Hristiana Velichkova*
Ricardo J. E. Andrade**, Guilhermino J. M. Fechine**, Rumiana Kotsilkova*, Verislav Angelov*
* Institute of Mechanics, Bulgarian Academy of Sciences, Acad. G. Bonchev Street, Bl. 4, Sofia, Bulgaria
** MackGraphe-Graphene and Nanomaterials Research Center, Mackenzie Presbyterian University, Rua da Concolacao 896, Sao Paulo, SP, CEP 01302-907, Brazil

Contact@E-mail: hristiana_velichkova@abv.bg

Influence of carbon nanotubes and graphene nanoplatelets on the surface free energy and zeta potential of high density polyethylene

Abstract

In the recent years, graphene as multifunctional 2D-atomic nanomaterial, was found of interest in different research fields such as biomedical, tissue engineering, material sciences etc. Graphene becomes one of the most studied nanomaterials in the world, due to its properties. In the frame of this experimental investigation Graphene nanoplatelets (GNPs) were chosen as one of the nanofillers for preparation of binary and ternary nanocomposites, due to the unique properties of graphene. As second filler in this experimental investigation multi-walled carbon nanotubes (MWCNTs) were used. In order to obtain innovative composites focused on the applications in fused deposition modelling (FDM) technique, thermoplastic polymer was chosen as basic polymer matrix. The most widely used thermoplastic materials are polyolefins, due to their excellent thermomechanical properties and good environmental compatibility, including easy recycling [1].

High density polyethylene (HDPE) is one of the most commonly used polyolefin polymers, due to its low cost, good processability, nontoxicity, light weight, high mechanical flexibility, high specific strength and high chemical resistance. However, the preparation of nanocomposites based on HDPE is challenging due to its strong non-polar behavior. This is especially true for CNT- and graphene-based composites, as their high surface area make the agglomeration phenomenon most likely during the processing, especially for melt-mixing techniques. This happens despite the fact that both graphene and MWCNT, in their pristine forms, are hydrophobic, with reported water contact angles of ~92˚ [2] and ~139˚ [3], respectively. However, recently advances have been done to understand the peculiarities of these systems, especially when using two-dimensional (2D) fillers into high-shear processes (e.g. twin-screw extruder).

In this study two-step method for developing HDPE/MWCNT, HDPE/graphene and HDPE/MWCNT/graphene nanocomposites were proposed. This methodology was applied in order to obtain exfoliation of the graphene and wrapping of both fillers onto polymer particles. As first step for mixing of polymer powders with the carbon fillers was chosen ball milling technique [4-6].

In frame of this experimental study, contact angle measurements were provided, firstly in order to evaluate the influence of the fillers (graphene and CNT) on the surface properties of the polymer matrix. By the results of contact angle of mono-filler and bi-filler composites, we can evaluate the influence of fillers on the wettability and surface free energy (SFE). On other hand, streaming potential measurements were carried out to evaluate the charge changing on the surface of the thin films by the presence of the fillers. Both techniques allowed a more complete understanding of the surface properties of the composites and correlate these results with the morphology of these materials.

Experimental results show quite homogeneous hybrid materials with increased wettability, of all investigated nanocomposites. Figure 1 present water contact angle results of composites containing graphene nanoplatelets (GNP). On the graph can be seen water contact angle versus weight content of GNP filler.

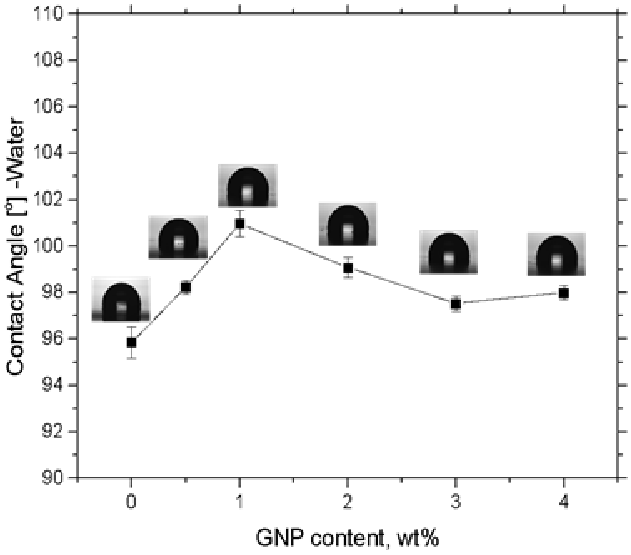

Figure 1. Water contact angle of HDPE/GNP composites

The contact angle results show negligible changes in surface free energy of mono-filler and bi-filler systems. On other hand, dispersive components for all samples are increased, which is due to better Van der Waals interactions. Due to non-polar behavior, of HDPE and both fillers, all composites have increased contact angles and decreased polar components, which is related to dipole-dipole forces in the investigated materials.

Zeta potential results show that composites with added MWCNT (mono-filler and bi-filler) have better stability and quite well dispersed fillers. In the case of GNPs composites, only HDPE/1wt% GNP have good filler distribution and stable system, which was also observed by optical microscopy analysis.

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