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Generation of Plasma in Artificial Porous Dielectric Materials Filled with a Gas-Liquid Mixed Phase Medium

人工多孔質体を用いた気液混合媒質中プラズマの生成

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A three-dimensionally integrated micro-solution plasma (3D IMSP) reactor has been fabricated using an artificial porous dielectric materials using 3D printer technology for generating a large number of microplasmas in contact with a liquid medium. While conventional 3D IMSP reactors are fabricated with silica pumices which consist of random-size pores, this new 3D IMSP reactor is fabricated with 3D-printed lattice structure in which the same-size pores are arranged regularly. We have successfully obtained microplasmas in this reactor by feeding the gas-liquid mixed medium of Ar and water.

1. Introduction

Solution plasma [1] has attracted much attention because of its possible application to nanomaterial synthesis, surface modification, water treatment, sterilization, the recycling of rare materials, the decomposition of toxic compounds, and medical surgery. Previously, we have proposed a novel reactor, 3D integrated micro-solution plasma (3D IMSP), for realizing efficient large-scale plasma processing in liquid [2]. In this reactor, a large number of microplasmas are generated in porous dielectric materials filled with a gas-liquid mixed medium. We have already reported that 3D IMSP has shown 15-fold higher efficiency in methylene-blue degradation in water than conventional solution plasma [3]. We have also demonstrated synthesis of Au nanoparticles [4].

However, the pores have different diameters and their positions are not regularly distributed in the porous dielectric materials used in our previous work. This means that we cannot design the processes using 3D IMSP. Thus, in this work, we have utilized artificially designed porous dielectric materials fabricated using 3D-printer technologies [5] for exploring possibility of designing 3D IMSP reactor with micro-fluid mechanics and electromagnetics.

2. Experimental

Figure 1(a) shows the design of the porous dielectric material used in this work. Since this is the first trial fabrication and experiment, we have prepared very simple lattice structure. The pore shape in this lattice is cubic of which side length is 1 mm. The lattice frame work is consist of the rectangular rod shape structure of which cross section is 1 mm^2. Total length of the lattice is 30 mm. Gas (Ar, 3 L/min) is fed from the center of the porous dielectric material using stainless tube (1/4 diam.) with four holes (2 mm diam.). Figure 2(b) shows the actual 3D object.

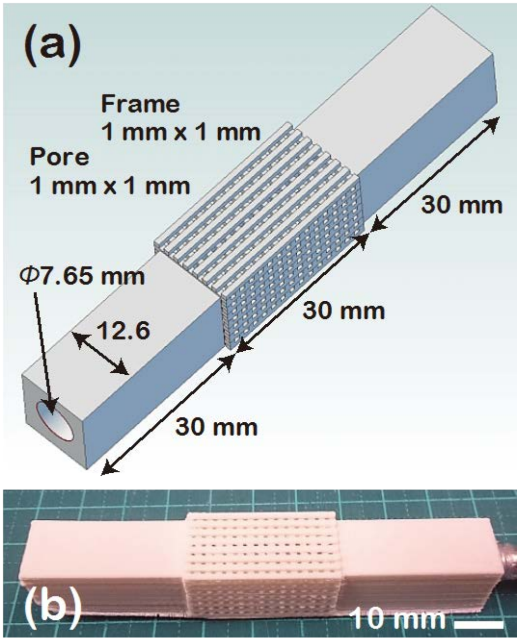

Fig. 1 An artificial porous dielectric material. (a) Its Design and (b) Overview of 3D-printed actual object.

The liquid medium is D.I. water with electrical conductivity of 0.8 mS/m, temperature of 25^{o}C. Configuration of a glass tube and electrodes is the same to those in our previous reports [3] as shown in Fig. 3. Applied voltage is 5 kV pulse voltage with frequency of 20 kHz and pulse width of 2 us.

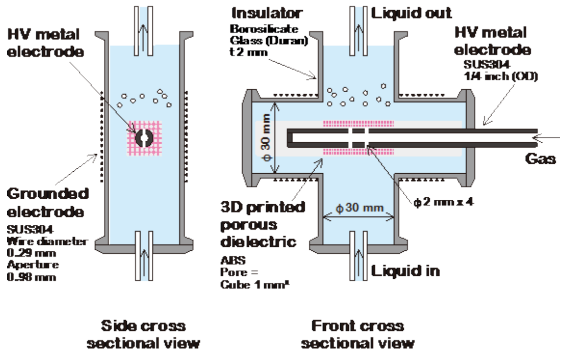

Fig. 3 Schematic illustration of the reactor.

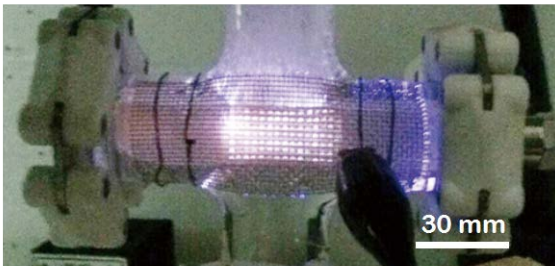

Fig. 4 An overview of 3D IMSP obtained using the 3D-printed porous dielectric material.

3. Results and Discussion

At this moment, we have only preliminary results of actual overviews of the reactor during operation. Figure 4 shows an overview 3D IMSP obtained using a 3D-printed porous dielectric material. We can confirm that the artificial 3D-printed porous dielectric materials work well for generating 3D IMSP.

In comparison to previous random porous dielectric materials, the 3D-printed regular one has channeling structure in it. Because of that, the high optical emission has been observed only near the holes of central electrode. This nature seems to be a disadvantage of this reactor, but this result implies an advantage that we can control the discharge position in the porous structure by designing proper flow channel. We have just started investigation on various unique porous structures on the basis of micro-fluid mechanics and electromagnetics.

4. Summary

A 3D IMSP reactor has been fabricated using an artificial porous dielectric materials using 3D printer technology for generating a large number of microplasmas in contact with a liquid medium. This new 3D IMSP reactor consists of 3D-printed lattice structure in which the same-size pores are arranged regularly. We have successfully obtained microplasmas in this reactor by feeding the gas-liquid mixed medium of Ar and water. Although we have observed concentration of electrical discharge at the region in the porous dielectric material near the gas-feed region, we expect that this kind of local electrical discharges can be distributed in whole area of the porous dielectric material by properly designing the pore arrangement.

Acknowledgments

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