Micro-discharge in Porous Ceramics

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Fundamental characteristic of micro-discharge in porous dielectric materials has been investigated in this study. We expected that the application of DC high voltage could generate many narrow micro-discharges inside and on the surface of various ceramics materials. Five types of ceramics with different perforation levels (size of pores) have been tested using negative or positive DC high voltage. Needle-mesh and mesh-mesh type electrodes were investigated. A stable micro-discharge was formed using ceramics with average pores of 90µm and 15µm. The micro-discharge was affected by water vapor concentration.

1. Introduction

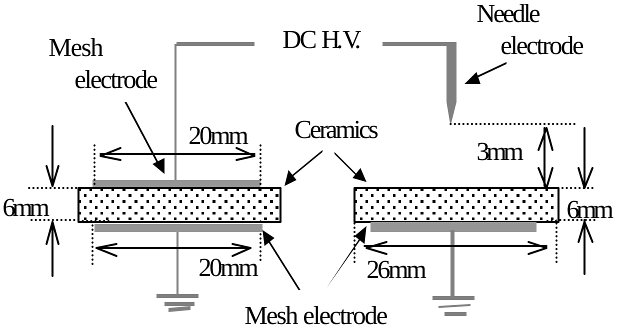
Catalytic processes of combustion gas treatments usually need high temperatures around 300-500℃. Recently, several combinations of plasma and catalyst were studied to decrease the treatment temperature[1)]. In case of the packed bed reactor, an intense plasma occurs in a limited area between many contact points of pellets. The packed bed reactors show good performance in spite of the small plasma area[2)]. Honeycomb catalyst is preferred in practical use, however, it is difficult to generate a non thermal discharge plasma in a honeycomb catalyst. If we find an effective combination method of plasma and honeycomb catalyst, the performance will be improved.

For this purpose, the micro-discharge has been tested. The porous ceramics are used to generate the micro-discharge due to electrical breakdown of the fine channels. DC voltage can be used because transition to flashover can be suppressed. The micro-discharge could possibly be used to generate electrical discharge in honeycomb catalyst.

2. Experimental setup

Fig.1 shows the mesh-mesh and needle-mesh reactors for the micro-discharge. The experiments were carried out using positive or negative D.C. high voltage. Two disk electrodes (20mm-diameter) made of fine stainless steel mesh were placed on each surface of the ceramic disk as shown in Fig.1 (a). Corona discharge was also used instead of inserting a ballast resister. A needle electrode was placed 3mm above the ceramics disk as shown in Fig.1 (b).

Disk-type porous ceramics plates (6mm thickness and 26mm diameter) were used in the experiment. Table 1 shows the detailed properties of the ceramics. Ceramics A, B and C having different pore size are sintered from alumina powders of different size. Ceramics D and E are made of cordierite and alumina. Both plates had high porosity. We investigated the fundamental characteristics of the micro-discharge taking place in these porous ceramic plates with different pore size. Dry and humid conditions were also tested in the experiment.



(a)Mesh-Mesh type (b)Needle-Mesh type

Fig.1 Two types of micro-discharge reactor

Table1 Detail information of ceramics

	Al_2O_3 contents [%]	Pore size[µm]	Powder size[µm]	Porosity [%]
Ceramics A	92	90	100	37
Ceramics B	92	15	40	42
Ceramics C	99	0.8	2	38
Ceramics D	-	800	-	80〜90
Ceramics E	-	1250	-	80〜90

Negative and positive D.C high voltage power supply (Pulse electric. Co. Model502) were used. A 5kΩ resistor was inserted in series to the reactor for current limitation. Applied voltages and current were monitored during the experiment. The transient waveforms of the voltage and current were measured with an oscilloscope (Tektronix TDS644A and TDS2000) using a high voltage probe (Tektronix P6015) and a current probe (Tektronix P6021).

3. Results and discussion

Negative or positive D.C. high voltages were applied to the ceramic layer in ambient air. Fig.2 shows the I-V characteristics of the negative polarity tests using the needle-mesh and the mesh-mesh electrodes. Because the negative DC corona has higher flashover voltage than positive corona, the micro-discharge can be generated more stably using the negative DC in the needle-mesh electrode.

The transient discharge of the mesh-mesh type is shown in Fig.3. In case of ceramics A and B, the voltage dropped pulsively. This pulsive voltage drop was first observed when the applied voltage exceeded the value marked by the arrows in Fig.2 for both the needle-mesh and the mesh-mesh electrodes. Several hundreds mA of transient current was observed in this case. At the same time, short and intense light emission associated with sound was observed in the widely spread areas of the surface and inside the ceramics. These transient discharges are called the micro-discharge, which was quite different from typical corona discharge and spark discharge. Due to fine channels of ceramic material, transition from streamers to leaders that lead to a flashover can be avoided due to cooling of the streamer channel by the heat-resistive ceramic wall. This is the main reason to generate the micro-discharge.

The micro-discharge did not take place when the ceramics C was used. The micro-discharge could not be generated with the ceramics D nor E. These results suggest that ceramics C did not induce the micro-discharge because the pore size was too small. On the other hand, in ceramics D or E, pore size was too large and flashover took place easily.

Fig.4 shows the effect of water vapor on the micro-discharge using the mesh-mesh electrode with the ceramics B. Dry and humid conditions were tested using humid air of 1.2mg/L and 5mg/L of the water concentrations. Square (□) shows the I-V characteristics just after starting the high voltage application. Blank circle(○) represents the I-V curve measured at 30 seconds after starting the voltage application when the discharge condition reached to a steady state. As shown in Fig.3, larger current flowed in the humid condition. The current was gradually decreased with time and eventually saturated after 30 seconds. The micro-discharge started when the applied voltage exceeded the value marked by the arrows shown in Fig.4. The current was further decreased with time after the micro-discharge was started. This result suggested that the water adsorbed in the ceramics was evaporated by the micro-discharge in the humid condition. On the other hand, very small current was observed when the micro-discharge occurred in the dry condition. The on-set voltages of the micro-discharge were affected by the water concentration.

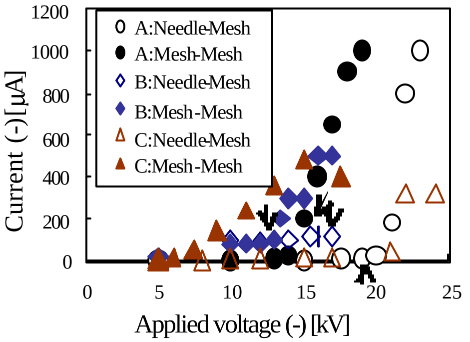


Fig.2 V-I characteristics using ceramics A, Band C with negative polarity in ambient air

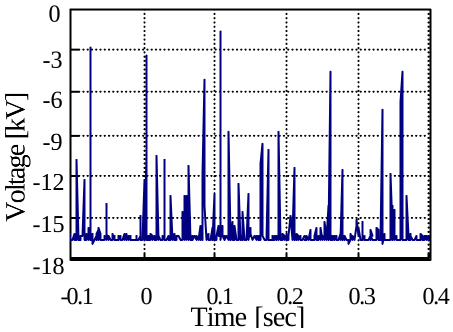


Fig.3 Voltage waveform of micro-discharge with negative polarity in ambient air

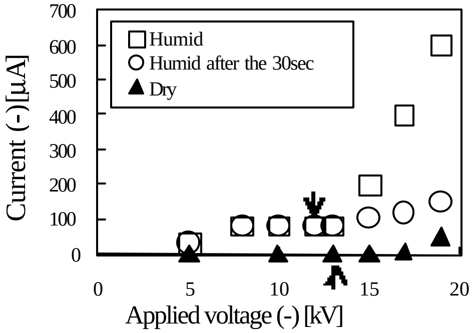


Fig.4 V-I characteristics using ceramics with negative polarity in dry and humid condition

4. Conclusions

Stable micro-discharges can be generated using porous ceramics with average pores size of 90μm and 15μm, and a DC energization. Inside the channels and on the surface, pulsive discharge, or the micro-discharge takes place, while the fine channels suppress the transition to flashover. On-set voltage and current of the micro-discharge were affected by water vapor concentration. The micro-discharge could possibly be used to fabricate a honeycomb-type plasma reactor.

References

1)A. Mizuno et al, Journal of Physics D: Applied Physics, Vol.34, pp.604-613, 2001

2)Y. Matsui et al, SAE Technical paper, No.2003-01-1185