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Study on Transition from Field Emission to Delay Breakdown

The application of an electric field to a metal surface induces field emission (FE), serving as the initial electron source for vacuum breakdown. Delay breakdown, occurring randomly under a relatively low electric field, poses a critical challenge in engineering applications compared to immediate breakdown. However, the physical mechanisms that lead from FE to delay breakdown are still unclear.

This paper aims to elucidate the process leading from FE to delay breakdown by obtaining two-dimensional FE patterns over an extended time scale (4 –6 h). We established an experimental platform capable of concurrently capturing FE patterns and measuring electron current. Tip emitter DC voltages were manually set to generate electron signals in the FE pattern while avoiding immediate breakdown.

The experiment results show that delay breakdown always occurs after the manifestation of bright spots in the FE electron pattern. Notably, bright spots may dissipate without inducing delay breakdown, emphasizing their role as a necessary condition for delay breakdown. Additionally, the occurrence of bright spots did not induce a significant change in the magnitude of the electron current, indicating that the total number of electrons remained essentially constant and FE persisted within the space-charge limited regime. The appearance of bright spots signifies localized, intense electron emission due to surface modifications on the tip apex under emission-generated heat and field-induced force. During the presence of bright spots, there exists the potential to overcome space charge limitations, ultimately leading to delay breakdown.

Our results provide a description of the conditions leading to delay breakdown, contributing to the enhancement of reliability and continuous performance in vacuum devices and systems.

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