HF PLASMA PENCIL FOR PLASMACHEMICAL TREATMENT OF MATERIALS

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Introduction

The plasma pencil represents quite a new principle of atmospheric pressure discharge generation [1]. The optical diagnostics of discharges generated by the plasma pencil evidence that this plasma is in non-equilibrium state [2]. Preliminary experiments show suprisingly high universality and applicability the plasma pencil to various fields of interest.

Experimental

The core of equipment is the extension piece made of pencil-shaped dielectric with a built-in special hollow electrode. Gas, liquid or the mixture of dispersed particles (powders) can flow through the hollow electrode of the plasma pencil. The electrode is connected by means of a cable with the matching network of the voltage supply (HF, AC or DC).

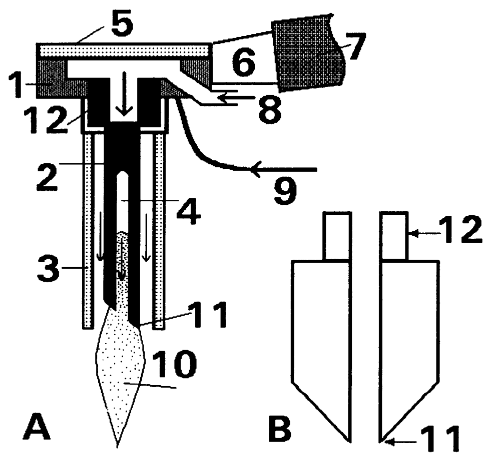

Fig. 1 Plasma pencil **A)** with hollow needle **B)** with hollow cylinder: 1-carrier electrode, 2-hollow electrode, 3-quartz capillary, 4-slit, 5-glass window, 6-hinge, 7-grip, 8-gas, 9-power supply, 10-plasma jet, 11-sharp edge of nozzle, 12-thread

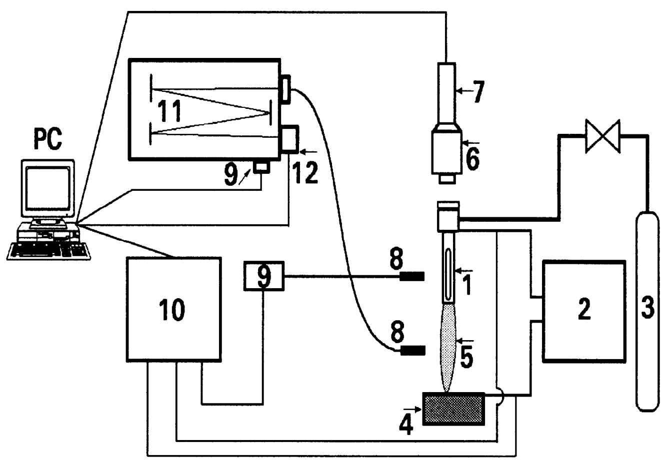

Fig. 2 Scheme of experimental arrangement: 1-hollow electrode, 2-power supply, 3-gas, 4-counter electrode, 5-plasma jet, 6-microscope, 7-video camera, 8-optical fibre, 9-photomultiplier, 10-oscilloscope, 11-monochromator HR640, 12-optical multichannel analyzer

Two different designs of the hollow electrode that are shown in Fig. 1 were used. Discharges were ignited between the hollow electrode of the plasma pencil and a counter electrode represented by a metal electrode and/or a liquid surface or burning under a liquid surface. The hollow electrode was coupled to RF, AC and/or DC power supply. The supplied power was from 1 to 200 W and the voltage changed from 100 to 1000 V.

The electrical parameters of the discharge, voltage U and current I, were monitored with the digital multichannel oscilloscope (Tektronics TDS 210). The time and spatial development of the emission from plasma were detected by the photomultiplier connected to the oscilloscope. The recording of electrical parameters (U, I) were synchronized with optical emission. The spatial distribution of optical emission from plasma were recorded with a video camera, too and treated by the digital image processing. The spectra emitted from the plasma in different environments were detected with Jobin Yvon HR 640 monochromator equipped with optical multichannel analyzer. The rotational and vibrational temperatures from molecular bands of OH (306.4 nm system) and N_2 second positive system $C^3\Pi_u$ - $B^3\Pi_g$, respectively. The experimental arrangement is depicted in Fig. 2.

Results and Discussion

In Fig. 3 there are shown power dependencies of rotational and vibrational temperatures for both types of the hollow electrode, respectively. They characterized temperature distributions

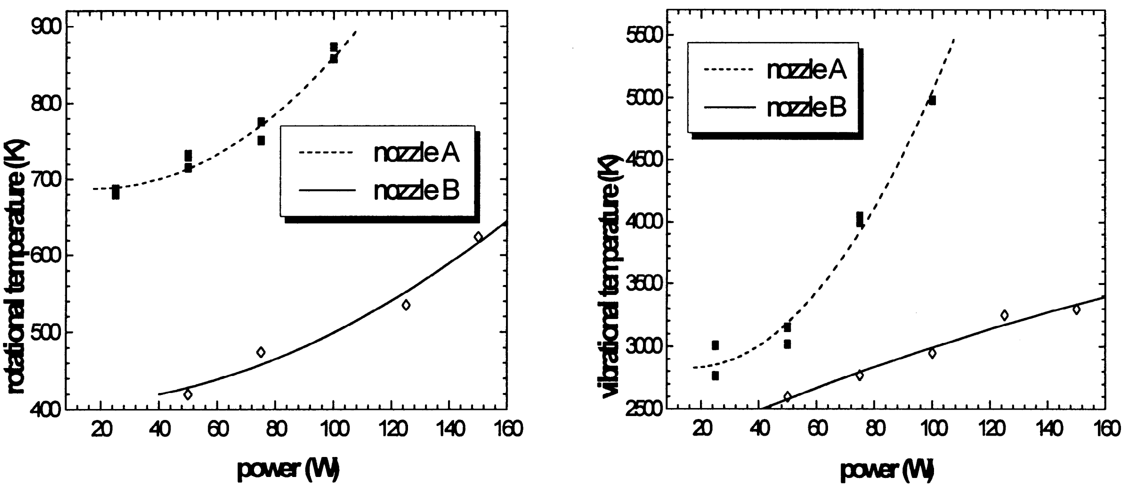

Figure 1 Rotational temperatures from OH bands and vibrational temperatures from N_2 bands in RF plasma jet of argon flow cca 500 sccm. Nozzles A and B represent hollow needle (Figure 1A) and hollow cylinder (Figure 1B), respectively.

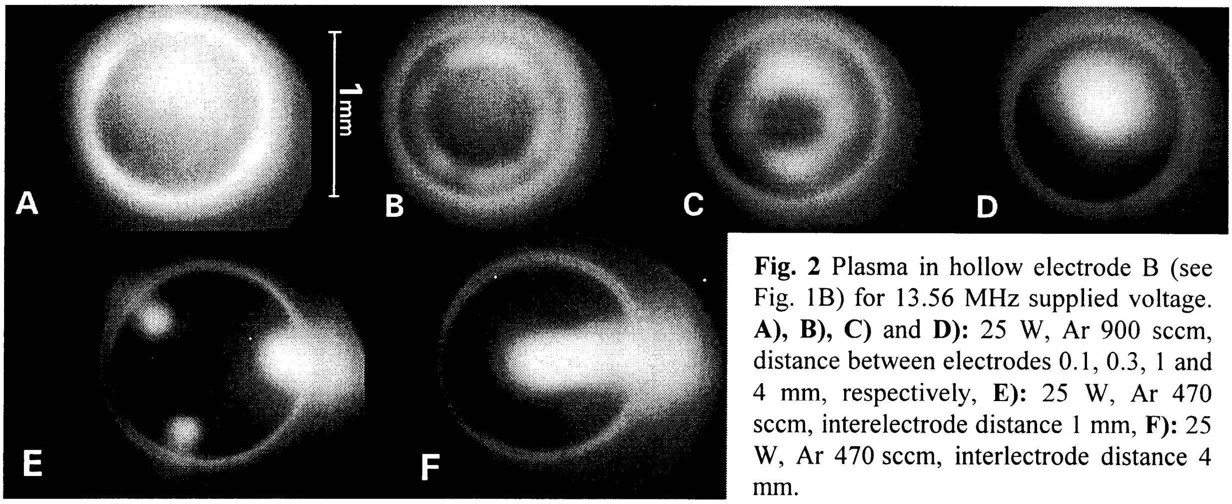

Fig. 2 Plasma in hollow electrode B (see Fig. 1B) for 13.56 MHz supplied voltage. **A), B), C)** and **D):** 25 W, Ar 900 sccm, distance between electrodes 0.1, 0.3, 1 and 4 mm, respectively, **E):** 25 W, Ar 470 sccm, interelectrode distance 1 mm, **F):** 25 W, Ar 470 sccm, interlectrode distance 4 mm.

of plasma flow from the nozzle of the hollow electrode. Rotational temperature can approximate the temperature of the neutral gas.

Studying optical emission we found that discharges were burning deep inside the hollow electrode but in the atomar gasses. For the voltage frequency higher than approximately 1 kHz, the plasma inside the hollow electrode did not have time to die away during positive half-periods of the voltage and existed inside the electrode permanently. Series of Fig. 4 A-F depict images of discharge inside of the hollow electrode from Fig. 1B observed through the hollow electrode in the direction of flowing gas (argon) for 13.56 MHz. The discharges in the hollow were recorded with a video-camera through a projection microscope of high depth of focus in the optical configuration allowing magnification more than 300x.

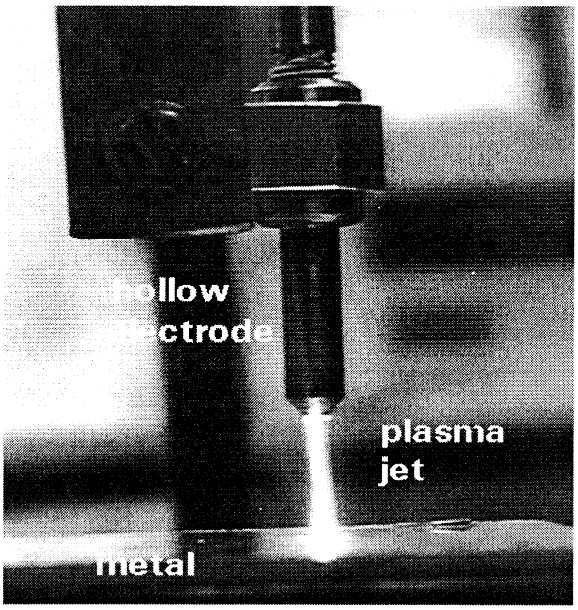

Fig. 5 Application of the RF plasma pencil in free atmosphere on the surfece metal treatment.

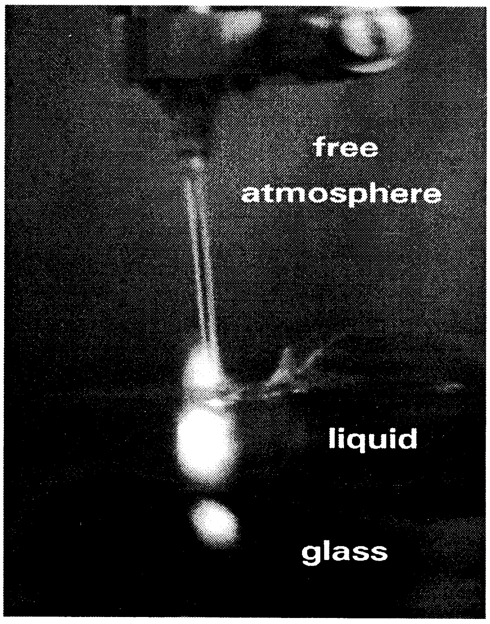

Fig. 6 Application of the RF plasma pencil in liquid.

The observed slow cone contracting of the hollow electrode caused by our optical arrangement allow to distinguish a depth dimension. Therefore we could observe a spatial image of the discharge inside as well as outside the hollow electrode.

Conclusion

The design of our device is destined for current hand operation. The advantages of the plasma pencil are its small dimensions, its high mobility and the generation of discharges at very low supplied power in the wide frequency range inclusive of DC. Another advantage of the plasma pencil is the possibility to work in the free atmosphere, in liquid, at lowered or increased pressures. The new technology was practically utilized for the treatment of archaeological glass and metals artifacts [3,4], fullerene production, fragmentation of molecules for microelectrophoresis, plasma polymerization in liquds, etc.. For the time being, the possibilities of highly directed and selective plasma etching, plasma ablation and locally initiated plasmachemical reactions on the surface of solid substrates appear to be most important.

Acknowledgement

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References

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