Abstract

Mgr. Mária Maťašová: Characterization of field emission current generated in microdicharges (Dissertation thesis). Comenius University in Bratislava. Faculty of mathematics, physics and informatics. Department of Experimental Physics. Supervisor: doc. RNDr. Matej Klas, PhD. Qualification degree: PhD. Bratislava: FMPH CU, 2025.

To ensure uniform treatment of samples by plasma at atmospheric pressure, it is crucial to maintain plasma homogeneity. One effective approach is to generate plasma within micrometer-scale electrode gaps. At such small electrode separations, extremely high electric fields (exceeding 10^7 V/cm) lead to field (cold) emissions. These emissions and the associated processes during the pre-breakdown phase are generally considered key to the initiation mechanism of discharges at micrometer distances. However, studying the field emission effects at high pressures presents technical challenges due to the complex phenomena caused by the presence of gas and the rapid ionization occurring during breakdown. To investigate pure field emission, it is necessary to perform measurements in a vacuum, where the influence of the carrier gas can be neglected.

Despite numerous studies, there is a lack of comprehensive investigations into cold emission processes from different metals under identical conditions, especially in the pulsed regimes. Most experiments have focused on common metals such as stainless steel and tungsten, which, while important in plasma technologies, degrade rapidly under oxidative, high-pressure, and high-temperature conditions. Therefore, identifying alternative materials is essential for the long-term reliability of field emission-based discharges. Moreover, reliable studies only report the average values, which fail to capture the range of behaviors occurring during the discharges.

Based on these findings, this thesis primarily focuses on the characterization of noble metals, particularly those from the platinum group, due to their high thermal conductivity and strong resistance to oxidative environments. For comparison, several commonly used engineering metals are also included in the study.

The main objective of this work is the detailed statistical characterization of pulsed microgap vacuum breakdowns. The analysis of field emission current is based on Fowler–Nordheim theory in the pre-breakdown stage, using different metal electrodes. All measurements were carried out in a quasi-homogeneous electric field using high-voltage pulses with a ramp speed up to 10^7 kV/s, applied across electrode gap sizes ranging from

0.5 to 10 μm. Prior to measurements, all electrode surfaces were conditioned to ensure accurate determination of breakdown voltages. The influence of surface conditioning was studied for different combinations of virgin and conditioned anode and cathode surfaces.

One of the most important outcomes of this thesis is the statistical analysis of successive breakdown events. This investigation revealed a novel type of memory effect, observed in vacuum microdischarges. For graphical representation, the relationship of the difference between successive pulses $V_{B(i+1)} - V_{Bi}$ and breakdown voltage V_{Bi}, (where i represents number of breakdowns in the one pulse burst) was proposed, showing unique patterns for different metals. The memory effect was studied for noble metals such as Pd, Pt, and Au, as well as for common metals like Cu, SS and W extending up to near-atmospheric pressures. Furthermore, based on Fowler–Nordheim theory, the key coefficients – including the field enhancement factor β, emission area A, and field emission current density j – were calculated and compared across all investigated metals.