High Performance CNT Point Emitter with Electrical and Thermal Interfacial Graphene Layer

Jeong Seok Lee, Taewoo Kim, Junho Lee and Yong Hyup Kim

School of Mechanical and Aerospace Engineering, Seoul National University, Seoul, Republic of Korea
misty7@snu.ac.kr

Abstract

By taking advantages of the superior material properties and high aspect ratio geometry of CNT (carbon nanotube) [1], many researchers have developed CNT point emitters which are capable of providing low turn-on voltage, high emission current density and long-term operating stability [2]. Extremely high current density of the point emitter plays an essential role in generating sufficient power sources for microwave amplifier tubes, high-resolution electron-beam instruments and X-ray sources. One-dimensional geometry of the point emitter can reduce the operating voltage in the applications due to amplification of field enhancement.

Two distinct approaches have been investigated to fabricate the CNT point emitters, such as directly growing of CNTs or attaching CNTs at the end of a sharp metal tip. The direct growth method forms metal catalysts on the end of a metal tip followed by growing CNTs using chemical vapor deposition (CVD) process at high temperature. However, it comes with a limitation that the metal material with high melting temperature should be utilized. Moreover, the as-grown CNTs generally contain metal catalysts and carbonaceous impurities which degrade the field emission performances such as turn-on voltage and operational stability. The approach that attaching CNTs at a metal tip may be a more appropriate way to fabricate a point emitter when considering the temperature limit and purification issues of CNTs in the direct growth method. However, it is unavoidable in the process that high thermal and electrical contact resistances between metal and CNT would degrade field emission performances, which issues also have been brought up through past studies. High electrical contact resistance increases not only threshold electric field for electron emission, but causes electrical Joule-heating at the contact interface. High thermal contact resistance generally induces the decrease in the life expectancy of the emitter through sublimination of CNT emitters.

In the present study we have investigated graphene as an interfacial layer between metal and CNT to improve the interfacial contact properties. Single layer graphene has remarkable electron mobility (~150,000 $cm^2V^{-1}s^{-1}$) and thermal conductivity (~3,100 – 5,300 $Wm^{-1}K^{-1}$) [3]. Moreover, since graphene is a two dimensional material and basically consists of the same atomic structure as CNT, exhibiting a similar work function of ~4.5 eV [4], graphene has a great potential for the interfacial layer to improve the electric and thermal interfaces between metal surface and CNTs. Adopting graphene to interfacial layer between metals and CNTs, we successfully achieved a dramatic decrease of electrical contact resistance by an order of 2, and the increase of the thermal conductivity by 16%. The performance of CNT point emitter including the graphene interfacial layer is also greatly improved.

References

[1] Ray H. Baughman, Anvar A. Zakhidov, Walt A. de Heer, Science, **297** (2002) 787.
[2] Eric Minoux, Oliver Groening, Kenneth B. K. Teo, Sharvari H. Dalal, Laurent Gangloff, and William I. Milne, Nano Letters, **5** (2005) 2135.
[3] Chandan Biswas and Young Hee Lee, Advanced Functional Materials, **21** (2011) 3806.
[4] G. Giovannetti, P. A. Khomyakov, G. Brocks, V. M. Karpan, J. van den Brink, and P. J. Kelly, Physical Review Letters, **101** (2008) 026803.

Figures