Spectroscopic and differential scanning calorimetry studies of the impact of amide-functionalized single-walled carbon nanotubes on the structure and dynamics of lipid bilayers

*Victoria Vitkova, Peter Rafailov, Boyko Katranchev, Tihomir Tenev, Ilko Miloushev, Minko Petrov, Krassimir Panajotov and Yordan Marinov**

Institute of Solid State Physics, Bulgarian Academy of Sciences, Sofia, Bulgaria

ymarinov@issp.bas.bg

The limited solubility and high cytotoxicity of carbon nanotubes hinder their use in biomedicine (1-4). However, functionalizing them with amide groups can mitigate these limitations by improving solubility and biocompatibility while reducing toxicity (5). Therefore, understanding the interactions between amide-functionalized single-walled carbon nanotubes (af-SWCNTs) and lipid bilayers is crucial to grasping the biophysical effects of these nanomaterials on membranes and their potential biomedical applications (5). In this study, we examined the interactions between af-SWCNTs and two types of lipid bilayers: one prepared from saturated phosphatidylcholine (1,2-dimyristoyl-sn-glycero-3-phosphocholine [DMPC]) and one prepared from monounsaturated phosphatidylcholine (1-stearoyl-2-oleoyl-sn-glycero-3-phosphocholine [SOPC]). We examined these interactions using differential scanning calorimetry, Raman spectroscopy, and attenuated total reflectance Fourier transform infrared spectroscopy. Our results suggest that increasing af-SWCNT concentration decreases acyl chain lateral packing density, accompanied by enhanced rotational disorder and an increased population of gauche conformers. These changes are reflected by reduced intermolecular chain coupling and a shift in the intramolecular gauche/trans ratio, collectively indicating a reduction in intermolecular packing order. Overall, these findings suggest that af-SWCNTs disrupt the structural organization of lipid membranes. This offers insight into their potential effects on membrane fluidity and permeability, as well as their possible applications in biomedicine and nanobiotechnology.

Keywords:
lipid membranes, thermal shape fluctuations, giant vesicles, bending elasticity, Attenuated Total Reflectance-Fourier Transform Infrared Spectroscopy

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