Biopolymer-graphene nanocomposites: properties, applications and safety issues

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Introduction

Based on the superior properties of graphene, the polymer nanocomposites offer enhanced mechanical properties and functionality, which make them attractive for variety of applications. However, many factors are found to govern the final nanocomposite properties and due to the complexity of the factors, contradicting properties may be obtained [1]. The present study addresses the role of the dispersion and the loading of graphene nanoplatelets (GNPs) in the polylactic acid (PLA) biopolymer for the enhancement of mechanical, electrical and thermal properties of nanocomposites (NCs), towards 3D printing and packaging applications.

Results and Discussion

The PLA composites of varying GNP contents from 1.5 to 12 wt.% are prepared by melt extrusion using a masterbatch approach. By increasing the filler loading, GNP/PLA nanocomposites demonstrate a significant enhancement of Young's modulus, and scratch resistance, but the tensile strength and elongation slightly decrease (Fig.1). The coefficient of friction in wear is strongly decreased by increasing the GNP contents if compared to the neat PLA, demonstrating the self-lubricating properties of GNP/PLA nanocomposites. The electrical percolation threshold was determined between 3-6 wt.% GNP content, while the thermal conductivity gradually increases by increasing the amount of filler. The highest values of the conductivities is observed for the 12 wt.% GNP/PLA nanocomposites, with dc-conductivity of 1.3 S/m and thermal conductivity of about 1.0 W/mK, while the matrix polymer is an electrical and thermal insulator.

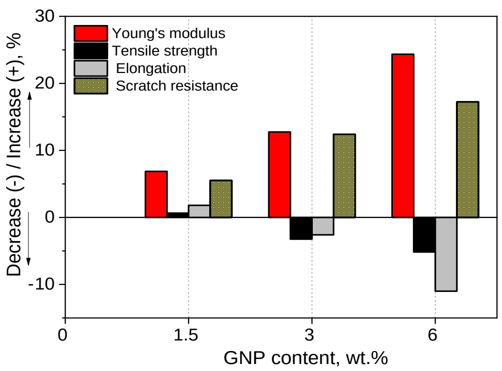

Fig. 1. Mechanical properties of GNP/PLA NCs

The highly improved mechanical properties (tensile, bending and friction), as well as the strongly enhanced electrical and thermal conductivity of the PLA-based nanocomposites at GNP loading above the percolation threshold, allowed us to propose the 6-12 wt.% GNP/PLA as a novel multifunctional material for 3D printing application (FDM/FFF). The good printability is due to the lubricant effect of graphene nanoplatelets during the flow, which is associated with sliding of the GNPs one over another and hydrodynamic slip at the filler-polymer interfaces. The slip-sliding effects of GNPs increase significantly by increasing the filler content, which makes printable the highly filled GNP/PLA nanocomposites [2].

At low filler loading around the percolation threshold (3 - 6 wt.% GNPs), the improved tensile properties, the enhanced scratch resistance with 12-15%, dc-conductivity in the range 10^{-6}-10^{-2} S/m and 2 to 3-folds enhanced thermal conductivity compared to the neat PLA, make the biodegradable GNP/PLA nanocomposite films a good candidate for packaging applications. However, our study on safety showed that the graphene platelets may release from the films into the food simulants if a high temperature treatment (4 hours at 90^{o}C) is applied [3]. Although the nanoparticles are tightly bound in the matrix polymer, the release of GNPs mostly due to the swelling and partial degradation of the PLA polymer in alcohol and acetic acid media at high temperatures. Therefore, if the GNP/PLA nanocomposite films are used for food packaging application the potential hazard of graphene associated with the high temperature treatment of the packaged food needs of further investigations.

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References

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