3rd Asia-Pacific Conference on Plasma Physics, 4-8,11.2019, Hefei, China

Effect of Process Parameters on the Growth and Field Emission Properties of Graphene -Carbon Nanotube Composite

Suresh C. Sharma, Neha Gupta, Shruti Sharma and Rinku Sharma.

Abstract: Since the discovery of carbon nanotubes (CNTs) in 1991 by Iijima[1], there has been great deal of interestamong material scientists and engineers due to its unique structure and properties. In particular, field emission (FE)of electron from CNTs is one of the most promising electronic properties as far as its practical application is concerned. Although number of studies explored CNTs as the promising candidate for FE devices, the FE is believed to predominantly occur from the tips rather than the side walls. A report by Konishiet al.[2] suggests that the intensity of electric field concentrated on the tip of CNT is 2.8 times higher than the side walls. The field emission of CNTs is also problematic because they burn out during emission, ceasing the emission completely, i.e., they have less FE stability. In order to achieve the FE enhancement, graphene-CNT composite(g-CNTc)with graphene layers protruding from the CNT have been synthesized by many researchers with a vision to create more emission sites and exceptional field emission performance than individual CNT [3-5]. This composite made of CNT and graphene is a three-dimensional conductive carbon network which offers the advantage of high surface area framework of CNT coupled with the high edge density of the graphene sheets.

In order to enhance or control the electron emission characteristics of (g-CNTc), process parameters such as, gas pressure, input power, and substrate bias on the number density and dimensions of VG sheet grown over CNT surface are investigated. Plasma enhanced chemical vapor deposition (PECVD) is considered as the most viable technique for the growth of g-CNTcas it exhibits better control over the g-CNTc structure at relatively low temperatures and also offers the advantage of g-CNTc structure modification by process parameters. In the present work, a theoretical model is developed to describe the growth of CNT and thereafter nucleation and growth of graphene sheets on CNT in the presence of CH4/H2/N2 plasma. The defects generated on the CNT
surface during its growth are considered as the nucleation sites for the growth of graphene sheet on CNT surface. The model incorporates the charging rate of the g-CNTc, kinetics and energy balance of all plasma species i.e., electrons, positively charged ions and neutral atoms along with the process parameters, and growth rate of the g-CNTc. Numerical calculations on the effect of process parameters on the growth of g-CNTchave been carried out for typical glow discharge plasma parameters. It is observed that the electron density, electron temperature, and ion energies in the plasma increases on reducing the gas pressure and on increasing the input power and substrate bias, which subsequently enhances the ion bombardment and carbon generation on the CNT surface, and thereby the height as well as number density of VG sheets on CNT increase, and thickness of VG sheet decreases. Some of the results of the present investigation are in compliance with the existing experimental observations [5-7].

List of related published papers

[1]S. Iijima, Nature 354, 56 (1991).
[2]Y. Konishi, S. Hokushin, H. Tanaka, L. Pan, S. Akita, Y. Nakayama, Jpn. J. Appl. Phys. 44 1648 (2005).
[3]J. Liu, B. Zeng, X. Wang, W. Wang, and H. Shi, Appl. Phys. Lett. 103, 053105 (2013).
[4]J.-H Deng, R.-Ting Zheng, Y. Zhao, and G.-An Cheng, ACS Nano 6, 3727(2012).
[5]V. Kaushik, A. K. Shukla, V. D. Vankar, Appl. Phys. A 117, 2197 (2014).
[6] D. H. Seo, S. Kumar, A. K. Rider, Z. Han, and K. Ostrikov, Opt. Mat. Express 2, 700(2012).
[7]W. Takeuchi, H. Sasaki, S. Kato, S. Takashima, M. Hiramatsu, and M. Hori, J. Appl. Phys. 105, 113305 (2009).