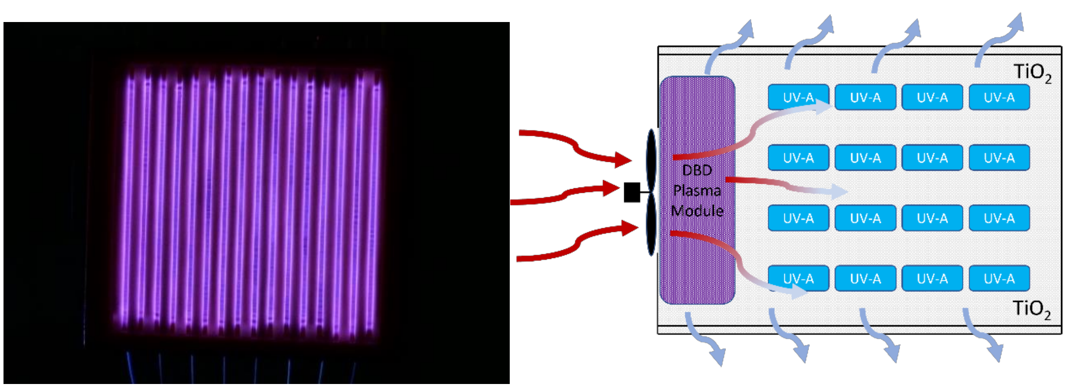

Fig. 1. Photo of the DBD module and schematic of the air decontamination device combining DBD and UV-A induced photocatalysis.

The chemical analysis of the VOC contaminants (formaldehyde) and the gaseous species produced by the DBD was performed by FTIR absorption spectroscopy (Shimadzu IRSpirit-X spectrometer) using a 542 cm absorption path gas cell equipped with ZnSe windows. Single-pass of the bio-contaminated water aerosols through the reactor was set at a high gas flow rate (>300 L/min). The aerosol-borne bacteria *E. coli* and *S. aureus* were collected on Petri dishes for 30 seconds and evaluated by microbiological thermostatic cultivation.

3. Results and discussion

The removal efficiency of about 40% was reached for the formaldehyde concentration, as shown in Fig. 2, and it slightly decreased with the air flow rate. We also monitored the concentration of ozone generated by the DBD, which is not desired for human exposure, thus it must be decomposed by the photocatalytic process before exiting the reactor.

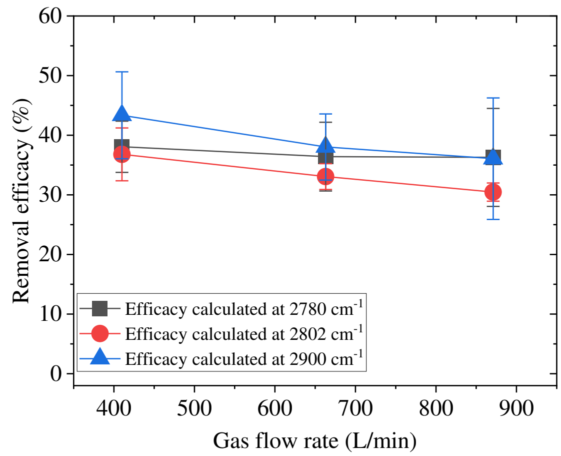

Fig. 2. Removal efficacy of formaldehyde (HCHO) in a single pass vs. gas flow rate, measured by infrared absorption spectra at three different wavenumbers typical for HCHO absorption.

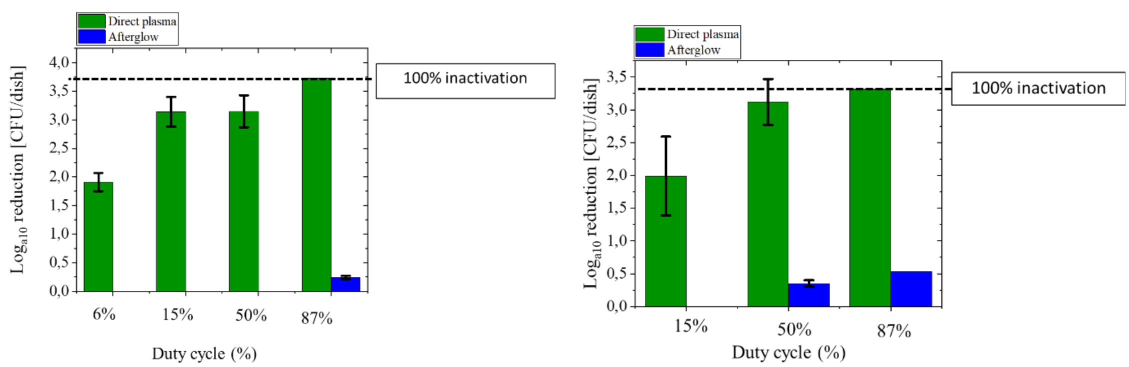

Fig. 3. DBD effects on water aerosol-borne *E. coli* (left) and *S. aureus* (right) bacteria at various duty cycles of the power supply.

The obtained results of the decontamination of bio-aerosols are also very promising. We reached 3,73 log (99.98%) and 3,32 log (99.95%) reduction for the inactivation of water aerosol-borne *E. coli* and *S. aureus,* respectively. 100% inactivation for both bacteria was achieved with a power supply duty cycle set at 87%, and high inactivation was achieved even at a low duty cycle with lower ozone production [3].

4. Conclusions

We developed a new design for indoor air decontamination allowing for better efficacy of air chemical (formaldehyde) and biological (*E. coli* and *S. aureus* bacteria) contaminants. It employs combined effects of DBD plasma and UV-A activated TiO_2 photocatalysis. The device is applicable for high gas flow rates (>300 L/min). It enables complete mineralization of organic pollutants to H_2O and CO_2. As the NTP technology, it produces a strong oxidant ozone, which helps to remove the pollutants and pathogens. On the other hand, ozone is an undesirable product to be emitted into the indoor air, thus has to be removed by the photocatalytic effect. High inactivation of both organic chemical pollutants (40%) and airborne bio-pathogens (up to 100%) was achieved at a low specific input energy and very high gas flow rates. This combined NTP-photocatalysis technology can be applied in all sorts of indoor settings, including hospitals and public spaces, as well as in potential manned space missions.

5. Acknowledgments

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