High-performance CNT line emitters using the macroscopic mechanical clamping process

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Abstract

Many researches have clearly revealed that individual carbon nanotube (CNT) is excellent electron field emitter with a low turn-on field for emission, a high emission current density and long-term emission stability.[1] The superior emission characteristics stem from the unique one-dimensional structure and the extraordinary properties of CNT.[2] Recently, a variety of efforts have been devoted to enlarging the applicability of CNT emitters to industrial applications, including microwave amplifier tubes, high-resolution electron-beam instruments, X-ray and terahertz power sources.[3] Structural geometry of a CNT emitter is also extended to non-planar prototypes by demonstrating wrappable CNT fiber, yarn and sheet cathodes for field emission applications.[4] These recent advances in a CNT emitter have synergistically accomplished with the development of macroscopic architectures based on assembled CNTs.

Various macroscopic forms of CNTs have been produced ranging through fibers, yarns, films, sheets and foams. Each structure shows unique geometry and functionality depending on the manner in which CNTs are assembled. The properties of individual CNT are unrivaled by any other materials, however it has proven difficult to simultaneously retain the intrinsic properties of CNT at engineering-relevant scales due to synthesis and fabrication issues. Moreover, several parameters need to be considered to design and fabricate a macroscopic CNT emitter, including orientation, aspect ratio, uniformity, and density of CNTs as much as the physical contacts of CNTs with a supporting electrode.

We report a robust and scalable method to fabricate a high performance carbon nanotube (CNT) line emitter by using macroscopic mechanical clamping process. The process utilizes a handheld metal tong, which also serves as an electrode, applying uniaxial mechanical compression to the upper part of CNT forest in the lateral direction. While the lateral dimension of the CNT forest decreases uniaxially by 2% in the form of densely packed CNT strip, the bottom part of CNTs is subsequently detached from a substrate and is radially spreading out like bundling of flowers. As a result, a hemicylindrical shape of CNT structure strongly held with the tong electrode is achieved. Our approach is advantageous for a variety of applications, especially binder-free, density-controllable CNT electrodes, and here we demonstrate its use as a high performance CNT line emitter. With robust contact characteristics created by the mechanical clamping, a CNT line emitter shows superior field emission performance with current density of 2700 mA/cm^2, net current of 40 mA and stable operation over 10 hours. Furthermore, an extremely high current of 100 mA is achieved by clamping multiple CNT forests in a tong, showing scalability of the present approach.

References

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