Single-walled carbon nanotubes defected by ion beams

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Defective single-walled carbon nanotubes (SWCNTs) is a promising material for various applications such as nanowire processing [1], beams control [2], cross-linking [3], optoelectronics [4], and others. There are several ways to create defects in SWCNTs. One of them is the use of ion beams [5,6]. Accepting the stability of SWCNTs over the energetic ion beams and investigating the irradiation with different fluences it is possible to controllably create the required amount of defects in SWCNTs. Raman spectroscopy is a powerful tool for the estimation of the amount and type of defects in SWCNTs [7].

In the work, we used single-walled carbon nanotubes produced by OCSiAl company with an average diameter equal to 1.8 nm. We prepared thin films on the Si or glass substrates and irradiated them with Ar and He ions with energies of 80 and 50 keV respectively. We varied fluences from 10^{12} to $2*10^{16}$ ions/cm^2 in order to achieve the smooth change of the defects density up to the amorphous stage. We conclude the defectiveness of SWCNTs by Raman spectra.

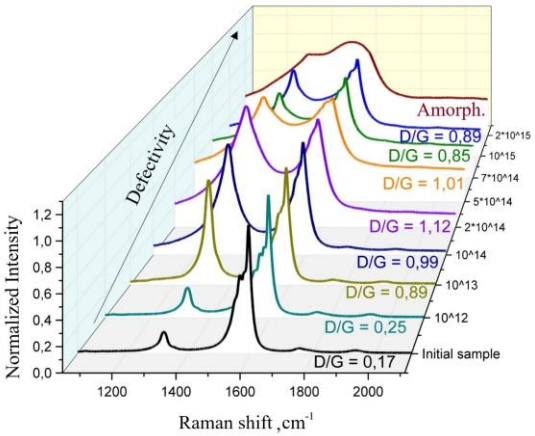

Fig. 1. Raman spectra of defected single-walled carbon nanotubes by Ar^+ ions

In some applications, it is important to further modify the properties of SWCNTs by various dopants [8]. We used a gas-phase technique to obtain the doping of SWCNTs with iodine [9-10]. We found by Raman spectra and by the UV-vis-NIR absorbance spectroscopy that the effectiveness of doping can be increased for ion irradiated SWCNTs with low fluences. We also found that the conductivity of the films with any level of defectiveness was dramatically reduced after the iodine doping.

Acknowledgments:
The research was funded by the Academy of Finland project 340831.

[1] Yun, W. S., Kim, J., Park, K. H., Ha, J. S., Ko, Y. J., Park, K., ... & Forró, L. (2000). Fabrication of metal nanowire using carbon nanotube as a mask. Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films, 18(4), 1329-1332.
[2] D'Acunto, G., Ripanti, F., Postorino, P., Betti, M. G., Scardamaglia, M., Bittencourt, C., & Mariani, C. (2018). Channelling and induced defects at ion-bombarded aligned multiwall carbon nanotubes. Carbon, 139, 768-775.
[3] Krasheninnikov, A. V., Nordlund, K., Keinonen, J., & Banhart, F. (2002). Ion-irradiation-induced welding of carbon nanotubes. Physical Review B, 66(24), 245403.
[4] Sevik, C., Sevinçli, H., Cuniberti, G., & Cagın, T. (2011). Phonon engineering in carbon nanotubes by controlling defect concentration. Nano Letters, 11(11), 4971-4977.
[5] Zhang, Y., Chen, L., Xu, Z., Li, Y., Shan, M., Liu, L., ... & Wang, C. (2012). Effects of ion irradiation on carbon nanotubes: a review. International Journal of Materials and Product Technology, 45(1-4), 1-30.
[6] Shemukhin, A. A., Stepanov, A. V., Nazarov, A. V., & Balakshin, Y. V. (2019). Simulation of defects formation in nanotubes under ion irradiation. Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms, 460, 230-233.
[7] Dresselhaus, M. S., Jorio, A., Souza Filho, A. G., & Saito, R. (2010). Defect characterization in graphene and carbon nanotubes using Raman spectroscopy. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, 368(1932), 5355-5377.
[8] Terrones, M., & Rao, A. M. (2007). Doped carbon nanotubes: synthesis, characterization and applications. In Carbon nanotubes (pp. 531-566). Springer, Berlin, Heidelberg.
[9] Tonkikh, A. A., Obraztsova, E. D., Obraztsova, E. A., Belkin, A. V., & Pozharov, A. S. (2012). Optical spectroscopy of iodine-doped single-wall carbon nanotubes of different diameter. physica status solidi (b), 249(12), 2454-2459.
[10] Tonkikh, A. A., Tsebro, V. I., Obraztsova, E. A., Suenaga, K., Kataura, H., Nasibulin, A. G., ... & Obraztsova, E. D. (2015). Metallization of single-wall carbon nanotube thin films induced by gas phase iodination. Carbon, 94, 768-774.