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Physical Properties and Plasma-Chemical Effects of Microdischarges in Porous Ceramics

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Abstract

Physical properties of microdischarges inside porous ceramics have been investigated by means of electrical and optical measurements. The plasma-chemical effects of the microdischarges were evaluated by absorption spectrometry. The effects of pore size, discharge power, gas mixture composition and gas flow on the discharge properties and its plasma-chemical activity were examined.

Introduction

Non-thermal plasmas generated by various types of electrical discharges (mostly streamer and pulsed coronas, and various types of barrier discharges) are widely applied for various environmental applications. These discharges are typical with non-equilibrium character and a large amount of thin filamentary channels, called microdischarges. The chemical effect of the discharges can be enhanced if they are combined with catalysts (e.g. of pellet bed or honeycomb structure). Several works dealing with the generation of microdischarges in narrow cavities and capillaries of porous dielectrics and catalysts by pulsed power were published recently [1-3]. We have found the microdischarges can also be generated with a DC and an AC power [4, 5]. The objective of the presented research was the investigation of the physical properties of the microdischarges inside porous ceramics and the test of their plasma chemical efficiency. The methods of the investigations consisted of oscilloscopic measurements and optical emission and absorption spectroscopy. Pore size, gas flow rate, gas composition and discharge power were tested to determine the optimal conditions of the discharge generation.

Experimental Set-up

The detailed description of the experimental setup consisting of a discharge reactor and electric and optical measuring circuits can be found elsewhere [5, 6]. The pore size of the ceramics was 0.8 - 200 μm, their diameter and thickness were 31 and 7 mm, respectively. AC high voltage power supply was used to ignite the discharge. The discharge voltage and current were measured by probes linked to the oscilloscope. Emission spectroscopy optical system consisted of a dual fiber-optic compact spectrometer with CCD detector. Besides, the photographs of the discharge were taken by a digital camera with adjustable aperture and exposure time. The experiments were carried out in various mixtures of oxygen and nitrogen at the atmospheric pressure and at room temperature. The total gas flow rate ranged from 0.4 to 2.0 l/min.

Results and Discussion

In the previous work [5] we have commented on the effect of the pore size, discharge power, and gas mixture on the discharge properties based on the electrical measurements and visual observation (mainly a digital photography) of the discharge. In this paper, we summarize the main results and add more information obtained from the optical emission spectroscopic measurements.

Generation of microdischarges inside the ceramics was possible only at the specific discharge power depending on the pore size of the ceramics. At a small voltage a surface discharge over the surface of the ceramics may be observed. With the increase of the applied voltage, however, microdischarges inside the ceramics are formed. The onset voltage of the microdischarges increased with the decreasing pore size. For a very small pore size (less than 2 μm) only a surface discharge can be observed. The results are in the agreement with what can theoretically be derived from the Paschen's law. Upon the transition from the surface discharge to the microdischarges, the slope of the I-U characteristics increases. The bigger is the pore size the bigger is the slope, as the result of the increase of the discharge current. The amplitude of the current pulses increased with the applied voltage and discharge current, the maximal observed with 50 and 80 μm pore size ceramics.

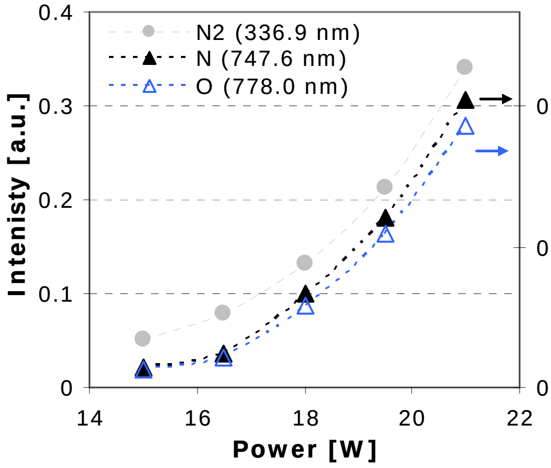

Fig 1: Emission intensity as a function of total power (5% O_2 in N_2, Q = 1.0 l/min).

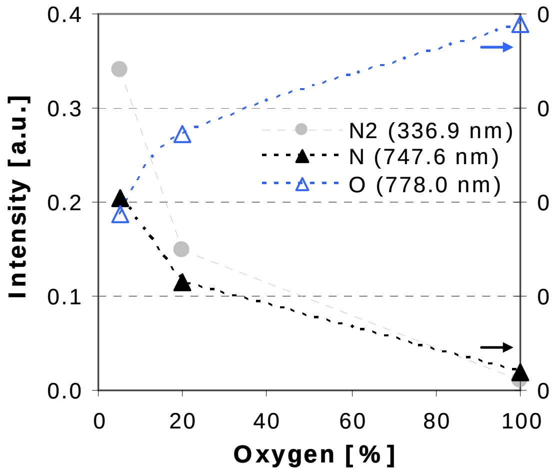

Fig 2: Emission intensity as a function of O_2 content (P= 17.5 W, Q = 1.0 l/min).

The optical observations by photography and emission spectroscopy showed the spatial and temporal distribution of channels was not steady, but changed randomly in time. Light emission increased with the discharge power (Fig.1). In pure nitrogen the light emission was homogenously distributed over the whole surface of the ceramics. Oxygen in the mixture caused the channels concentrated mainly at the outer circumference of the ceramics. The effect of oxygen on the emission intensity can be seen on Fig.2. In nitrogen and air, the 2nd positive system of N_2 in the violet region corresponding to the transition $C^3\Pi_u$ – $B^3\Pi_g$ of N_2 excited states, the 1st positive system of N_2 corresponding to the transition $B^3\Pi_g$ – $A^3\Sigma_u^+$ and atomic N and O lines were observed. Their presence indicated relatively cold plasmas with a high level of non-equilibrium. Non-equilibrium conditions were confirmed also by calculated vibrational (T_V) and rotational (T_R) temperatures, obtained by fitting the experimental spectra (using SpecAir simulation program [7]). The typical measured temperatures in pure nitrogen are T_R = 350-400 K, T_V = 1100-1250 K, gradually increasing with the contents of oxygen in a mixture. Many other unidentified bands have been observed in the spectra and they may be due to the material of the ceramics, which besides alumina and silica includes compounds containing Ca, Mg and Na. The further investigation and interpretation of the bands in needed.

Plasma-chemical effects of microdischarges were studied too. Generation of ozone and oxidation of nitrous oxide were tested to evaluate the chemical efficiency of the discharges [5, 6].

Conclusions

Physical properties and plasma-chemical effects of microdischarges in porous ceramics generated by AC high voltage power have been investigated. The effect of the pore size, discharge power and gas mixture was described. The obtained were in the agreement with those obtained by DC power. The microdischarges present a novel way to generate the stable atmospheric pressure plasmas in hybrid plasma-catalyst reactors and can be effectively used for flue gas treatment.

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