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Characteristics of discharge in porous ceramics at atmospheric pressure

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Abstract: The microdischarges generated inside porous ceramics by AC high voltage represent a novel way to create stable atmospheric pressure plasmas. The physical characteristics of discharge in porous ceramics were investigated by photographic visualization and electrical measurements. Experimental results show that the surface discharge is not converted into pore microdischarges, and the onset voltage of pore microdischarges increases with the thickness of ceramics, while significantly decreasing with increasing porosity of ceramics.

Key words: microdischarge; porous ceramics; surface discharge; non-thermal plasma

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大气压下多孔陶瓷内放电的特征

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摘要:在外加交流高压的条件下,多孔陶瓷内可以产生稳定的大气压微放电.通过对放电的图片以及电压、电流的分析得出微放电的部分物理特性.结果显示:陶瓷微孔内的微放电并不是由陶瓷的表面放电转变而成;多孔陶瓷孔内微放电的起始放电电压随着陶瓷厚度增加而升高,而随着多孔陶瓷孔隙率的增加而降低.

关键词:微放电;多孔陶瓷;表面放电;低温等离子体

0 Introduction

Atmospheric pressure non-thermal plasmas show great potential in various environmental applications, such as removal of volatile organic compounds and nitrogen oxides, ozone generation, biomedical processing, and so on[1-6]. The hybrid plasma-catalyst system is very effective for gas treatment, and the most common hybrid reactor is plasma packed bed[7]. However, porous materials

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as a packed bed are in much wider use than the traditional packed bed due to their more effective synergy of plasma and catalysts[8]. The generation of microdischarges in porous ceramics was explored and reported in previous studies[7-9]. Microdischarges can be stably generated with an AC or a DC high voltage power supply at atmospheric pressure. In this work, we investigate the physical characteristics of discharge in porous ceramics by photographic visualization and electrical measurements. The results will help to better understand the mechanism of the discharge process in porous ceramics, and should be beneficial to determine optimal working parameters.

1 Experimental setup

Our experimental setup is shown in Fig. 1. The high voltage electrode is a liquid electrode composed of a quartz cup filled with saline solution. The wall thickness and inner diameter of the quartz cup are 2 mm and 26 mm, respectively. The grounded electrode is a metal one covered with a ceramic dielectric sheet with a thickness of 1 mm. Porous ceramic is placed between the liquid electrode and dielectric sheet. Due to the rough surface of the porous ceramic, some discharge light leaks from between the porous ceramic and dielectric sheet. The ceramic is sintered from alumina (mass fraction 94%), silica (mass fraction 3.5%) and MgO (mass fraction 2.5%), and the thickness range of the ceramics is from 4.0 mm to 10.7 mm and their diameters are 46 mm. The pore size of the ceramic is 100 μm, and the porosities of the ceramic are 35%, 39% and 45%, respectively. The discharge is generated by AC high-voltage power supply (20 kHz), and the discharge current and applied voltage are measured through a current-monitoring resistor of 50 Ω and a capacitive divider (1 000 : 1) set in the power supply. Both current and voltage signals are recorded by a digital oscilloscope (Tektronix TDS2014B) and photographs of discharge are taken with a digital camera (Pentax K-x) with manually adjustable aperture and exposure time. All experiments are carried out at atmospheric pressure and room temperature.

2 Results and discussion

The typical photographs and waveforms of the

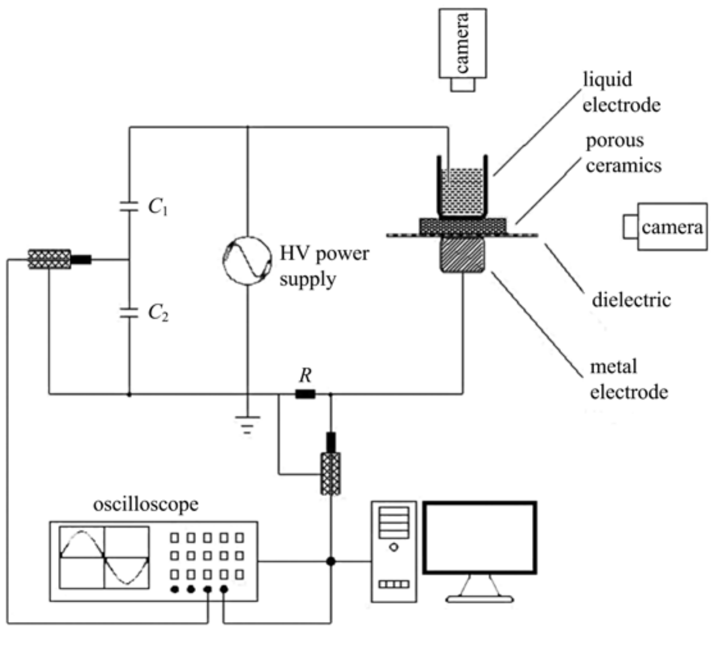


Fig. 1 Schematic of the experimental setup

discharge using a porous ceramic with a pore size of 100 μm, porosity of 45% and thickness of 4.0 mm are shown in Fig. 2. The top-view images (Fig. 2 (a)) show that discharge streamers are not observed in the central region of the liquid electrode when the applied peak voltage is lower

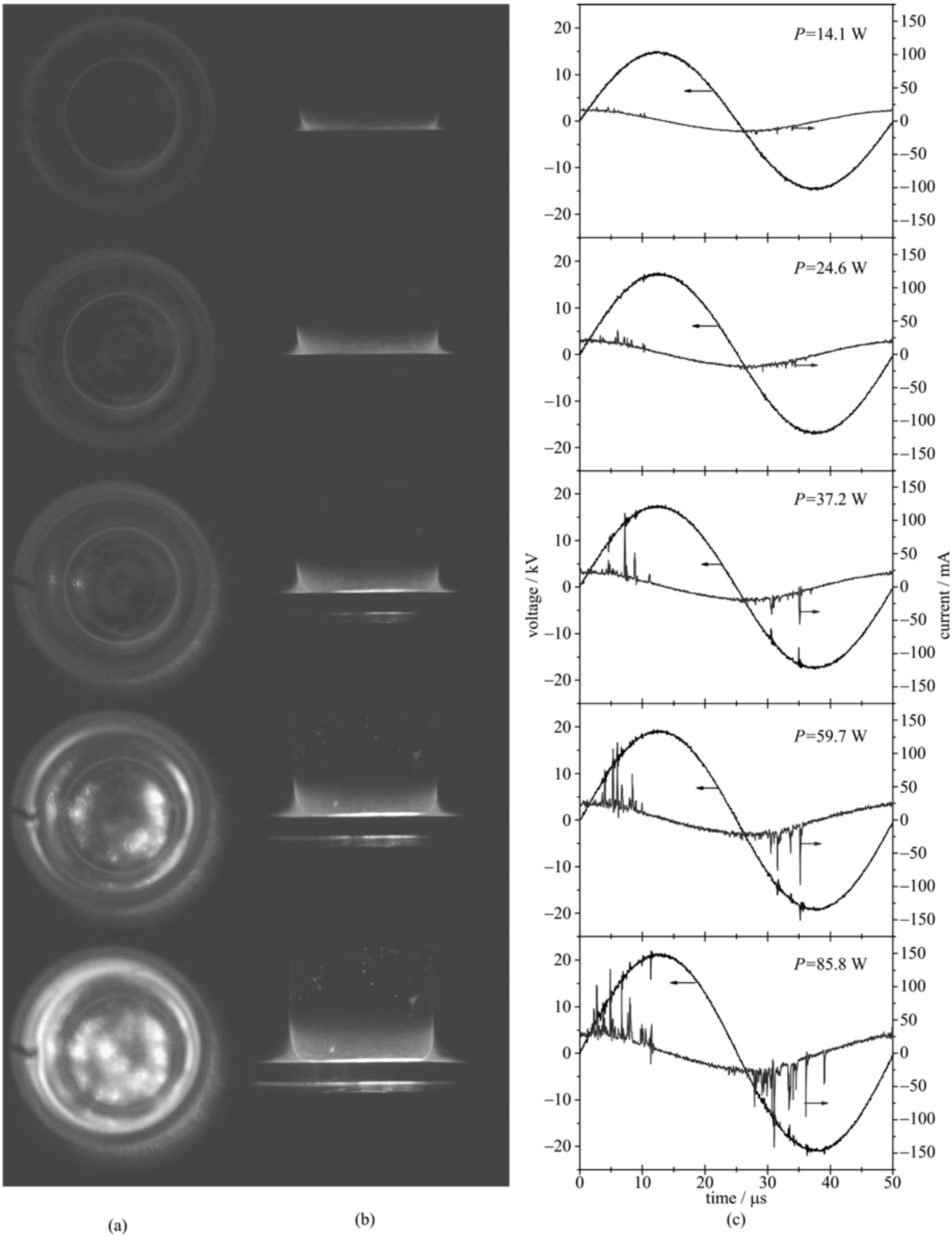
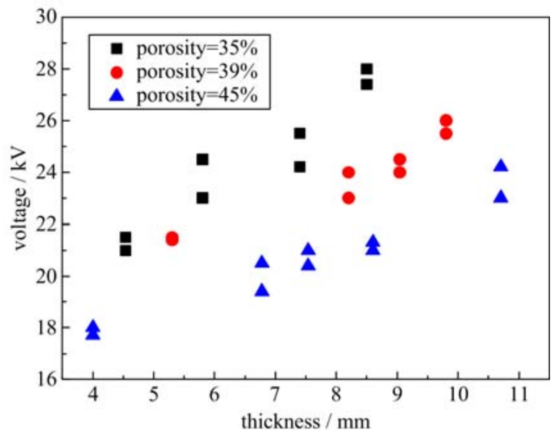


Fig. 2 Top view (a) and side view (b) images of discharge with increasing applied voltage (exposure time 1/2 s, ISO 800, F/8), and the corresponding waveforms of applied voltage and discharge current (c)

than 17.7 kV, and the discharge streamers only develop and propagate along the edge of the liquid electrode surface and form two violet blue "luminous rings". The inner "luminous ring" is the location of surface discharges, and formation of the outer "luminous ring" is due to the propagation and collection of discharge light in the quartz cup. The white emission of randomly distributed pore microdischarges is observed in the central region of the liquid electrode when the applied voltage increases above a critical value (the value is 17.7 kV under this condition). With further increase of the voltage, the white light emission becomes much more intense and homogeneously distributed. From the side view (Fig. 2(b)), there is only one luminous discharge region on the upper surface of the porous ceramic, until the pore microdischarges is generated, and then another luminous discharge region is formed between the lower surface of the porous ceramic and the dielectric sheet. It is found that the volume of the two luminous discharge regions increases with applied voltage. In previous literature reports[7-9], with a further increase of applied voltage, the surface discharge is converted into pore microdischarges inside the porous ceramic. However, in our experiment, we observed that there is no conversion of surface discharge into pore microdischarges, and that both can exist and develop simultaneously when applied voltage reaches a certain value. Fig. 2 (c) shows the corresponding waveforms of applied voltage and discharge current. From these waveforms, it can be seen that the discharges occur both in positive and negative polarity of the applied voltage. Some of the current pulses exceed 50 mA and the voltage drop (voltage pulses) during the current pulses is significant when the discharge mode is a hybrid of surface discharge and pore microdischarge (applied voltage > 17.7 kV). However, the surface discharge shows current pulses of shorter amplitudes (<50 mA) and an insignificant voltage drop, which is in agreement with the previous work reported by Hensel[9]. The comparison of the images shows that the diameter of the emission spot increases with the applied voltage and corresponding discharge current pulses. Comparative analysis of Fig. 2(a), 2(b) and 2(c) can also suggest that the development of surface discharge is maintained throughout the whole process, though the formation of pore microdischarges is found only above the specific applied voltage. The charge particles are accumulated on the porous ceramic and intensifies the electric field when the voltage drop across the porous ceramic exceeds a critical value, the microdischarges are formed inside the porous ceramics. In other words, surface discharge is not converted into pore microdischarges in porous ceramics. It is also denoted that because of the power superposition of surface discharge and pore microdischarges, the hybrid discharge power increases more sharply with the applied voltage, compared with the single surface discharge.

Fig. 3 shows the applied peak voltage at the moment of pore microdischarges generated inside the porous ceramics with various porosities. As can be seen, the onset peak voltage of the microdischarges increases with the thickness of ceramics and also increases as the porosity of the ceramic decreases. The onset voltage increases all the way proportionally along with the thickness of



pore size=100 μm

Fig. 3 Onset peak voltage of the pore microdischarges in porous ceramics with various porosities

ceramics. The porosity determines the number and distribution of pores in the ceramics. It is possible that the number and homogeneity of distribution of pores may play an important role in distorting the electric field and in determining the onset voltage of the pore microdischarges. With the increase of the number of pores the charge particles "leak into" ceramics more easily and cause the significant decrease in onset voltage. It is found simultaneously that at the same given discharge voltage the discharge power of the bigger pore porosity is larger, due to the increase of the number of the discharge channels and volume of the generated microplasma.

3 Conclusion

Characteristics of discharge in porous ceramic at atmospheric pressure were investigated. It was found that the surface discharge is not converted into pore microdischarges. Surface discharge and pore microdischarges can exist and develop simultaneously when applied voltage increases above a critical value. The effects of thickness and porosity of ceramics on the onset voltage were described. It was found that the onset voltage of pore microdischarges increases with the thickness of ceramics, while significantly decreasing as the porosity of ceramic increases.

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