Influence of the type and combination of carbon nanofillers on the nanomechanical properties of PLA-based nanocomposites

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The polymer used in this study for the compounding formulation was IngeoTM Biopolymer PLA-3D850 (Nature Works, Minnetonka, MN, USA). Four types of carbon nanofiller were chosen to manufacture the nanocomposites: (1) industrial graphene TNIGNP (Times Nano, Chengdu, China); (2) industrial MWCNTs – TNIMH4 (Times Nano, Chengdu, China); (3) graphene – TNGNP (Times Nano, Chengdu, China); and (4) MWCNTs – N7000 (NC7000TM series, Nanocyl® SA, Sambreville, Belgium). The four types of nanofillers, with different size, shape, aspect ratio and specific surface area, were used in order to estimate the influence of their characteristics on the nanomechanical properties of the obtained mono-filler (PLA/MWCNT and PLA/GNP) and bi-filler (PLA/MWCNT/GNP) nanocomposites up to 6 wt%. The mono and bi-filler nanocomposites were processed, using the melt extrusion method trough preparation of masterbatches and further dilutions. In order to prepare films, pellets were dried, followed by hot pressing. The obtained samples were with around 150 microns of thickness. Nanoindentation and nanoscratch tests were performed on Hysitron TI 980 instrument (Bruker, MN, USA). The nanoindentation measurements were done to minimum five selected areas of each composite film, with size of each indented area of 70 um x 70 um, grid of 7 × 7 indents and spacing of 10 μm. The maximum force of 1500 um and spacing were carefully selected so that individual indents did not affect each other. The results shows that the sample filled with 6 wt% of MWCNTs have a maximum improvement for the hardness and Young's modulus, in comparison with the PLA. The samples with hybrid combination of both nanofillers MWCNTs and GNP (1:3, 1:1 and 3:1), also shows improvement, but no synergistic effect is observed. Coefficient of friction at scratch (COF) is calculated from the ratio of the exerted lateral force during material plowing to the constant normal force set in load function and it could measure the surface resistance of a composite against scratch. Figure 1 presents 3D SPM topography image of nanoscratch test trace, made on the surface of 3 wt.% MWCNT/3 wt.% GNP/PLA composite sample. The maximum improvement is reached for the COF at scratch for two bi-filler composite films containing 1.5 wt.% MWCNT/4.5 wt.% GNP/PLA and 4.5 wt.% MWCNT/1.5 wt.% GNP/PLA. Synergy effect with combining GNPs and MWCNTs is found pointing out higher scratch resistance of the bi-filler composites compared to mono-filler composites, with same carbon loading.

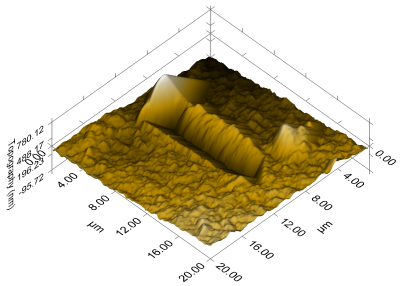

Figure 1. 3D SPM topography image of nanoscratch test trace, made on the surface of 3 wt.% MWCNT/3 wt.% GNP/PLA composite sample

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