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Real-time observation of strong electric-field-induced surface modification

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When a metal surface is exposed to a high heterogeneous electric field, surface modifications may occur, leading to the appearance of new, as well as the reconstruction of existing, fine surface features that can act as field emitters. This, on the one hand, is an undesirable process in crucial applications like the CLIC [1] accelerator in CERN, where it causes electrical breakdowns on Cu electrodes. On the other hand, this opens the opportunity for unique surface engineering and the design of novel nanostructures.

Our study is dedicated to the experimental investigation of the processes occurring on metal surfaces under strong electric field in vacuum conditions, in order to gain deeper insights and better control over the electric-field-induced surface modifications. Our intent is to create the conditions for controlled emitter formation and growth in predetermined locations on Cu surface with immediate visual feedback in order to get better understanding of the process. For this, experiments are performed inside a scanning electron microscope (SEM), relying on the advanced nanomanipulation platforms [2], [3]. The investigated samples are placed under a strong electric field generated locally by a counterelectrode attached to a piezo-positioner. Since the high voltage applied to the investigated objects disturbs the e-beam, strong electric fields will be achieved at small voltages via decreasing the curvatures of both the sample and counter-electrode and by reducing the separation distance between them. The use of sharp probes enables reaching extreme local electric field gradients at low voltages due to curvature effects. With curvatures and separation of a few tens of nm, the required field strength is achieved at voltages in the range of 10 V. Localized sample heating by fiber-fed laser irradiation in SEM can be used to boost surface diffusion.

Besides modification of the metal surfaces, a strong non-uniform electric field can affect other processes, such as the deposition of carbon-based molecules ionized by e-beam, a common process inside SEM. In the absence of an external field, deposition is uniform. However, the introduction of a highly localized electric field would direct the ionized molecules to the desired location. It opens opportunities for creating fine conductive surface features with a high degree of control.

References

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