Temperature Influence on Properties of Microdischarges

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Abstract—**The effect of temperature on the visual and electrical characteristics of the microdischarges generated inside porous alumina ceramics is presented. The temperature was found affecting discharge onset voltage, current pulse amplitudes, and other discharge properties. The increase in temperature caused the onset voltage to decrease and the current pulse amplitudes to increase. The uniformity of the discharge distribution was also improved by the temperature increase.**

Index Terms—**Microdischarge, porous ceramics, temperature influence.**

THE USE of nonthermal plasma for various environmental and biomedical applications has received much attention in the past decades. Among various types of atmospheric pressure electric discharges used for the plasma generation, discharges generated in confined spaces and cavities has recently become quite popular [1]. In our previous works, we presented a generation of microdischarges in porous ceramics by using ac and dc high voltage power and described the electrical and optical properties of the discharges [2], [3]. We found that their properties can be easily affected by many parameters, e.g., applied voltage, pore size, gas mixture, or moisture. Another important parameter is gas temperature. In environmental applications, e.g., volatile organic compound removal, the increase in temperature enhances the removal efficiency of plasma or plasma-catalytic systems, improves carbon balance, and optimizes by-product selectivity. In addition to chemical effects, the temperature rise is expected to also affect the basic physical properties of the discharges. Up to now, only few data about the effect of the temperature on discharge properties can be found in the literature. Blackbeard *et al.* [4] reported no variation of the electrical power or voltage and current waveforms as a function of temperature. However, we found that the temperature may slightly affect the discharge onset voltage, current pulse amplitudes, and even other discharge parameters. Information on the influence of temperature on microdischarge properties may be critical for optimization of the plasma-catalytic system performance based on a porous ceramics system, which is a terminal goal of this research.

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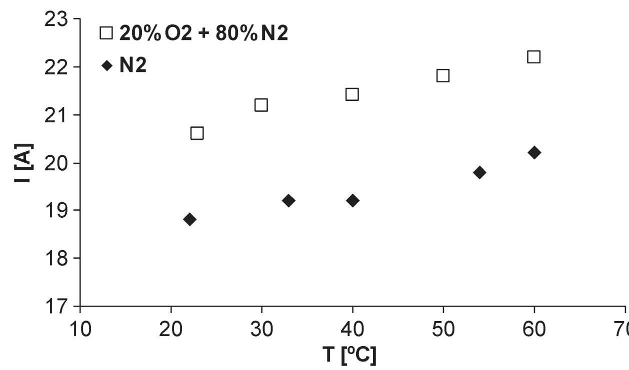

Fig. 1. Effect of temperature on the current pulse amplitude (with a pore size of 80 μm, $U_o = 15$ kV, and N_2).

The experimental setup used in this work is similar to that presented in [2] and [3]. We used a 50-Hz ac high voltage power supply. The discharge reactor was heated by a ribbon heater (Merci 233), and the temperature of the ceramics inside the reactor was monitored by temperature probes. Two ceramics with various pore sizes (30 and 80 μm) and three gas mixtures (N_2; 20% O_2 in N_2; O_2) were used.

Photographic visualization of the discharge to evaluate the macroscopic changes of the discharge distribution and intensity as a function of temperature has been performed. Fig. 2 shows the effect of temperature on the microdischarges inside the ceramics. The photographs present the discharge images being recorded by the digital camera during 1-s exposure time. They show that, with the increase in temperature, the number of discharge per given time also increased. In addition, the emission intensity increased due to an increase in the discharge current, as will be explained later. These effects were observed without increasing the applied voltage or discharge power. By increasing the discharge power, the emission intensity increased rapidly, as a result of increasing the discharge current and current density. The photographs unveiling the effects of the applied voltage, discharge power, pore size, and composition of the gas mixture can be found in our previous work [3].

Simultaneously with the photographic images, electrical measurements were performed to explain the influence of the temperature on the discharge. First, we investigated the effect of temperature on the discharge onset voltage. The onset voltage of the microdischarges, i.e., the transition of surface barrier discharge to capillary microdischarges, decreased with the increase in temperature. For the temperature increase from 24 °C to 64 °C, the decrease was about 2 kV. We noticed this trend, regardless of the pore size and gas mixtures. The decrease in onset voltage can be probably explained by an

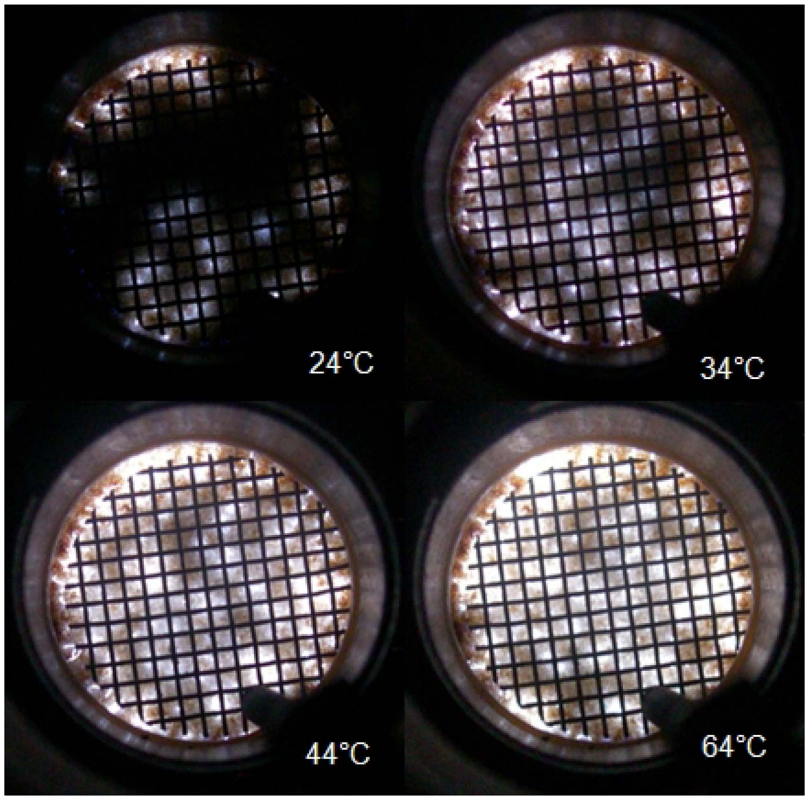

Fig. 2. Effect of temperature on the microdischarges generated in porous ceramics (with a pore size of 80 μm, F2.8, exposure time of 1 s, and N_2).

increase in reduced electric field E/n due to decreasing gas density n caused by gas expansion, which is due to deposited heat. The onset voltage also changed significantly with different gas mixtures. The onset voltage for nitrogen was found to be low, compared with mixtures with O_2 and CO_2, regardless of temperature. The effect of gas mixtures on the onset voltage was described in detail in [3].

The second parameter that was found to be influenced by temperature was current pulse amplitude. The amplitudes of the current pulses were usually in the range of 10–35 A, depending on the applied voltage, pore size, and used gas mixture. Fig. 1 shows the amplitudes of the pulses at a given applied voltage (15 kV) as functions of temperature and gas mixture. The figure shows that the amplitude increased with temperature. A relative increase of about 1.5 A was observed for a temperature increase of 40 °C. The reason for the increase is closely related with the effect of E/n that was mentioned earlier. For a specific applied voltage and increasing temperature, higher values of mean discharge current were obtained. The increase is evidently caused by the increase in current pulse amplitude, although the increasing repetition rate of the discharge pulses may also play a role. The effect of the increasing amplitude of the pulses with the increasing applied voltage was observed for all temperatures and in all gas mixtures. The repetition rate of the microdischarges varied from 1 to 10 kHz. The repetition rate increased with the applied voltage and was independent of the temperature.

Fig. 1 also shows that the amplitude of the current pulses depends on the used gas mixture. The lowest amplitudes were observed in pure nitrogen. With the increase in O_2 or CO_2 in the mixture, the amplitudes increased. This is caused by a change in the microdischarge distribution inside the pores of the ceramics. In pure nitrogen, the discharges are uniformly distributed in the whole ceramics. On the other hand, in O_2 and CO_2, the spatial distribution is not further uniform, and discharges more often occur at the edges of mesh electrodes attached to the ceramics. The discharges occurring at the edges gave current pulses with higher amplitudes due to higher electric field intensity [3].

REFERENCES

[1] K. H. Becker, K. H. Schoenbach, and J. G. Eden, "Microplasmas and applications," *J. Phys. D, Appl. Phys.*, vol. 39, no. 3, pp. R55–R70, Feb. 2006.

[2] K. Hensel, "Microdischarges in ceramic foams and honeycombs," *Eur. Phys. J. D*, vol. 54, no. 2, pp. 141–148, Aug. 2009.

[3] K. Hensel, V. Martišovitš, Z. Machala, M. Janda, M. Leštinský, P. Tardiveau, and A. Mizuno, "Electrical and optical properties of AC Microdischarges in porous ceramics," *Plasma Process. Polym.*, vol. 4, no. 7/8, pp. 682–693, Oct. 2007.

[4] T. Blackbeard, V. Demidyuk, S. L. Hill, and J. C. Whitehead, "The effect of temperature on plasma-catalytic destruction of propane and propene," *Plasma Chem. Plasma Process.*, vol. 29, no. 6, pp. 411–419, Dec. 2009.