Micropatterned Diamond/Carbon Field Emission Diode and Triode

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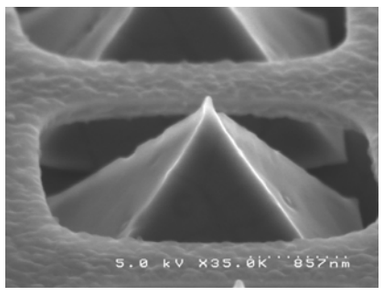
Abstract
Chemical vapor deposited diamond/carbon micro- and nanostructures are excellent cathodes for vacuum field emission applications because of their low electron affinity and excellent mechanical and chemical properties. However, the “direct” usage of these materials as cathodes falls short for most practical applications due to non-uniform emitter structures, uncontrolled emission sites, and inconsistent emission behavior. Consequently, practical engineering design and control of emitter structures are needed to fully exploit the use of diamond/carbon field emitters. This paper describes the use of microfabrication methods to achieve various forms of “morphologically-engineered” structures (see figure) such as micro pyramidal tips, micro edges, and lateral microstructures with built-in self-aligned gate for electron emission modulation and control.

We report the achievement of micropatterned diamond field emission diodes and triodes with excellent field emission characteristics. Self-aligned gated diamond vacuum triodes were fabricated from a silicon-on-insulator substrate. This fabrication technique utilizes conventional silicon micropatterning and etching techniques to define the anode, gate, and cathode. The fabrication has achieved diamond field emitter triodes over practical wafer areas. The field emission of the triode array exhibits transistor characteristics with high dc voltage gain and transconductance values. For lateral field emission structures, a novel diamond patterning technique utilizing a selective oxide and lift-off process was employed to fabricate a diamond vacuum diode. The lateral diamond emitter diode exhibits excellent emission characteristics with a low turn-on voltage and high emission current, which is larger when compared with reported lateral field emitter structures of other materials.

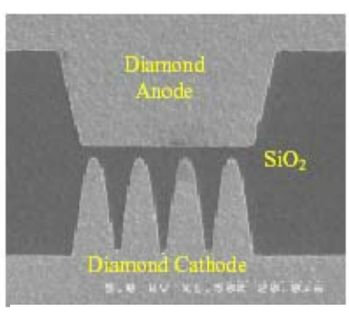
We also present the development of self-aligned gated carbon nanotubes (CNTs) for cold cathode applications. Electron emission results demonstrate that CNTs configured as diode field emitters exhibit low turn-on fields and high emission current. Also, the emission characteristics show gate-controlled modulation of emission current in triode configuration.

The field emission results of these micropatterned diamond/carbon diodes and triodes, suggest that potential applications of diamond/carbon emission devices beyond conventional vacuum microelectronics will be possible.

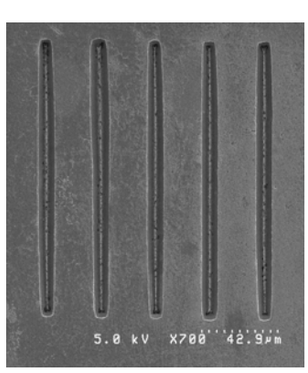
Keywords: diamond/carbon, carbon nanotubes, field emission diode/triode, micro patterning



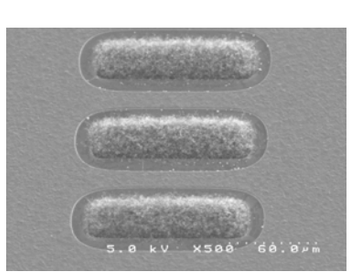
Diamond gated pyramidal tip triode



Diamond gated lateral triode



Diamond gated edge-shaped triode



Carbon nanotubes gated triode