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Atomically heterogeneous surface with microconical arrays of field emitters generated using plasma based low energy ion beams

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Plasma based ion beam patterning is attributed to surface atoms removal and rearranging as self-organized micro/nanopatterned arrays [1]. Apart from being atomically heterogeneous due to implantation of inert gaseous ions, these patterned arrays due to their protruding tips act as naturally selected micro or nano field electron emitters and, have tremendous applications in field-emission displays, electron microscopes, electron guns and vacuum electronics [1]. Their electrical, optical, surface and field emission properties have been explored in literature [2-5]. The self-organized micro-conical arrays are observed on copper surface produced after irradiating with 2 keV argon ions and krypton ions with flux of 5.4×10^{15} cm^{-2} s^{-1} and 4.1×10^{15} cm^{-2} s^{-1} at normal incidence, respectively. Optimization of fluences increase the number of emitters per unit area, due to production of multiple nucleation sites that stabilizes the growth of these features. The aspect ratio (base width/height) of microstructures decreases at increased fluence variation from 1.3×10^{18} cm^{-2} to 4.7×10^{18} cm^{-2} for argon and 3×10^{17} cm^{-2} to 3.9×10^{18} cm^{-2} for krypton ions, as observed by secondary electron microscope (SEM) and atomic force microscope (AFM). The highest percentage of implanted argon ions at the atomic length scale is 3.89, for the surface irradiated with fluence of 4.7×10^{18} cm^{-2} and 4.25, for the surface irradiated with krypton ions at fluence of 3.9×10^{18} cm^{-2} (X-ray Photoelectron Spectroscopy analysis). Theoretical models for field emission (Fowler Nordheim theory) uses Wentzel Kramers Brillouin (WKB) approximation to evaluate transmission coefficient through 1D image charge modified triangular barrier [6]. This model gives exact solution for smooth planar surface. The conversion of Fowler Nordheim current density (1D) to emitter current (3D) requires knowledge of emission area and local field at emission site. From, Jensen's analysis, the local field at the apex of rotationally symmetric hyperbola and its' emitter current is calculated, which is then, extended over arrays of emitters by using multiplicative factors like number of emitters and distribution factor associated with spread of tip radii [6]. In naturally formed field emitters, the structures are nonuniform in terms of both geometry and atomic composition. Hence, we develop a model based upon existing theories, by statistically distributing uniform arrays of micro conics of similar aspect ratio on a pure copper substrate. The aspect ratio variation is incorporated by varying height and base width groupwise for micro conical arrays and, subsequently developing a model for generalized structures. Then, argon and krypton ions are placed uniformly up to certain skin depth over the arrays to make the array surface heterogeneous. The emission current obtained from this model is compared to experimentally obtained emission current to understand the contribution of structural deformities and compositional heterogeneities on field emission parameters.

References

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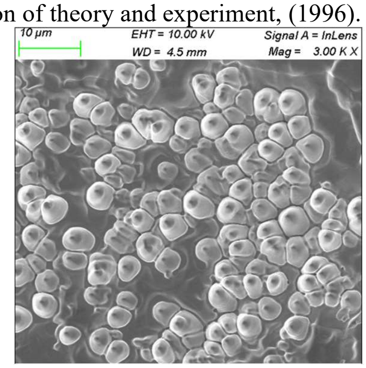

Figure 1: SEM image (40 µm × 40 µm scan area) of 2 keV Ar^+ ions bombarded Cu sheet at fluence of 2.7×10^{18} cm^{-2}.

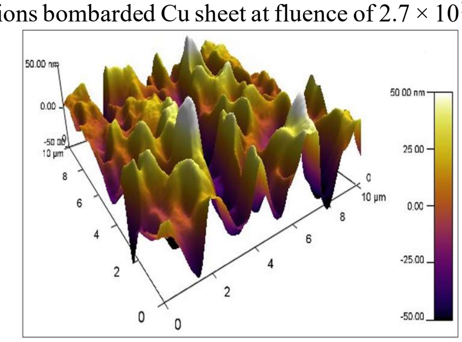

Figure 2: AFM image (10 µm × 10 µm scan area) of 2 keV Ar^+ ions bombarded Cu sheet at fluence of 2.7×10^{18} cm^{-2}.