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ABSORPTION COEFFICIENTS OF SPARK-CHANNEL PLASMA IN A SOLID DIELECTRIC

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UDC 537.529

It is usually assumed [1-4] that a spark in a liquid radiates as a perfect black body (PBB). This assumption lies at the heart of the many estimates that have been made of the temperature of the spark channel in liquid dielectrics. The high particle density of the plasma column and the continuous emission spectrum give a certain basis for extending the PBB model to the case of sparks in solid dielectrics. However, the small radial dimensions of such sparks, especially in the initial phase of expansion (spark diameter 0.1-0.2 mm), may be insufficient to give the optical depth necessary for the PBB model.

In the work reported here we determined the absorption coefficients of the plasma of a spark channel in a KCl single crystal at two wavelengths λ = 330 and 370 nm. The KCl crystal chosen as the spark channel is accurately oriented along the crystallographic direction, thereby enabling the emission to be reliably directed onto the spectrograph slit.

The investigated spark-channel radiation was produced by discharging, across a "point—point" gap, an artificial line of wave impedance 3.5 Ω charged to 70 kV. The dimensions of the sample were 20 × 20 × 5 mm; the spacing between the electrodes was 5 mm.

The absorption coefficient was determined by transillumination of the investigated object with light from a source of known characteristics [5] (we used an ÉV-45 light source [6]). As shown in [5],

$$a_\lambda(t) = 1 - e^{-\alpha_\lambda(t)l(t)} = 1 - \frac{J_\lambda^\Sigma - J_\lambda^{\text{inv}}}{J_\lambda^{\text{st}}},$$

where a_λ is the spark-channel absorption coefficient at wavelength λ; α_λ is the index of absorption; l is the thickness of the plasma sheet; J_λ^{inv}, J_λ^{st}, J_λ^Σ are oscillograms of the intensity (spectral brightness at wavelength λ) of the investigated emission, of the standard source, and of the total light.

The absorption of standard-source light in the crystal was taken into account by recording J_λ^{st} with the sample present. The photoelectronic recording system (ISP-30 spectrograph, FÉU-36 photomultiplier, S1-17 oscilloscope) had a time constant τ = 40 nsec.

To check the dynamics of the filling of the input slit of the spectrograph with light and the calculation of the index of absorption α_λ, the spark channel was photographed by an SFR-2M high-speed photorecorder; illumination from the ÉV-45 was used to produce a shadow pattern.

Tomsk. Translated from Zhurnal Prikladnoi Mekhaniki i Tekhnicheskoi Fiziki, No. 4, pp. 38-39, July-August, 1977. Original article submitted June 28, 1976.

0021-8944/77/1804-0459$07.50

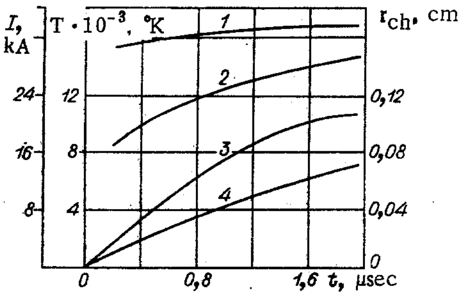

Fig. 1

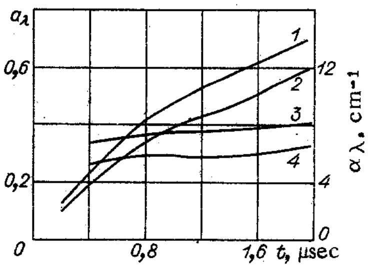

Fig. 2

The spark channel was projected in the plane of the slit with fourfold magnification; the input slit of the spectrograph had a width of 0.02 mm and a height of 0.75 mm. The slit was completely filled with light by the moment t = 0.2 μsec; by the moment t = 0.5 μsec we can set $l = D$ (D is the diameter of the spark), the error in the measurement of α_λ due to this approximation not exceeding 10%. The absorption coefficient a_λ was determined in the range 0.2-2 μsec; the index of absorption α_λ was determined in the range 0.5-2 μsec. At times t > 2 μsec the sample was fragmented by radial cracks away from the channel, which distorted the results of the experiments. The results of the experiments and calculations are presented in Figs. 1 and 2. In Fig. 1, curve 1 is the temperature T(t) of the spark in the KCl crystal allowing for the true emissivity; curve 2 is the temperature $T_p(t)$ of the spark in the KCl crystal on the assumption that the PBB model is valid; curve 3 is the current I(t) through the spark; curve 4 is the radius of the discharge channel $r_{ch}(t)$. In Fig. 2, curves 1 and 2 show the absorption coefficient a_λ, and curves 3 and 4 the index of absorption α_λ; curves 1 and 3 are for a wavelength λ = 370 nm; curves 2 and 4 are for a wavelength λ = 330 nm. The brightness temperature $T_p(t)$ was determined in the same series of experiments as the coefficient a_λ on the assumption that the PBB model is valid by the method described in [7]. The temperature T(t) was determined from $T_p(t)$ by taking the correction for the true emissivity into account. The temperatures determined for wavelengths 330 and 370 nm differ by not more than 5%; Fig. 1 shows the values of $T_p(t)$ and T(t) for λ = 370 nm.

The absorption coefficient a_λ was determined with an error of 10-15%; however, the deviation of a_λ from 1 lies well outside these limits. The use of the PBB model for sparks in solid dielectrics, especially in the initial stage of expansion of the channel, is accordingly problematical. When allowance is made for the deviation from the PBB model, the corrections to the temperature for the spark investigated in the present work are 44, 25, and 12% for times 0.2, 0.8, and 2 μsec, respectively, after the onset of breakdown.

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