NANOPARTICLES OF REDUCED GRAPHENE OXIDE AND GRAPHENE NANOPLATELET – HOW AND THEY ORGANIZED IN POLYLACTIDE MATRIX?

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The polymer composites composed of biodegradable synthetic Polylactide (PLA) and carbon allotrope additives reduced graphene oxide (RGO) and graphene nanoplatelets (GNP) were studied with Small Angle Neutron Scattering (SANS) at the YuMO instrument located at the IBR-2, Dubna.

Filling PLA with nanosize particles (NPs) of RGO or GNP results in clusterization of nanoparticles in the bulk of the polymer matrix, decreases its segmental mobility, changes thermal, conductive and mechanical properties (strength, toughness), thereby improves their operational characteristics important for different industrial, economic and medical applications.

Recently, the PLA composites filled with RGO and GNP nanoparticles were carefully studied; in [1], [2], [3], synthesis of nanocomposites (by solid-phase- and liquid-phase mixing) and their characterization with thermogravimetrical analysis, thermophysical analysis for the original PLA (4043D manufactured by NatureWorks, USA, with a crystallinity of 30.8%,) and its compositions with RGO and GNPs (from 1 to 5 wt%) nanofillers were carried out, electrical and mechanical properties of the composites at 0.25-15wt% of RGO and GNPs in PLA were clarified. The percolation thresholds of PLA/RGO (2wt%) and PLA/GNP (7wt%) were found, as well as differential distributions of RGO and GNP particles sizes in the bulk. Aggregated carbon nanoparticles RGO and GNP have high polydispersity in the bulk of PLA, they reach the maximum sizes in plane from 0.34 to 80 μm and from 2.24 to 88.4 μm for RGO and GNP particles respectively, whereas original particles are of units to tens nm sizes; as the SEM data showed [1], [2], [3].

At the same time, at the filling PLA with NPs, obscure shifts were observed X-ray microtomography images of the composites, which have to be interpreted as formation of new functional groups or new unknown intermolecular interactions.

At the YuMO instrument, we obtained the SANS spectra $I(Q)$ for pure PLA and PLA compositions with RGO concentrations 0.05, 0.1, 0.15, 0.2, 0.25 wt% and GNPs concentrations 0.05, 0.1, 0.25, 1 and 5 wt% of solid-phase's and 0.1, 0.2, 0.25 wt% liquid-phase's method of synthesis. Theses spectra $I(Q)$ for pure PLA and 3 series with "PLA/GNPs from a solid-phase", "PLA/GNPs from a liquid-phase" PLA/RGO samples are shown in Figure 1.

We present the results of Guinier (at $Q<0.04$ Å^{-1}) and Porod (at $Q>0.04$ Å^{-1}) analysis of the experimental SANS curves: structure factor and formfactor of the nanofillers, such as the gyration radii R_g, fractal dimensionality of the RGO ($d_f \sim 2$) and GNP nanoparticles [4], [5]. For instance, we found out the organization of RGO in PLA matrix into ellipsoid-like sheets of ~0.5 nm thickness and confirmed high polydispersity of nanoparticles.

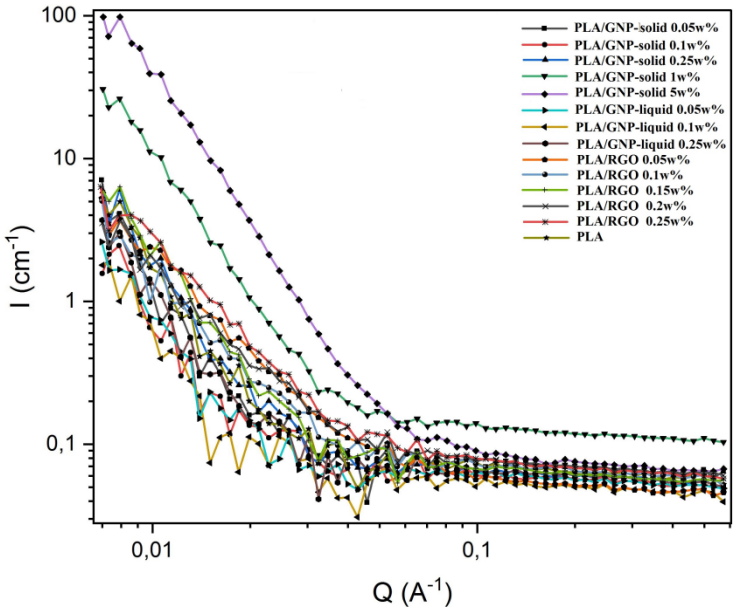

Fig.1. Experimental intensities $I(Q)$ SANS for PLA, PLA/RGO and PLA/GNP samples

Our SANS data analysis is useful for refined nondestructive evaluations of morphology of RGO and GNP particles in PLA and further scientific substantiation of unknown mechanisms of self-organization of carbon allotrope nanoparticles under various synthesis conditions.

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