Effect of carbon nanofillers on the permeability, conductive and nanomechanical properties of PLA-based composites films

C. Santillo[1], G.G. Buonocore[1], R. Di Maio[1], M. Lavorgna[1], E. Ivanov[2,3], T. Batakaliev[2], R. Kotsilkova[2]

[1]National Research Council of Italy, Institute for Polymers, Composites and Biomaterials, P.le E. Fermi 1, Portici, Naples 80155, Italy

[2]Open Laboratory on Experimental Micro and Nano Mechanics (OLEM), Institute of Mechanics, Bulgarian Academy of Sciences, Acad. G. Bonchev Str. Block 4, 1113 Sofia, Bulgaria

[3]Research and Development of Nanomaterials and Nanotechnologies (NanoTech Lab Ltd.), Acad. G. Bonchev Str. Block 4, 1113 Sofia, Bulgaria)

Corresponding author Rosa Di Maio: rosa.dimaio@ipcb.cnr.it

Poly(lactic acid) (PLA) is one of the most widely used polymers during the last years which finds versatile applications in packaging, pharmaceutical, textiles, engineering, chemical industries, automotive composites, biomedical and tissue engineering fields. However, the low mechanical properties limit the number of its applications. In this context, carbon-based nanomaterials, offer the potential to combine PLA properties with several of their unique features, such as high mechanical strength, electrical conductivity, thermal stability and bioactivity and a significant research has dealt with the use of fillers for improving the properties of PLA [1-3]. In the present work, two- and three-component PLA-based nanocomposites with carbon nanotubes and graphene have been developed by the method of melting carbon fillers into the polymer matrix suitable for FDM 3D printing. In particular, the effect of nanoparticles, such as two different types of carbon nanotubes, graphene and their combination, on nanomechanical, permeability and conductive properties of PLA nanocomposites prepared by the melt blending method was investigated. Results show a remarkable improvement in the thermal conductivity of graphene-based composite. RX analysis show that in presence of GNPs and at low concentration of MWCNTs an increase of the size of the bundles (d1) is observed. Moreover, q2 and d2 values suggest an increase of the distance between MWCNTs in the PLA matrix, as decreasing the content of MWCNTs and increasing the content of GNPs. Water permeability tests of the developed films show a good improvement in water barrier properties, mainly due to the effect of GNPs which reduce the diffusion of water molecules through the polymer matrix. Results of conductivity tests suggest that a combination of conductive carbon fillers (MWCNT and GNP) in an equal weight ratio leads to the formation of a more effective percolation path: a conductive network can be formed thanks to the flexible MWCNTs rods that are bridged between the planar GNP nanoplatelets

Nano-indentation tests performed with a new rapid type of nanoindentation show that a synergistic effect was found on the combination of graphene with carbon nanotubes on the mechanical properties of nanocomposites based on PLA. This mechanical reinforcement of the nanocomposites is probably related to the specific structure and geometry of the particles of the hybrid fillers, the interactions between the fillers, the effect of the concentration of carbon nanoparticles and the processing method.

Acknowledgement.

Authors acknowledge the support from MSCA RISE H2020-MSCA-RISE-2016 Project Graphene 3D (Grant Number: 734164), H2020-SGS-FET-Graphene Flagship-881603 Graphene Core 3, Bilateral collaboration between BAS-CNR (2019-2021) and Project MIRACle № BG05M2OP001-1.002-0011.

References

[1] Ivanov, E.; Kotsilkova, R.; Xia, H.; Chen, Y.; Donato, R.K.; Donato, K.; Godoy, A.P.; Di Maio, R.; Silvestre, C.; Cimmino, S.; Angelov, V.. *Appl. Sci*., 9, 1209 (2019).

[2] Kotsilkova, R.; Ivanov, E.; Georgiev, V.; Ivanova, R.; Menseidov, D.; Batakliev, T.; Angelov, V.; Xia, H.; Chen, Y.; Bychanok, D.; Kuzhir, P.; Di Maio, R.; Silvestre, C.; Cimmino, S.. *Polymers*, 12, 1208 (2020).

[3] Spinelli, G.; Kotsilkova, R.; Ivanov, E.; Georgiev, V.; Ivanova, R.; Naddeo, C.; Romano, V. *Polymers*, 12, 2414. (2020).