Properties of corona discharge plasma near metal surface

M Lavrinenko[1], E Biktashev[1] and D Kirko[2,3]
[1] Moscow State University of Instrument Engineering and Computer Science, Stromynka 20, Moscow, 107996, Russian Federation
[2] National Research Nuclear University MEPhI (MEPhI), Kashirskoe shosse 31, Moscow, 115409, Russian Federation

E-mail: kirko@plasma.mephi.ru

Abstract. Properties of corona discharge near metallic surface were researched. Electrical oscillations in discharge plasma of 1 kHz – 100 MHz rate were registered. Spectrum of electrical oscillations in this range was obtained. Possible plasma waves for observed electronic oscillations explanation are discussed.

1. Introduction

Nowadays a variety of corona discharges is used for treatment and modification of non-organic materials surfaces [1]. High-frequency oscillations within a wide frequency range [2, 3] is one of peculiar features of corona discharges. A typical (characteristic) electrode system normally has a sharpened electrode and a flat electrode [1, 4]. In this work we studied the properties of a corona discharge near a metal surface.

2. Experimental setup

Figure 1 shows the scheme of the experimental setup. We used a conic electrode (1) made of steel (3-4 mm in diameter, cone angle $\alpha \approx 55°$) and a cylindrical electrode (2) made of aluminum (25-35 mm in diameter, 20-25 mm thick) located at a distance d=0.5-45 mm from each other. High-voltage power supply (4) provided 0.5-25 kV at 2 mA. The conic electrode had a positive potential relative to the cylindrical electrode. A static kilovoltmeter and microampermeter were used to measure the voltage and current, respectively. The glow of corona discharge had a weak blue color.

During the experiments, two main modes were discovered. The first mode took place at d=0.5-5 mm within U=1.5-3.5 kV voltage range. The discharge current was of I=5-45 μA. The dependence of the voltage U on the distance d is nearly linear and follows the formula: $U \approx 1.1 + 0{,}76d$ (kV) (d is in cm). In this mode the corona discharge was stable. In the second mode the voltage rose up to U=4,5-25 kV for d=5-45 mm and I=60-140 μA. The corona discharge had a branched structure with a large number of narrow channels and was unstable.

[3] To whom any correspondence should be addressed.

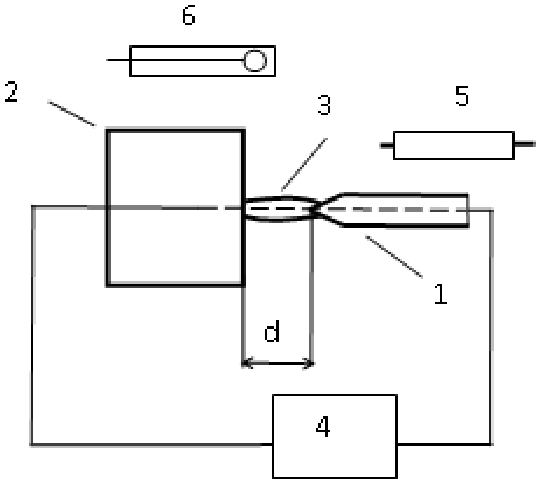

Figure 1. Experimental setup: 1 – anode, 2 – cathode, 3 – corona discharge, 4 – power supply, 5 – electrostatic probe, 6 – magnetic probe.

During the experiment, the electric oscillations were studied as well. For this purpose we used electric (5) and magnetic (6) probes connected to the Tektronix TDS 2024B oscilloscope (figure 1). Electric probes were made of metal rods (3-7 cm long and 2-4 mm in diameter) while magnetic probes were made as coils (2-4 mm in diameter, 80-160 turns, wire 0.1 mm thick). Electric and magnetic probes were 0.2-1.2 m away from the discharge. When oscillations began, the discharge current became to look like a series of separate pulses of ν=1-15 kHz frequency. Figure 2(a) shows a typical form of single pulse. A pulse had a leading edge of 15-35 μs and the falling edge of 150-200 μs. On the pulse droop an oscillations with frequency of ν=0.1-100 MHz appeared. The obtained oscillograms of pulses were processed with the Origin software suit. The most characteristic frequencies were: 4.1±0,2 kHz, 35±2 kHz, 102±5 kHz, 231±12 kHz, 2,4±0,1 MHz, 27±1 MHz, 95±5 MHz. The spectrum of corona discharge electric oscillations is presented in figure 2(b).

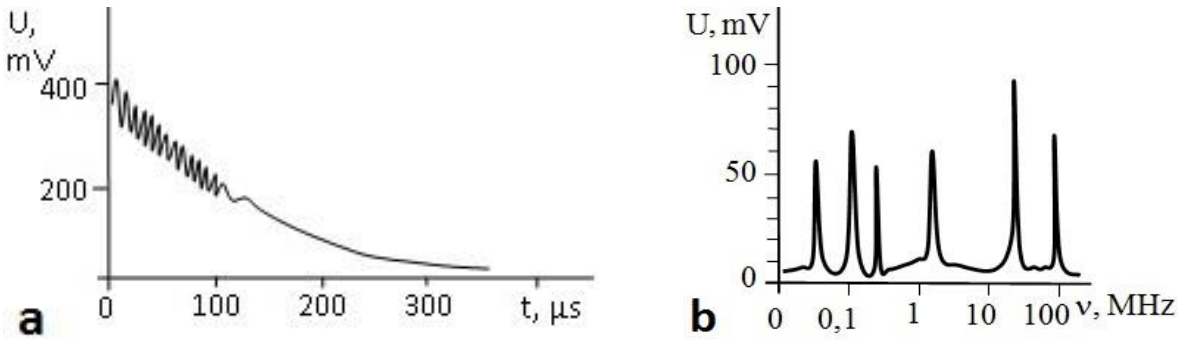

Figure 2. Electric oscillations of corona discharge: a) time dependence of the electric current, b) frequency spectrum of current's oscillations.

3. Discussion

Let us consider plasma processes in the corona discharge. For the values of plasma concentration in corona discharge n_e=10^4-10^{10} cm^{-3} the values of plasma frequency $\omega_p = (4\pi n_e e^2 / m_e)^{1/2}$ lie in the range $\omega_p = 5{,}5\times10^6 - 5{,}5\times10^9$ s^{-1}. Electron concentrations n_e=10^4-10^7 cm^{-3} in this type of corona discharge were registered in [2, 4]. The higher values, n_e=10^6-10^7 cm^{-3}, were found in the 0.3-0.5 mm wide layer around the sharpened part of the conic anode where the generation of electron avalanches is possible. Due to this fact, oscillations of the discharge within ν=1-100 MHz range can be associated with the excitation of high-frequency plasma waves in the corona discharge [5].

The materials with new reflective properties within optical and high-frequency ranges of electromagnetic irradiation are investigated in [6]. These properties are related to the phenomena taking place in a thin micron layer on the surface of a solid. According to this monograph, there is a chance that plasmon waves may exist in a metal at the frequencies lower than plasma frequency. These waves propagate in a surface layer of 10-80 μm thickness. That is why the excitation of plasmon waves with frequencies within ν=1 kHz-150 MHz range is possible in the thin surface layer of anode metal in presence of corona discharge. Thus, the electromagnetic waves with the same frequency ranges can exist both in the anode plasma layer of corona discharge and the anode surface layer. Generation of waves in plasma can be a result of solitary electron avalanches. These waves may also exist in a thin layer of an anode metal.

While studying the corona discharge near the surface of the metal we observed the oscillatory processes. The oscillation frequencies (1 kHz-150 MHz) recorded during the experiment were compared to the frequencies of plasma waves that can exist in the discharge plasma. Plasmon waves generation in a thin micron layer of the anode metal is suggested.

References

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