Contribution ID: **7** Type: **Oral**

Quantum model of field emission from dielectric coatings

Monday 2 June 2025 12:00 (30 minutes)

In the present work, the theory of field emission from surfaces covered with both dielectric coatings and naturally formed oxide layers or adsorbates is considered.
A modified Fowler-Nordheim theory was used to describe the field emission processes, considering the two-layer potential barrier formed by the dielectric coating. This allowed us to create analytical models for calculating the field emission current. The process of electron passage through thin (up to 1 nm) and thick dielectric layers was studied. The use of asymptotic approximations for the Airy functions in the case of thin layers provided high accuracy and significant simplification of calculations. For thick dielectric layers, the model showed a good correspondence to simplified expressions for thicknesses not exceeding the average free path length of electrons in the dielectric.
Particular attention is paid to the influence of physical parameters of the dielectric on the field emission current. The dependence of this current on the thickness of the dielectric layer, the strength of the external electric field, the dielectric constant of the medium, and the electron affinity energy is established. The study has shown that at a dielectric layer thickness of up to 1 nm and high electric field strength (over 1 GV/m), the field emission current is significantly reduced due to the increase in the barrier height and width. Instead, an increase in the layer thickness above 1 nm leads to an increase in the field emission current due to a decrease in the width of the potential barrier. This is important for optimizing the operating parameters of accelerator systems.
The paper also compares the quantum model with quasi-classical approaches, in particular the modified Fowler-Nordheim equation. The results show that the quantum model provides a higher emission current density and demonstrates resonant peaks that are not observed in quasi-classical models. This confirms the importance of accounting for quantum effects for accurate field emission calculations.
Thus, the study emphasizes the need to use quantum models to predict the emission characteristics of dielectric-coated materials. The developed analytical solutions improve the accuracy and efficiency of numerical calculations, which is important for the physics of accelerator structures and high voltage technologies.

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Field emission

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Session Classification: Field emission