Electron emission from detonation nanodiamond

V. V. Zhirnov, T. Tyler, D. L. Jaeger, A. V. Kvit and J. J. Hren
North Carolina State University, Raleigh, NC 27695-7907

Electron emission properties of detonation nanodiamond particles were studied by different techniques such as field emission, field emission microscopy (FEM), UV photoelectron spectroscopy (UPS), and high-resolution transmission electron microsc opy (HRTEM). Results on comparison of the emission properties of detonation nanodiamonds with CVD diamond coatings will be presented.

Nanodiamond coatings of different thickness on the tips of metal needles were investigated. The effects of surface modification, the size of diamond crystallites, and hydrogen plasma treatments were studied. A technique for isolation and characterization of single nanometer-sized particles of diamond was demonstrated. Electron emission from a multi-particle nanodiamond coating and an isolated diamond nanoparticle were measured. The emission characteristics were a complex function of coating thickness and particle size. Current-voltage curves shifted to a considerably higher voltage for emission from a single diamond particle than for the metal substrate alone. However, for thicker deposits of particles (~20 nm) with approximately uniform nanoparticle coverage, the I-V plot was sharply shifted to a voltage much lower than for the uncoated metal substrate. After emission experiments, HRTEM did not reveal the formation of nano-protrusions or graphite inclusions in the diamond particle; however, the particle appeared to be in much better contact with the metal substrate than by deposition alone. The observed anomalous thickness effect is not completely understood.

Our results indicate that classical electrostatic and Fowler-Nordheim analysis cannot wholly explain the thickness and size selective dependencies of diamond nanodots-coated metal field emitters. Different factors affecting the emission mechanism will be discussed. The observed suppression of field emission due to the presence of a single isolated diamond nanoparticle on a metal tip, compared to that of a more uniformly coated emitter, suggests that there are size-dependent effects contributing to emission suppression. It is suggested that quantum confinement effects leading to an increase in the bandgap of the diamond may contribute to the emission suppression for particles less than 5 nm in size. In addition, electrostatic effects, resulting from the small dimensions and morphology of the isolated diamond nanoparticle, may further suppress emission. Understanding these effects requires further inquiry into the structure of the near surface potential barrier, quantum confinement effects, and surface phenomena that may affect electron emission. Emission in the two-barrier system depends upon the transmission coefficient of the first and second barriers and any additional carrier generation from electron transport between thetwo barriers (e.g. impact ionization). Also, surface dipoles may play an important role in electron transport and field emission in this structure. For example, the electron affinity may show a transition from negative, to positive, as a function of surface size and curvature.