17th Symposium on Application of Plasma Processes

Visegrad Workshop on Research of Plasma Physics

Visegrad Fund

Book of Contributed Papers

Liptovský Ján, Slovakia
January, 17-22, 2009

Edited by P. Papp, J. Országh, J. Matúška, Š. Matejčík

Coplanar Surface Barrier Discharge Assisted Generation of Discharges inside the Honeycomb Monolith

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Abstract

The discharge generated inside the bundle of quartz capillaries that emulated the honeycomb monolith structure was investigated. The diffuse plasma generated by the diffuse coplanar surface barrier discharge was extended into the capillaries by the application of the additional DC electric field component across the capillaries. The proposed technique resulted in a homogenous plasma formation inside the capillaries. The paper presents essential electrical and optical characteristics of the discharges inside capillaries and describes basic discharge properties.

Introduction

Automotive catalytic converters have been developed and used for abatement of exhaust gases emitted by various vehicles for several decades. Despite their high efficiency, legislation limits for automobile emissions require still new and new technologies to be applied in order to meet the current emission standards. The present catalytic converts must have high activity (up to 98%) and selectivity even at low temperatures and high thermal stability. The major problems of the catalysts consist of their low activity at low temperatures and performance in non-stiochiometric conditions. Several techniques have been applied to overcome the low temperature problem including hydrocarbon adsorbing trap, electrical or chemically heated catalysts placed upstream of the main catalysts system, closely coupled catalysts, along the effort to develop new catalysts [1]. Recently, we have proposed an idea to solve some of the problems by combination of the catalyst with non-thermal plasma generated by electric discharges in a hybrid common system. Generation of homogenous and stable plasma inside thin capillary channels of honeycomb-shaped catalysts was rather difficult, due to low discharge stability and mechanical breakdown of the washcoat caused by random discharge sparking. Therefore instead of generating the discharge directly inside the body of the catalysts (inside the channels), we generated it outside and subsequently extended it into the catalyst. It was done by combination of AC and DC powers in three-electrode geometry. In the past, we have demonstrated this technique by generating auxiliary AC discharge inside a pellet bed, which was then extended into the channels by the application of the additional DC electric field component across the monolith [2].

In this paper we do present a similar system capable to generate the stable and homogenous plasma inside the honeycomb monolith. Instead of discharge in the pellet bed, a diffuse coplanar surface barrier discharge (DCSBD) was used [3]. The DCSBD generates a thin layer of macroscopically uniform plasma over the surface of dielectric barrier with the higher number density of charged particles comparing to the standard volume dielectric barrier discharge. The role DCSBD in the reported system was to supply a sufficient amount of seed positive ions to ionize the inner capillary space. The paper presents essential electrical and optical characteristics of the discharges inside capillaries, describes basic discharge properties and addresses the effects of applied voltage, discharge power and dimensions of the capillaries.

Results and discussion

Schematic drawing of the discharge system is depicted on Fig. 1. The system consisted of alumina (Al_2O_3) made DCSBD discharge panel and a quartz tube ($\varnothing$ = 26 mm) filled with a bunch of quartz capillaries ($\varnothing$ = 1; 2 mm, L = 2 cm), which was positioned on the top of alumina barrier. The transparent capillaries were used instead of ceramic honeycomb monolith in order to be able to visually observe the discharge. System of electrodes consisted of silver strips embedded inside the alumina (DCSBD system), aluminum foil wrapped around the quartz tube and metal mesh placed on the top of the capillaries. The DCSBD reactor was powered by AC (14 kHz, 10kV), the mesh by negative DC high voltage, and the foil was grounded. The electrical parameters of discharges were monitored by the current monitors and high voltage probes and the signals were recorded by the oscilloscope. Optical measurements were performed by an emission spectrometer and the images were recorded by a digital camera. The experiments were performed in atmospheric pressure ambient air and at room temperature.

The discharge inside the capillaries was generated with the assistance of the DCSBD discharge, which produced diffuse homogenous plasma on the surface of the ceramics. Upon the application of DC voltage across the capillaries development of a stable streamer discharge inside them was observed. The stability of the streamer discharge was controlled and its transition to a spark was suppressed by using series resistance in the electric circuit. The amplitude of the current pulses of a streamer discharge measured on the grounded electrode increased with the DC applied voltage, but was found independent of the power of the DCSBD (Fig.2). By increasing the amplitude of DC voltage, stable and homogenous plasma is formed inside the channels. The discharge emission intensity measured in the middle of the capillaries increased with both applied DC voltage and power of the DCSBD (Fig.3). The measurements of the emission intensity along the axis of the capillary were also performed to evaluate the level of the plasma lateral homogeneity.

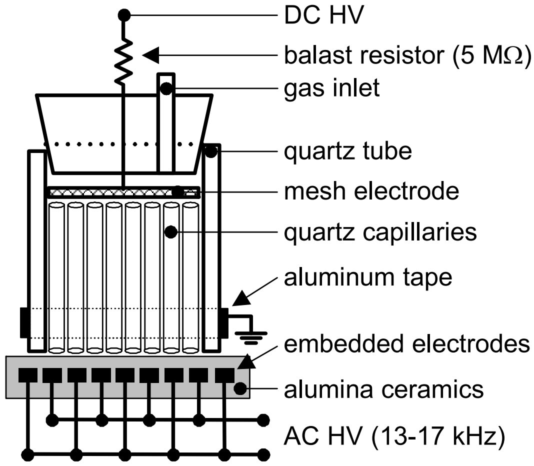

Fig.1: Scheme of the discharge system.

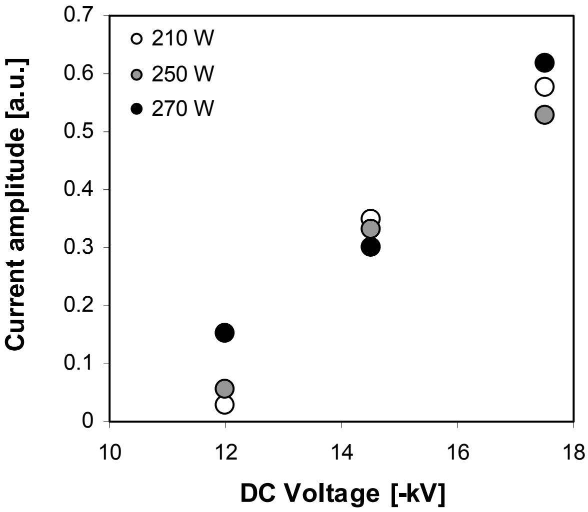

Fig.2: Amplitude of the current pulses as functions of the DC applied voltage and the DCSBD power.

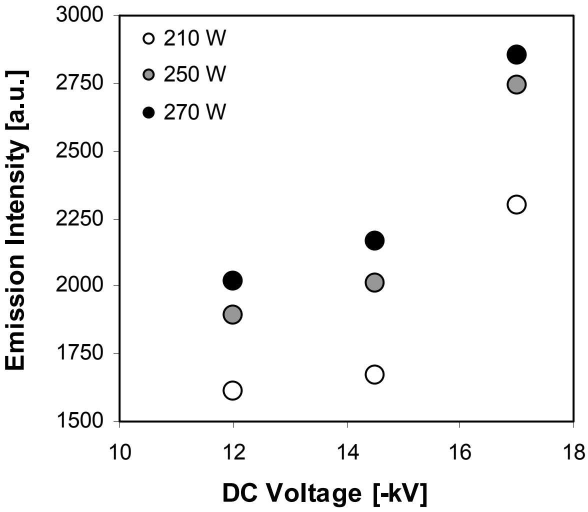

Fig.3: Emission intensity as functions of the DC applied voltage and the DCSBD power.

Conclusions

Generation of discharge inside spatially confined volume inside the glass capillaries emulating honeycomb monolith structure by using the DCSBD was presented. The discharge inside capillaries was generated by a superposition of DCSBD coupled in series with DC powered honeycomb monolith. The paper introduced the properties of the discharge based on electrical and optical measurements. The homogeneity and the stability of the discharge can be controlled by amplitude and power of the individual power supplies. The presented discharge generates relatively cold plasma with a high level of non-equilibrium.

The research has been supported by the Slovak Research and Development Agency, project No. APVV-0485-06 and the Slovak Grant Agency VEGA 1/0711/09.

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