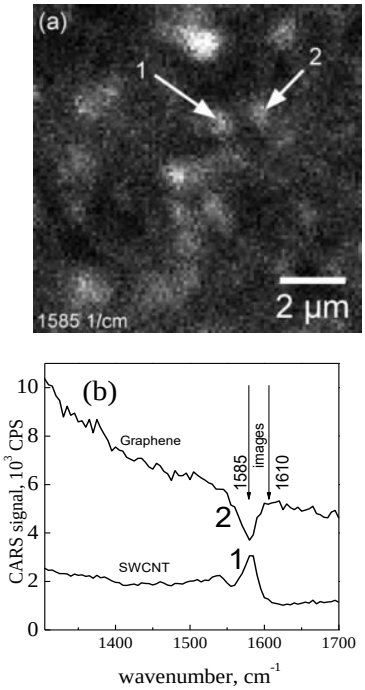
Anglies nano struktūrų tyrimas CARS mikroskopijos metodu

Investigation of carbon nano-structures by CARS microscopy

Andrej Dementjev[1], Alesia Paddubskaya[2], Galina Dovbeshko[3]
[1]Fizinių ir technologijos mokslų centras, Savanorių pr. 231, 02300 Vilnius, Lithuania
[2]Institute for Nuclear Problems, Belarusian State University, Minsk 220006, Belarus
[3]Institute of Physics, National Academy of Sciences of Ukraine, 46 Nauki Ave, Kyiv 03680, Ukraine
andrej.dementjev@ftmc.lt

In the recent years the composites or hybrid material based on graphene and carbon nanotube (CNT) have become a subject of extensive studies. At the same time, although the significant progress in the development of various techniques for the synthesis of CNT-graphene hybrid structures and composites has been achieved, the problem of separation of CNT and graphene in the final composition comprising both of them, as well as recognition of their spatial distribution are still challenging problems for many applications [1]. One of the most widely used methods for these purposes is the optical microscopic imaging using Raman scattering as a contrast mechanism. Coherent analog of spontaneous Raman scattering or coherent anti-Stokes Raman scattering (CARS, a particular case of four-wave mixing) can be applied to characterize CNT and/or graphene. It is worth noting that major contribution in the graphene CARS spectra is electronically enhanced the nonresonant background. At the same time, the contribution of the vibrational component to the four-wave mixing seems to be much smaller than electronic one. Due to Fano resonance nature [2], in this case at the resonance frequency a “dip” appears in the CARS spectrum instead of a “peak”. In this work we provide the systematic analysis of the possibilities to separate tiny amounts of CNTs deposited on the surface of CVD graphene by CARS spectroscopy. Furthermore, we propose the mapping algorithm which can be used for future characterization of CNT-graphene hybrid systems.

The “peak” and “dip” for SWCNT and graphene respectively, observed at the resonance frequency of G-band complicate their separation in imaging using CARS Spectroscopy [3]. This stimulates the search of an algorithm enabling separation of component in CNT/graphene composite system. The imaging only at 1585 cm-1 does not allow to separate components. We have demonstrated that two images are necessary for this. While an imaging at 1610 cm-1 gives direct mapping of graphene revealing its specific pattern, the identification of CNT requires images at both frequencies. The differential image was obtained by subtracting the image at 1610 cm-1 from the image at 1585 cm-1 disclosing the distribution of CNT and suppressing graphene. This approach allows separate imaging of CNT and graphene in CARS microscopy and can be useful for future characterization of novel hybrid composite materials.



1 pav. (a) Image of a CNT/graphene system obtained at 1585 cm^{-1}. Point #1 and point #2 have the same brightness while corresponding spectra (b) at resonance frequency show “peak” and “dip”, respectively.

Key words: Graphene, CNT, CARS imaging, G-band

Literatūra

[1] Yoshimura S.H., Khan S., Maruyama H., Nakayama Y., Takeyasu K. Fluorescence Labeling of Carbon Nanotubes and Visualization of a Nanotube−Protein Hybrid under Fluorescence Microscope. Biomacromolecules 2011; 12(4): 1200–1204, https://doi.org/10.1021/bm101491s.

[2] Limonov M.F., Rybin M.V., Poddubny, A.N., Kivshar, Y.S. Fano resonances in photonics. Nature Photonics 2017; 11(9): 543–554. https://doi.org/10.1038/nphoton.2017.142.

[3] Paddubskaya, A., Rutkauskas, D., Karpicz, R. et al. Recognition of Spatial Distribution of CNT and Graphene in Hybrid Structure by Mapping with Coherent Anti-Stokes Raman Microscopy. Nanoscale Res Lett 15, 37 (2020). https://doi.org/10.1186/s11671-020-3264-8