SAPP XXV

25th Symposium on Application of Plasma Processes
and
14th EU-Japan Joint Symposium on Plasma Processing

Book of Contributed Papers

Štrbské Pleso, Slovakia

31 Jan - 5 Feb, 2025

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

Book of Contributed Papers: 25th Symposium on Application of Plasma Processes and 14th EU-Japan Joint Symposium on Plasma Processing, Štrbské Pleso, Slovakia, 31 January – 5 February 2025.

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***.

Editors: G. D. Megersa, E. Maťaš, J. Országh, P. Papp, Š. Matejčík

Publisher: Society for Plasma Research and Applications, Bratislava, Slovakia

Issued: January 2025, Bratislava, first issue

ISBN: 978-80-972179-5-2

URL: https://neon.dpp.fmph.uniba.sk/sapp/

Local Organizers

Department of Experimental Physics
Faculty of Mathematics, Physics and Informatics
Comenius University in Bratislava
Mlynská dolina F2
842 48 Bratislava, Slovakia
URL: http://www.fmph.uniba.sk/
Tel.: +421 2 602 95 686
Fax: +421 2 654 29 980

Society for plasma research and applications
Faculty of Mathematics, Physics and Informatics
Comenius University Bratislava
Mlynská dolina F2
842 48 Bratislava, Slovakia
E-mail: spvap@neon.dpp.fmph.uniba.sk
Tel.: +421 2 602 95 686

Local Organizing Committee

Peter Papp (chairman)
Štefan Matejčík
František Krčma
Juraj Országh
Ladislav Moravský
Peter Čermák
Matej Klas
Barbora Stachová
Emanuel Maťaš
Filip Pastierovič
Samuel Peter Kovár
Priyanka Kumari
Gadisa Deme Megersa
Enmily Garcia
Angel Pardo

International Scientific Committee

25th Symposium on Application of Plasma Processes

Prof. J. Benedikt	Christian-Albrechts-University, Kiel, Germany
Dr. R. Brandenburg	INP, Greifswald, Germany
Dr. T. Field	Queen's University, Belfast, United Kingdom
Prof. S. Hamaguchi	Osaka University, Japan
Dr. P. Hartmann	HUN-REN Wigner Research Centre for Physics, Budapest, Hungary
Prof. F. Krčma	Brno University of Technology, Brno, Czech Republic
Prof. N. Mason	School of Physical Sciences, University of Kent, United Kingdom
Prof. Š. Matejčík	Comenius University in Bratislava, Slovakia
Prof. J. Pawlat	University of Technology, Lublin, Poland
Prof. M. Radmilović-Radjenović	Institute of Physics, Belgrade, Serbia
Prof. P. Scheier	Leopold-Franzens University, Innsbruck, Austria

14th EU-Japan Joint Symposium on Plasma Processing

Prof. S. Hamaguchi	Osaka University, Japan
Prof. N. Mason	School of Physical Sciences, University of Kent, United Kingdom
Prof. Z. Petrović	Institute of Physics, Belgrade, Serbia

Reading Committee

Prof. Š. Matejčík	Comenius University in Bratislava, Slovakia
Prof. F. Krčma	Brno University of Technology, Brno, Czech Republic
Prof. N. Mason	University of Kent, United Kingdom
Assoc. Prof. P. Papp	Comenius University in Bratislava, Slovakia
Assoc. Prof. J. Országh	Comenius University in Bratislava, Slovakia
Assoc. Prof. V. Medvecká	Comenius University in Bratislava, Slovakia
Assoc. Prof. M. Klas	Comenius University in Bratislava, Slovakia
Assoc. Prof. P. Čermák	Comenius University in Bratislava, Slovakia
Dr. Vahideh Ilbeigi	Comenius University in Bratislava, Slovakia

PLASMA-CATALYTIC GAS TREATMENT: THE ROLE OF PELLET-SHAPED MATERIAL IN PACKED-BED DBD REACTORS

Richard Cimerman[1], Jakub Roubíček[1], Jana Kšanová[1], L. Satrapinskyy[2], K. Hensel[1]

[1]Division of Environmental Physics, Faculty of Mathematics, Physics, and Informatics, Comenius University, Bratislava, Slovakia
[2]Department of Experimental Physics, Faculty of Mathematics, Physics, and Informatics, Comenius University, Bratislava, Slovakia
E-mail: richard.cimerman@fmph.uniba.sk

This study explores the role of solid pellet-shaped material in plasma-catalytic packed-bed DBD reactors for gas treatment applications. Different pellet-shaped materials, with varying catalytic properties, were tested, demonstrating their distinct influence on the efficiency of gas treatment. Additionally, the results indicated a significant influence of pellet-shaped materials' properties on the electrical characteristics of the reactors. The results emphasize the crucial role of material selection and its properties in optimizing plasma-catalytic gas treatment systems, especially for removing hydrocarbons and converting CO_2 from gas mixtures.

1. Introduction

Packed-bed dielectric barrier discharge (DBD) reactors are widely recognized for their applications in nonthermal plasma (NTP) gas treatment [1]. These reactors typically have a cylindrical geometry and are filled with solid packing materials, often in the form of small spherical or cylindrical pellets. When these materials possess catalytic properties, packed-bed DBD reactors offer a simple but effective combination of NTP and catalysis, i.e., plasma catalysis. Optimizing their performance requires a detailed understanding of how the pellet-shaped material influences both the chemical processes and the electrical characteristics of the discharge. This study investigates the impact of various pellet-shaped materials with distinct catalytic properties on the efficiency of packed-bed DBD reactors for gas treatment. Specifically, it examines the removal (conversion) of various model pollutants, where naphthalene ($C_{10}H_8$) and toluene (C_7H_8) represent organic gaseous pollutants (hydrocarbons), in contrast to carbon dioxide (CO_2), a major inorganic pollutant contributing significantly to climate change.

2. Methodology

In this work, NTP was generated by cylindrical packed-bed DBD reactors that were powered by an AC high voltage with a fixed frequency of 1 kHz at various energy densities (up to 2400 J/l) using various carrier gases (ambient/synthetic air or dry/humid N_2). The reactors were filled with various pellet-shaped materials depending on the gas treatment application. For the removal of naphthalene and toluene, titanium dioxide TiO_2, platinum or palladium coated on alumina Pt-, Pd/Al_2O_3, barium titanate $BaTiO_3$, zirconium dioxide ZrO_2, alumina Al_2O_3 and glass beads were used [2, 3], while titanium dioxide TiO_2, barium titanate $BaTiO_3$, zirconium dioxide ZrO_2, silicon dioxide SiO_2 and magnesium oxide MgO were tested for CO_2 conversion. In addition to examining the eventual catalytic properties of the materials, the effects of their dielectric constant (5–4000), shape (cylindrical vs. spherical), size (Φ 3–5 mm), and specific surface area (SSA; 37–150 m^2/g) were also investigated. Moreover, a combination of different packing materials in a single reactor was also studied. Both gaseous and solid products of toluene, naphthalene, and CO_2 conversion were analyzed by the Fourier-transform infrared absorption (FTIR) spectrometry. The surface of the pellet-shaped materials before and after the use was analysed by scanning electron microscopy (SEM) equipped with energy-dispersive X-ray (EDX) spectroscopy. In addition to the chemical effects of the packed-bed DBD reactors, their electrical characteristics were also examined. Out of them, discharge power, amplitudes, and numbers of current pulses, reactor capacitances and transferred charges were evaluated based on detailed oscilloscopic measurements and analysis of Lissajous figures.

3. Results and discussion

The study demonstrated that key material parameters (i.e., dielectric constant, shape, size, and SSA) significantly influence the dominant discharge mode (surface or filamentary) in the packed-bed DBD reactor, thereby determining its electrical characteristics. This discharge mode directly impacts reactor performance; however, materials that are efficient for one application may not perform equally well for another. For instance, Figure 1 compares the naphthalene removal efficiency (Fig. 1a), toluene removal efficiency (Fig. 1b) and CO_2 conversion efficiency (Fig. 1c) for reactors filled with various pellet-shaped materials. In all experiments, the reactor without any material (DBD alone) exhibited the lowest efficiency. While all packed-bed DBD reactors outperformed the empty DBD configuration, their efficiency varied significantly depending on the material used. The reactor filled with $BaTiO_3$ achieved the highest CO_2 conversion efficiency but was the least effective for naphthalene removal. In contrast, TiO_2 material showed the highest naphthalene removal efficiency, while its toluene removal and CO_2 conversion performance were among the lowest.

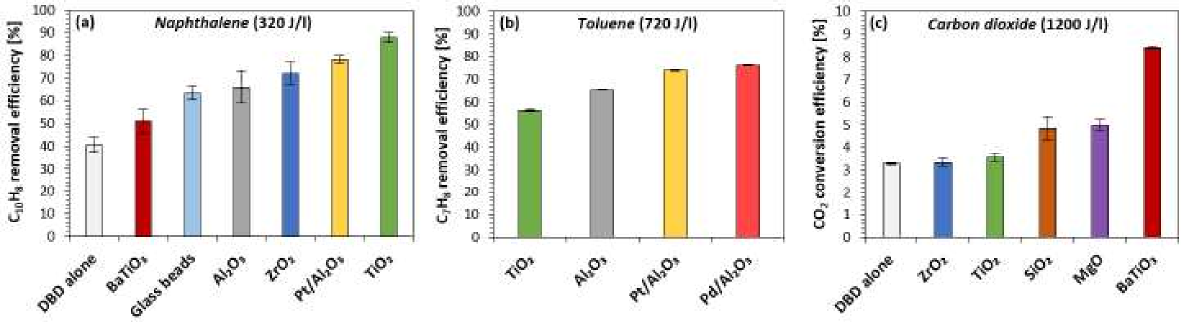

Fig. 1. Naphthalene removal efficiency (a), toluene removal efficiency (b) and CO_2 conversion efficiency (c) for different packed-bed DBD reactors filled with various materials.

Finally, the electrical characteristics of the packed-bed DBD reactors were strongly influenced by the properties of the pellet-shaped materials. However, the removal/conversion efficiencies of the model pollutants showed no direct correlation with these characteristics, suggesting a significant role of surface catalytic processes.

4. Conclusions

This research highlights the pivotal role of material selection in plasma catalysis. The findings reveal that a material highly efficient for one application, such as CO_2 conversion, may perform poorly in another, such as hydrocarbon removal. By examining the interplay between material properties, discharge characteristics, and pollutant removal efficiency, this work provides valuable insights for optimizing plasma-catalytic systems aimed at sustainable gas treatment solutions.

5. Acknowledgements

Funded by the EU NextGenerationEU through the Recovery and Resilience Plan for Slovakia under the project No. 09I03-03-V04-00092. The authors also express their gratitude to Mária Maťašová (Cíbiková) and Diana Priškinová (Račková) for their assistance with the experiments.

6. References

[1] Chen H L, Lee H M, Chen S H, Chang M B 2008 *Ind. Eng. Chem. Res.* **47** 2122–2130.
[2] Cimerman R, Račková D, Hensel K 2018 *J. Phys. D. Appl. Phys.* **51** 274003.
[3] Cimerman R, Cíbiková M, Satrapinskyy L, Hensel K 2020 *Catalysts* **10** 1476.