Effects of 2D crystals addition on the physical properties of polycarbonate-based composite

E. Lago, P.S. Toth, V. Pellegrini, and F. Bonaccorso

Graphene Labs - Istituto Italiano di Tecnologia, Via Morego 30, 16163, Genoa, Italy
emanuele.lago@iit.it

Two-dimensional (2D) crystals-based applications are gaining increasing attention in the past few years [1]. The current bottleneck hindering the full exploitation of the 2D crystal properties relies on their production strategies. In this context, liquid phase exfoliation (LPE) of layered materials [2,3] is the most promising approach for the scalable production of 2D crystals. In fact, by LPE it is possible to realize dispersions and inks, to be deposited on target substrates, as well as polymer composites [4]. In particular, 2D-crystals-based composites have shown improvements in mechanical, electrical and thermal properties compared to pristine polymer matrices [1,4]. Unfortunately, the impact of both 2D filler nature and morphology, *i.e.* lateral size and thickness, on the composite properties is still poorly understood, thus an in-depth study is urgently needed for further optimization.

Herein, we select polycarbonate (PC) as polymer for the production of both graphene- and hexagonal boron nitride (hBN)-doped composites, prepared by solvent blending technique. The 2D crystals addition to the polymeric matrix is evaluated by investigating the mechanical properties of the composites.

Exfoliation of bulk layered material is carried out by ultra-sonication [5]. The solvent used for graphene is N-Methyl-2-pyrrolidone, whereas for h-BN we used a novel water/surfactant solution. 2D-based crystals are then sorted by lateral size and thickness by using ultra-centrifugation [6-8]. The obtained graphene flakes of average lateral size of ~300 nm are obtained by ultra-centrifugation at 17000g; a cascade centrifugation [9] was developed in order to separate hBN flakes in two different dispersions with average lateral sizes of 200 and 400 nm, respectively. After the ultra-centrifugation, a solvent exchange process is used for the re-dispersion of the graphene and hBN flakes in 1,3-dioxolane, the same solvent used for the dissolution of PC pellets. 2D crystals and PC dispersions are mixed by means of ultra-sonication allowing a thorough mixing of flakes and PC polymer chains. The dispersions are then pelletized by pouring water, a non-solvent for the PC, which precipitates the composite materials. Finally, the pellets of composite are hot-pressed to form ~100 µm thick composite films.

Graphene/PC and hBN/PC composites are characterized morphologically and structurally using atomic force and scanning electron microscopies, and Raman spectroscopy. Static and dynamic mechanical measurements are carried out to investigate the effect of low loading (≤1%) of the two different 2D crystal fillers in PC matrix. We found an improvement of more than 25% in Young's modulus with respect to the neat polymer at 1 wt.% and 0.5 wt% of loading of graphene and hBN, respectively. Thus, hBN flakes provided the same improvement of graphene flakes with only half of the loading, highlighting how the differences in structure and morphology of 2D-crystals-based fillers play a key role in nanocomposite science and technology.

References
[1] A.C. Ferrari, et al., Nanoscale, **7** (2015) 4598
[2] J.N Coleman, et al., Science, **331** (2011) 568
[3] F. Bonaccorso, et al., Adv. Mater. DOI: 10.1002/adma.201506410
[4] J.R. Potts, et al., Polymer, **52** (2011) 5
[5] Y. Hernandez, et al., Nat. Nanotechnol., **3** (2008) 563
[6] O. M. Maragó, et al., ACS Nano, **4** (2010) 7515
[7] J. Hassoun, et al., Nano Lett., **14** (2014) 4901
[8] A. Capasso, et al., Solid State Commun., **224** (2015) 53
[9] C. Backes, et al., ACS Nano, **10** (2016) 1589