S3-4 Atmospheric Pressure Microwave Plasma System and Applications

大気圧マイクロ波プラズマシステムと応用

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A new type of atmospheric low temperature plasma source was developed utilizing a coaxial cable for microwave transmission rather than conventionally used waveguides. We have developed two kinds of plasma sources, one is resonator type cavity and another one is called non-resonance pen-style torch. Two-dimensional gas-temperature and gas-velocity distributions of the plasma are measured using the E-type thermocouple and the Pitot tube respectively and results are presented. The applications of the atmospheric pressure plasma in various fields such as surface modification, cleaning and sterilization are discussed.

1.Introduction

Microwave induced plasma sources have already been used for more than two decades [1-3] in spectrochemical analysis. Early types of plasma sources utilize waveguides for the microwave transmission. The bigger size, higher cost and fixed positioning is the drawback of the system. Another problem associated with the wave-guide fed system is the generation of thermal plasma and the need for an igniter for plasma ignition. The new type of microwave plasma system described in this paper utilizes co-axial cable for the microwave transmission and has several advantages such as compact, low cost, flexible for positioning and self ignition of plasma.

2. System description

The basic set-up is shown in figure.1. The system basically consists of a microwave power source, stub-tuners for impedance matching, the co-axial cable for the microwave transmission and the plasma generator. The microwave source is a standard industrial microwave oven magnetron operating at 2.45 GHz with power rating up to 600W. The Impedance matcher is a two-stub tuner. The co-axial cable is a standard RG-393 cable. There are two types of plasma generators one is a resonator cavity and another one is a non-resonance pen-style torch.

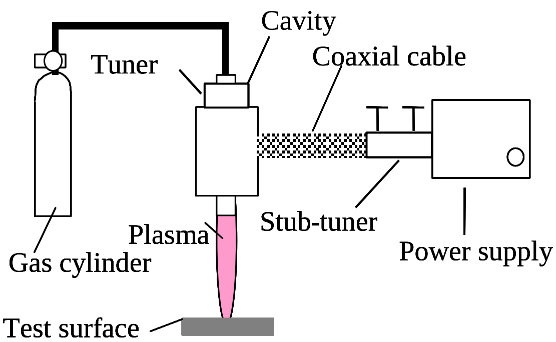
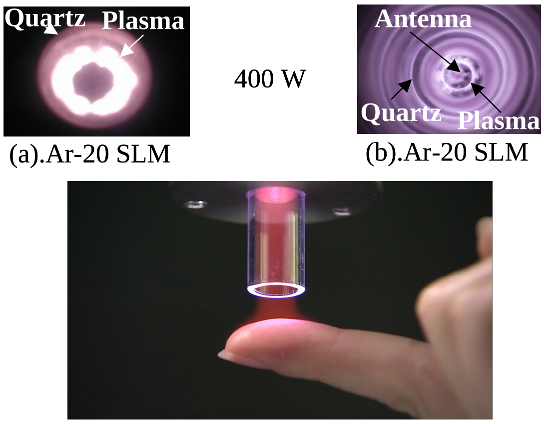


Fig.1.Schematic of the set-up



(a).Ar-20 SLM (b).Ar-20 SLM

(c). Ar(10)+N_2(0.1) SLM- 200 W

Fig.2.Plasma generation

3. Results and discussion

3.1. Plasma characteristics

In a resonator cavity the plasma is generated inside the discharge tube along the inner surface (Fig.2.a). In a non-resonator pen-style torch, plasma is generated between the gap of the antenna and the

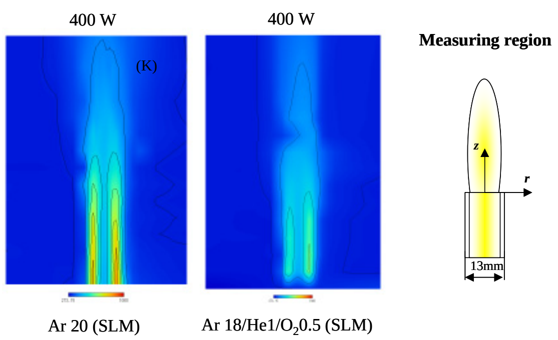


Fig.3.Temperature distribution

discharge tube (Fig.2.b). In both cases plasma looks like a surface wave discharge. The plasma jet below the discharge tube is cold plasma and can be touched by human fingers (Fig.2.c).

Figure 3 shows two dimensional temperature distributions of the plasma under conditions of argon with 20 L/min, Ar(18)+He(1)+O_2(0.5) L/min at input power of 400 W for resonator cavity.

The peak value of temperature is 863 K for Ar 20 SLM and the same is about 600 K for Ar(18)+He(1)+O_2(0.5) is observed in the vicinity of the wall at the nozzle exit (z = 0 mm, y = 5 mm).

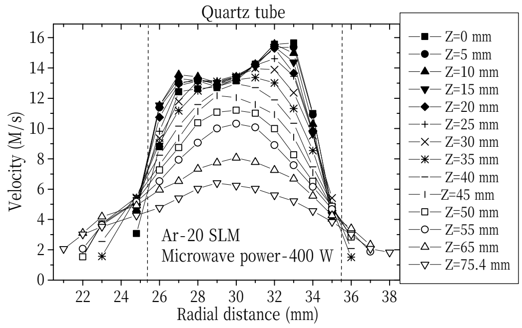


Fig.4.Velocity distribution

Figure 4 shows velocity distributions of the plasma under the condition of Ar(20 L/min). The maximum velocity is observed around 15 m/s in the vicinity of the wall. The peak velocity does not change much with the mixture of N_2 and O_2 with Ar.

4.**Applications**

4.1. Surface modification

Figure 5 shows the results of the improvement of wettability and contact change of the plastic, aluminum, Kapton after the treatment of Ar(10)+N_2(0.5) L/min plasma at input power of 400 W. The exposure time is 45 s. The improvement of wettability on the plastic surfaces after plasma exposure is clearly seen by the change in the contact angle of the water droplets.

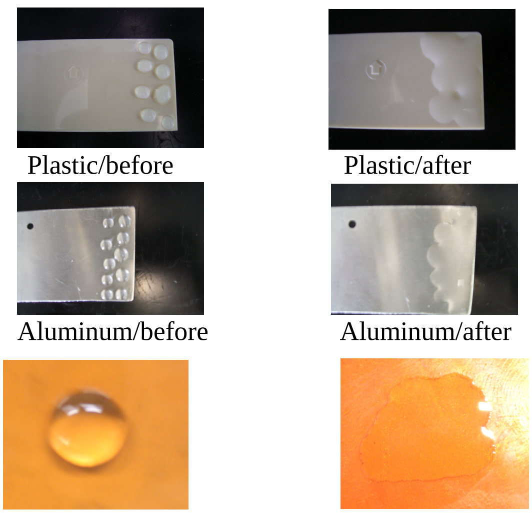
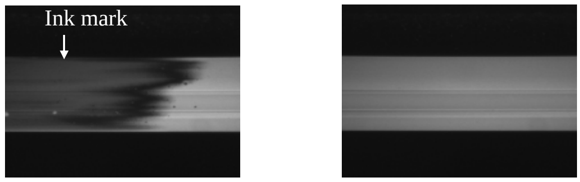


Fig.5.Improvement of wettability of surfaces

4.2. Plasma cleaning

Figure 6 shows the cleaning of the Si-wafer edge using Ar(10)+O_2(1) L/min plasma at input power of 400 W, exposure time of 30 s. The result shows that the plasma can be used to remove the organic contaminants. Experimental results show that our plasma torches can be used for the cleaning of the wafer backside and the ashing of photo-resist.



Before After

Fig.6.Si wafer edge cleaning

4.3.Sterilization

Figure 7 shows the sterilization rate in relation to the temperature for various sterilization methods. Plasma sterilization of bacteria using our torches at input power of 400 W with Ar and Ar+O_2 as plasma gas is superior to other conventional methods UV, ozone, steam and hot Ar gas. The sterilization rate is higher for plasma sterilization methods and the sterilization temperature also lower compared to other methods.

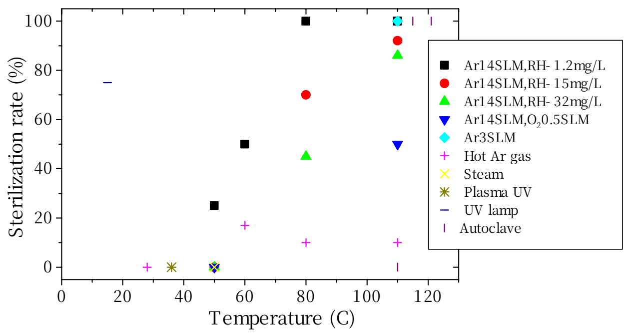


Fig.7.Sterilization rate Vs temperature

5.**Conclusion**

Atmospheric plasma has been generated using Ar, Ar+He, Ar+N_2, Ar+O_2, Ar+He+N_2, and Ar+He+O_2 feed gases. The torches can be used for surface modification of Kapton sheet, plastics and metal, cleaning of Si-wafer edge, reverse side and ashing of photo-resist and sterilization of bacillus subtilis and E-coli bacteria.

References

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