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INFLUENCE OF SURFACE CHARGES ON THE BREAKDOWN TIME DELAY IN NEON

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The influence of surface charges on DC breakdown time delay t_d in neon with a hard galvanic layer of gold on the copper cathode with nickel sublayer is studied by the breakdown time delay measurements as a function of the afterglow period τ (relaxation time) and the voltage. The memory curve $t_d(\tau)$ in neon [1] was explained by the action of the long lived metastable states remaining from the preceding glow. However, the authors neglected the quenching processes that reduce the effective lifetime of metastable states down to milliseconds. The early afterglow kinetics up to hundreds of milliseconds in [2] is explained by the decay of molecular neon ions and molecular nitrogen ions produced in Ne_2^+ collisions with nitrogen impurities $Ne_2^+ + N_2 \rightarrow N_2^+ + 2Ne$.

The electrical breakdown time delay t_d comprises the statistical time delay t_s (from the application of voltage greater than the static breakdown voltage U_s to the appearance of a free electron producing breakdown) and the formative time delay t_f (from this moment to the collapse of the applied voltage and occurrence of a self-sustained current) [3]. In the recent paper [4] the breakdown time delay in neon is studied with vacuum deposited gold layer on the cathode at different preionization levels (afterglow periods). The formative time increases linearly with the afterglow period consistent with an exponential Ne_2^+ decay, followed by conversion maxima.

The measurements were carried out on a gas tube made of borosilicate glass with volume of $V \approx 300cm^3$ and a $0.5\mu m$ hard galvanic layer of gold with $7\mu m$ sub-layer of nickel on the cylindrical copper cathode (diameter $D = 6mm$, gap $d = 6mm$). The tube was filled with research purity neon at the pressure of $13.3mbar$ (Matheson Co. with a nitrogen impurity below $1ppm$). The static breakdown voltage was $U_s = 197V$. The time delay measurements were carried out at glow current $I_g = 100\mu A$, glow time $t_g = 1s$ and at different working voltages U_w and afterglow periods. These measurements performed on the gas tube with galvanic layer of gold were compared with the measurements done on the tube with copper cathode, gold plated by vacuum deposition ($100nm$ thick layer) [2]. More details about the experimental procedure can be found in [2].

The breakdown time delay dependence on the afterglow period $t_d(\tau)$, as well as the standard deviation σ_{td} are shown in Fig. 1a. In the first part of the ionic region Ia of the vacuum deposited gold layer, t_f increases linearly with the afterglow period, followed by conversion maxima of molecular neon ions Ne_2^+ to nitrogen ions N_2^+ (region Ib) [2]. In the case of a hard galvanic layer on the copper cathode, the formative times and their standard deviations in the ionic region of the memory curve (I) are almost flat and extended to about $80ms$.

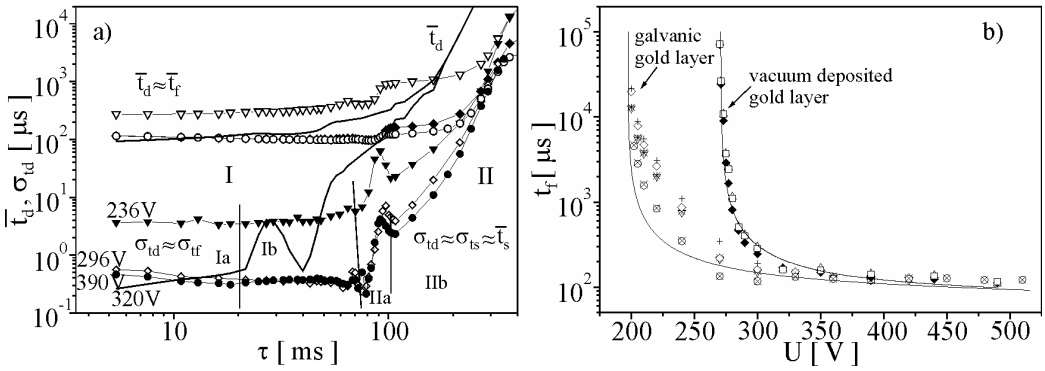

Fig. 1: a) Memory curves in neon (∇,♦,○-$\overline{t_d}$ and ▼,◊,●-σ_{td}) with a hard galvanic layer, solid lines-with a vacuum gold layer. b) Formative times (symbols) with a hard galvanic layer of gold and a vacuum gold layer with the fits (solid lines) based on the model from [4].

This can be explained by the presence of residual surface charges on the galvanic gold layer of the cathode surface. The exponential Ne_2^+ decay in afterglow, as well as the conversion maximum due to molecular nitrogen ions production are masked by the influence of surface charges (Fig. 1a). Moreover, the formative time retains the decreasing behavior with the overvoltage and the static breakdown voltage is significantly reduced compared to the vacuum deposited gold layer (Fig. 1b). The best fits of the experimental data (symbols) based on the model from [4] are shown by the solid lines in Fig. 1b.

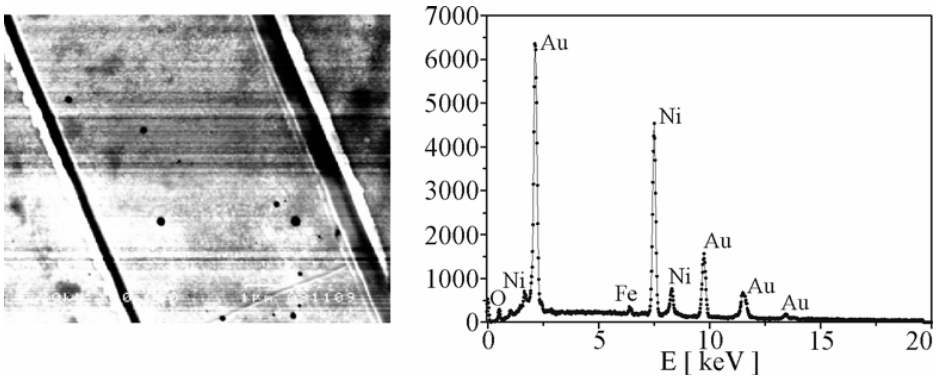

Fig 2: Surface regions with reduced conductivity: SEM image and EDX spectrum

Surface regions with reduced conductivity on a galvanic layer of gold retaining the surface charges, are confirmed by scanning electron microscopy (SEM) and energy dispersive X-ray (EDX) images (Fig. 2a,b). Nickel atoms from sub-layer diffuse into the gold layer causing defects, which can adsorb electrons in traps, whose energy is mostly $\leq 2ev$ [6].

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Reference

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