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Physics of Filamentary Discharges through Porous Media for Plasma Assisted Catalysis Applications

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Abstract

In the context of gas treatment by catalysis oxidation assisted by non-thermal plasma, investigations on pulsed corona streamers in porous catalysis media are reported. Fast optical imaging coupled with current waveforms analysis gives precise information on streamers propagation in heterogeneous structures such as “honeycomb” ceramic monoliths or simple porous ceramics. In those cases, it is observed that space and time development of discharges is very different according to the nature and the size of the support, which lets us suppose that charge mechanisms and porosity effects are mainly involved.

Introduction

In order to treat pollutants such as volatile organic compounds (VOC), recent research showed the interest of the association of two processes: oxidation by catalysis and treatment by non-thermal plasma. This combination requires the use of catalyst supports inevitably modifying the physicochemical properties of the plasma [1,2,3]. The optimization of depollution processes involving this technique requires then the comprehension of plasma development in strongly inhomogenous structures.

Our work mainly relates to the study of a point-to-plane reactor for which plasma is created by a “bush” of filamentary discharges and where the catalyst support is a honeycomb monolith of various nature and geometry. The main objective of the study is to understand the effects of the catalyst support on the space and time development of these discharges. It is completed by the work of K. Hensel on the development of pulsed filamentary discharge inside porous ceramics with different pore sizes [4].

For that purpose, filamentary plasma is generated under short impulse high voltage allowing the use and triggering of fast opening and streak cameras. Optical measurements will be made to describe rather precisely how the filaments propagate within the support. Besides, voltage and currents waveforms treatment will give information of how energy is distributed within the support. Comparisons will be made on plasma properties when developping within or without the catalytic support. The effects of the nature and the geometry of the support will be studied. Several types of materials will be tested with various sizes of channels.

This experimental study intends to bring comprehension on the effects of catalytic support surfaces on non-thermal plasma development and reactivity. Charge mechanisms and temperature effects due to these surfaces will be discussed. Previous experiments on a plane-to-plane cordierite DBD reactor where much more streamers propagated within the structure will support our discussion.

Results and discussion

The experimental setup consists of short positive high voltage pulses (50 ns) supplied by a coaxial line generator to a point made of rhodium with a tip radius of 100 µm. The ground plane is divided into five concentric rings, each grounded through a 50 Ω resistance. Small pieces of dielectric honeycomb monoliths made of porous cordierite or mullite-zircone and with different sizes can be inserted between the two electrodes. Different support walls thickness between 150 to 500 µm can be tested and the number of channels lying between the electrodes ranges from one to four. Currents and voltage waveforms are respectively recorded through 50 Ω resistances and a voltage capacitive divider, all connected to a fast digital oscilloscope. By means of appropriated delay units, a short time integration camera (50 ns) and a high speed streak camera (2mm/ns on images), both coupled to intensifiers, are triggered. By simultaneous recordings of still and streak images of a discharge, space and time development in honeycomb monoliths can be rather precisely determined.

When a monolith is inserted between the point and the plane, the behavior of the discharge is very different from what occurs in air and it depends on the properties of the support. Using cordierite of 2.5 mm height, with two channels and a wall thickness of 150 µm, only one, two or maximum three streamers propagate through the channels. On streak pictures as shown on Figure 1, the discharge in cordierite shows two luminous parts. The first one is its propagation from the point to the top surface of the monolith and the second one is inside the channels. One can estimate the propagation velocity of the streamers inside the channels to about 2.10^7 cm/s.

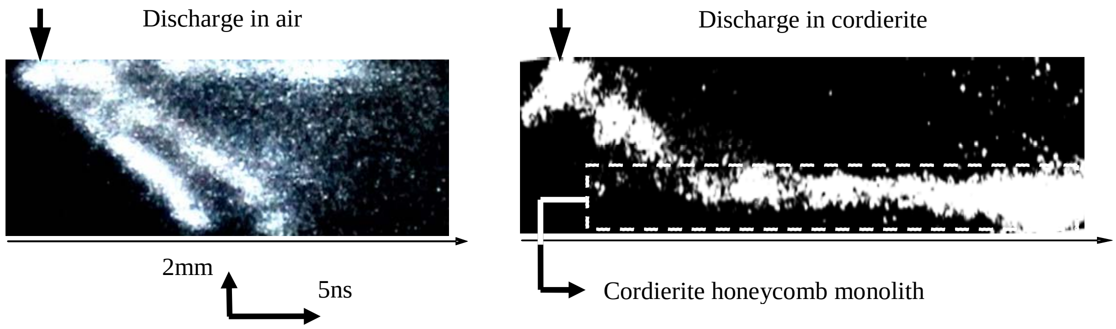

Figure 1. Streak pictures of discharges in air and in a monolith of cordierite (400 cpsi, 2 channels, 150 µm).

This two-steps process can be identified on the current waveforms where two different pulses can be observed. A first current pulse which is similar for all plane strips corresponds to a displacement current when streamers develop from the point and hit the dielectric surface. This part allows estimating the charge density deposited onto the surface, with a typical value of 200 $\mu C/m^2$, probably necessary to induce a sufficiently high electric field (about 25 kV/cm) inside the channels so that the discharge can propagate inside. The second pulse arises 20 to 30 ns later and displays the arrival of streamers at the plane electrode. When the number of channels or the wall thickness is increased, the ability for the discharge to initiate within the channels is weaker. This point does not seem so clear since the field at the surface should not depend on the geometric characteristics of the monolith. However, these observations are made with another material which is mullite-zircone, whose mechanical properties are quite different from those of the cordierite which seems to be quite much porous. The physical properties of the support such as porosity may then have an effect on the discharge development. This effect has been shown for AC discharges developing through porous ceramics of different pore sizes between two meshes [4].

Conclusions

Electrical and fast optical records are performed to analyse the propagation of streamers through the channels of a dielectric honeycomb monolith. It is observed that some streamers are able to expand through the channels with lower velocities than in the air. Their ability to cross the media seems to be correlated to the charge density deposited on its top surface, which needs to be high enough to reach the critical field for streamers development. The geometric and physical properties of the dielectric have a noticeable influence on the behavior of the discharge, with a better propagation for thin walls and porous materials.

References

[1] S. Ibuka, T. Nakamura, T. Murakami, H. Kondo, K. Yasuoka, S. Ishii, "Novel plasma reactor using honeycomb ceramics driven by a fast SI-thyristor for environmental applications", Pulsed Power Plasma Science, 2, 2001, pp. 1118-1121

[2] P. Tardiveau, C. Boyer, F. Jorand, C. Postel, S. Pasquiers, "Optical and electrical characterization of pulsed dielectric barrier discharges in heterogeneous structures", IEEE transactions on plasma science, 33, 2005, pp. 314-315

[3] N. Blin-Simiand, F. Jorand, S. Pasquiers, P. Tardiveau, "Removal of 2-heptanone by dielectric barrier discharge in air and in a monolith of cordierite", Proceedings of the 4th International Symposium on Non-thermal Plasma Technology for Pollution Control and Sustainable Energy Development, 1, 2004, pp. 254-258

[4] K. Hensel, M. Janda, M. Lestinsky, Z. Machala, V. Martisovits, P. Tardiveau, A. Mizuno, "Electrical and optical properties of AC microdischarges in porous ceramics", 10th International Symposium on High Pressure Low Temperature Plasma Chemistry, pp. 41- 46, 2006