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Studies on microscopic phenomena occuring during high gradient operation on normal- and superconducting surfaces

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Conditioning of a metal surface in a high-voltage system is the progressive development of resistance to vacuum arcing over the operational life of the system. This is relevant for accelerator cavities where high level of performance is only achievable after long conditioning period. Beyond the accelerator research field, this is an important topic for any technology where breakdowns can cause device failure, either by directly disrupting device operation or by causing cumulative hardware damage.
The cryogenic HV pulsing system in FREIA laboratory is used to study surface conditioning with high-repetition rate DC pulses, in function of a wide range of temperatures, down to 4K. It has been shown that the vacuum breakdowns are initiated by activities on the cathode, always accompanied by the field emission. To better understand this process, we are currently measuring field emission currents during the conditioning process of electrodes made out of different metals: copper, niobium and titanium.
We are also developing a new characterization method, consisting in measuring the surface resistivity of the metal surface that is being conditioned by inducing, in addition to DC pulses, a high frequency (GHz) radio-frequency current in the parallel-plate electrode system. If the system can function as a resonant cavity, the surface resistivity data would be encoded in its quality factor (Q-factor). The changes in the Q-factor measured in cryogenic conditions could indicate a formation of dislocations under the surface, something that has been speculated as an important process behind the conditioning, even more important than the changes on the surface.
We will present the results of the conditioning process and of the field emission measurements. Additionally, we will also present our plans for the surface resistivity measurements, the modified design of the electrode system, based on the choke cavity design of Shintake, and experimental data regarding the characterization of this resonant system. The results are relevant and bridge a knowledge gap between warm and cold, normal conducting, high gradient, accelerator projects.

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