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Mechanical and piezoelectric properties of pure and modified microtubes of diphenylalanine

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Self-assembled supramolecular peptide structures are a class of chiral organic piezoelectrics capable for biomedical applications and devices [1], nanoelectronics [2], etc. Functionalization of peptide nanostructures by nanoparticles (NPs) leads to formation of new organo-inorganic composites. Interaction between NPs and biological macromolecules via weak hydrogen bonds and van-der-Waals forces represents fundamental interest, since NPs act on the formation and structural stability of the supramolecular structures [3].

Diphenylalanine (FF) is a model material intrinsically chiral in pure form. Different chirality of structures – L- (left) and D- (right) conformations – can influence on their physical properties as well as embedding the NPs. Although physical properties of D-FF microtubes are well known, the properties of their composites with NPs and microtubes of L-conformation are insufficiently studied.

In this work, we studied the growth kinetics, structure, mechanical and piezoelectric properties of pure FF microtubes with different chirality and composite D-FF microtubes with inclusion of nanoparticles (NPs) of piezoelectric ZnO (diameter 30±11 nm) and nonpiezoelectric SiO_2 (diameter 43±11 nm) and TiO_2 (diameter 26±7 nm). Pure FF microtubes were obtained using conventional method of growth from water solution [4]. The composite FF-NPs microtubes were obtained using modified method: FF powder dissolved in 1,1,1,3,3,3-hexafluoro-2-propanol was mixed with stable NPs water suspensions (concentration 0.5 mg/mL).

The growth kinetics study didn't show noticeably influence of chirality and any type of NPs on growth of FF microtubes. Moreover, FF microtubes of both chiral conformations have similar values of Young's modulus and axial piezoelectric coefficients. In case of embedding of NPs it was shown that voids and cavities appeared in FF microtubes. The effective transverse Young's modulus of the obtained composite FF-NPs microtubes was slightly reduced due to these defects while their axial piezoelectric coefficients decreased almost two times. At the same time, insertion of ZnO NPs provided appearance of noticeable vertical piezoresponse which is absent in pure FF microtubes. The obtained results demonstrate the ability to control the properties of self-assembling composite biomaterials by various NPs.

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