Controlling electrical percolation in thermoplastic-hybrid nanocomposites

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Carbonaceous nanomaterials, including graphene, carbon nanotubes (CNT) and carbon blacks (CB), are excellent fillers for electrically conductive polymer composites due to their low density, high aspect ratio and high conductivity [1,2]. However, the nature of the percolated networks formed within these nanocomposites is still poorly understood due to the complex interdependencies between the filler morphology, processing conditions and network structure. Herein, we present our latest understanding of these interdependencies based upon a detailed combined modelling and experimental approach.

~0D (carbon black), 1D (nanotubes) and 2D (graphenes) nanomaterials were used as reinforcements within polycarbonate. The electrical percolation curves were established for both singular reinforcements and hybrid systems where different combinations of reinforcements (e.g. graphene-CB, CB-CNT etc) were used. The nature of the networks were explored through transmission electron microscopy and conductive AFM (Fig.1a). The experimental work was interpreted using Monte-Carlo simulations where we have focussed on understanding the role of clustering and secondary aggregate formation (Fig.1b). Despite reports of possible synergy between different nanomaterials in the literature, we show that the percolation threshold is ultimately determined by the average aspect ratio of the fillers and, importantly, their clusters. It was found that through selection of the hybrid fillers, one can control the percolation threshold, exponent of the percolation curve and ultimate electrical conductivity within an over-arching parameter window, allowing industry to produce composite systems which are robust against differing processing conditions.
We thank the DPI, European Graphene Flagship, Morgan Adv Materials & RAEng for funding.

References

[1] I.A. Kinloch, J. Suhr, R.J. Young, P.M. Ajyan, Science, 362 (2018) 547-553
[2] A.J. Marsden *et al.*, 2D Materials, 5 (3) (2018) 032003

Figures

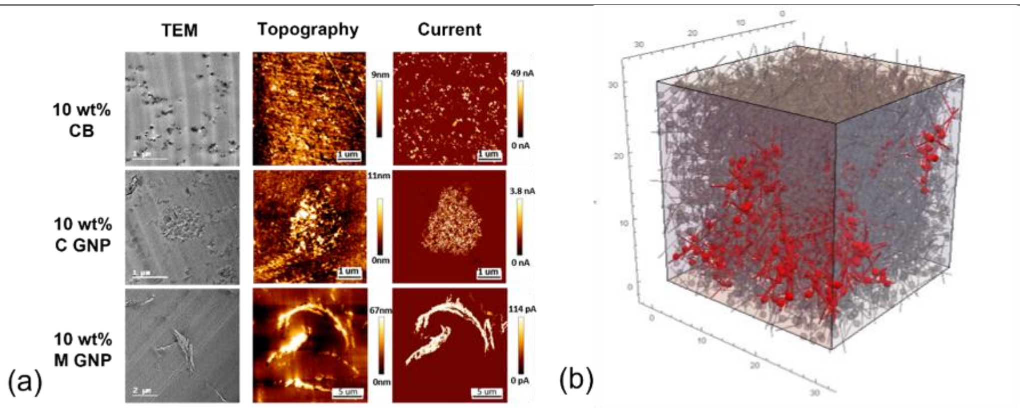

Figure 1: a) TEM image as well as topography and current mapping obtained from conductive-AFM of composites and (b) example Monte-Carlo simulation of hybrid system with the percolated pathway highlighted in red.