S10-3

# Novel Application of Microplasma
# マイクロプラズマの新規応用

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Recently, application of microplasma has been intensively performed in various fields. In this talk, as the examples, we report our recent works on materials synthesis by microplasma processing under a high-pressure environment up to supercritical fluid (SCF) and in liquid, and microwave excited atmospheric air maicroplasma based on microstrip technology.

## 1. Introduction

In these days, microplasma has been intensively studied not only from the viewpoints of pure science but also application. Based on the unique characteristics of microplasma, such as an extraordinary locality and high-density, developments of various novel application technologies are in progress. Those include, e.g., novel materials processing, biomaterials treatment, chemical analysis, light sources of ultra-short wavelengths, micro-machining and the functional plasma devices. Figure 1 shows typical examples of various micoplasma processing.

In this talk, as the examples, we report our recent works on materials synthesis by microplasma processing under a high-pressure environment up to supercritical fluid (SCF) and in liquid, and microwave excited atmospheric air microplasma based on microstrip technology.

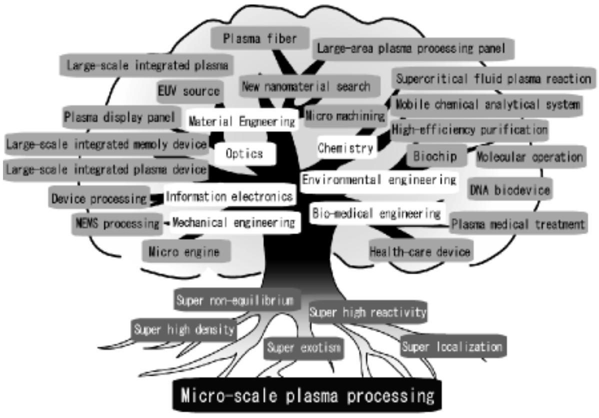


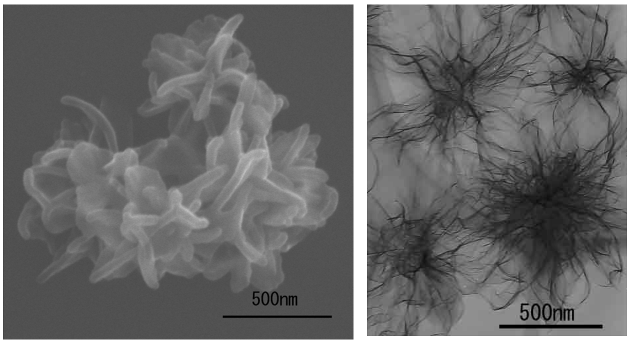
Fig. 1.　Application of micro-scale plasma processing.

## 2. Materials synthesis by microplasma in liquid and supercritical fluid

Generally speaking, for microplasma generation, relatively high-pressure (high-density) environment may be required. In other word, microplasma allows us easy generation under a high-pressure environment even up to SCF conditions and in liquid. In these exotic plasma media, new reactions through plasma processing, leading to the fabrication of novel materials may be anticipated.

In fact, for example, we successfully fabricated various carbon nanomaterials from $CH_4$/He gas at atmospheric pressure employing inductively-coupled microplasma (ICMP) and dielectric barrier discharge microplasma (DBDMP) in liquid solution. Employing He/$CH_4$-ICMP in water, we easily fabricated graphite, carbon nano-onions, MW-CNT (multi-wall carbon nanotube) and distinctive self-organized carbon nanostructures as shown in Fig.2 [1].

On the other hand, SCF has attracted much interest in scientific and engineering fields due to its unique characteristics such as its transport properties between gas and liquid [2]. There exists a



(a)　(b)

Fig.2 (a)SEM and (b) TEM of self-organized carbon system prepared by microplasma processing in liquid.

large density fluctuation resulting clusters of various sizes near the critical point and these can result in marked change in characteristics such as thermal conductivity. The use of SCF offers several advantages for processing, particularly in transport phenomena. During the past decade, these advantages have been successfully applied to material processing. So, plasma processing, usually performed in a gaseous environment, may yield a high efficiency by applying SCF conditions due to a combination of advantages, such as the high activity of plasmas and the superior transport properties of SCF. In addition, SCF plasma is anticipated to contain radical and ion clusters in SCF, which may lead to novel phenomena and reactions. We succeeded in the synthesis of nonequilibrium materials consisting of carbon nanotubes and nanopolyhedra with arc-discharge and DBD in SCF-$CO_2$ without catalysis [3]. The detail will be presented at the symposium.

## 3. Microwave (2.45GHz) excited atmospheric air maicroplasma based on microstrip technology

A novel plasma system based on microstrip technology was developed for the generation of atmospheric pressure microplasmas [4]. A discharge gap was placed between the striplines and the ground plane on the transverse cross-section of the direction of microwave propagation as shown Fig.3 and Fig.4. This plasma sources can provide the following advantages. (1) Atmospheric pressure eliminates the need for a vacuum pump. (2) No electrode is needed, reducing the contamination of plasma source by sputtering electrodes. (3) Microwave powers can be directed to the target area precisely, meaning no unnecessary radiation loss to external space and allowing the generation of high-density plasmas. (4) Discharge can be sustained stable over a wide range of gas pressures. (5) Matching impedance was conducted with using simple components. (6) The magnetron is used commercially in microwave (2.45GHz) ovens and the semiconductor microwave power generator is used in wireless telecommunication system, making the microwave source very economical. (7) Microstrip technology and small semiconductor microwave source make it possible the low power operation and the portable microplasma system. This microstrip structure permits the strong concentration of electric fields at the discharge gap, which is confirmed by a computer simulation using the 3-D simulation code based on the FDTD (Finite Difference Time Domain) method, producing atmospheric pressure plasmas even in air. The microplasmas were sustained in the discharge gap (width:0.2mm, length: 6mm) at a microwave power of 1W. The experimentally measured rotational temperature of nitrogen molecular was 800K, indicating these plasmas to be non-thermal plasmas.

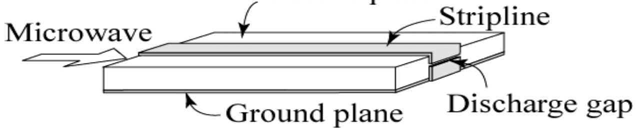


Fig. 3. A microstrip structure of the present system.

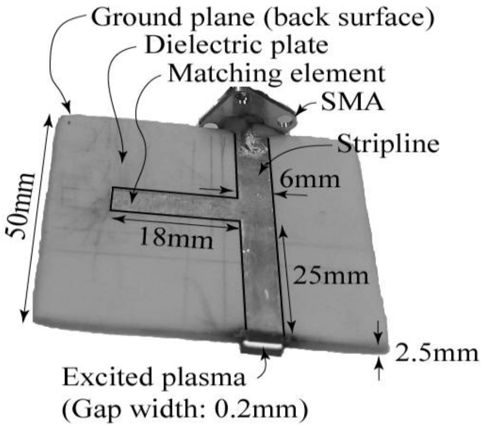


Fig.4 Picture of an actual system and excited plasma.

In future work, the proposed plasma system will permit a potable plasma system and a large-scale atmospheric pressure non-thermal plasma using the array configuration as shown in Fig. 5. The detail will be presented at the symposium.

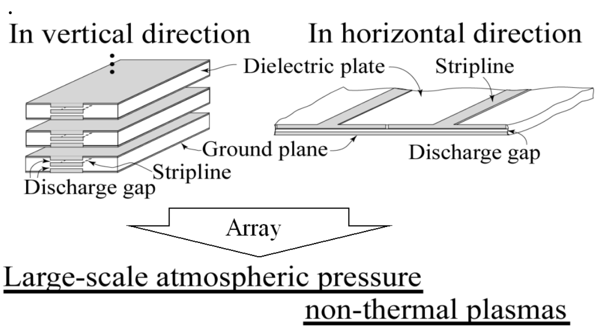


Fig. 5. Schematics of large-scale atmospheric pressure non-thermal plasma using the array configuration.

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