The Mechanics of Reinforcement of Nanocomposites by 2D Materials

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A detailed study has been undertaken of the mechanisms of stress transfer in polymeric matrices with different values of Young's modulus, E_m, reinforced by graphene nanoplatelets (GNPs) (Figure 1). For each material, the Young's modulus of the graphene filler, E_f, has been determined using the rule of mixtures and it is found to scale with the value of E_m. A theory has been developed to predict the stiffness of the bulk nanocomposites from the mechanics of stress transfer from the matrix to the GNP reinforcement based upon the shear-lag deformation of individual graphene nanoplatelets and the results are plotted in Figure 2. Overall it is found that it is only possible to realise the theoretical Young's modulus of graphene of 1.05 TPa for discontinuous nanoplatelets as E_m approaches 1 TPa; the effective modulus of the reinforcement will always be less for lower values of E_m. For flexible polymeric matrices the level of reinforcement is independent of the graphene Young's modulus and, in general, the best reinforcement will be obtained in nanocomposites with strong graphene-polymer interfaces and aligned nanoplatelets with high aspect ratios.

References

[1] RJ Young, MF Liu, IA Kinloch, SH Li, X Zhao, C Vallés, DG Papageorgiou, Composites Science and Technology, 154 (2018) 110-116.
[2] SH Li, ZL Li, TL Burnett, TJA Slater, T Hashimoto, RJ Young, Journal of Materials Science, 52 (2017) 9558-9572.

Figures

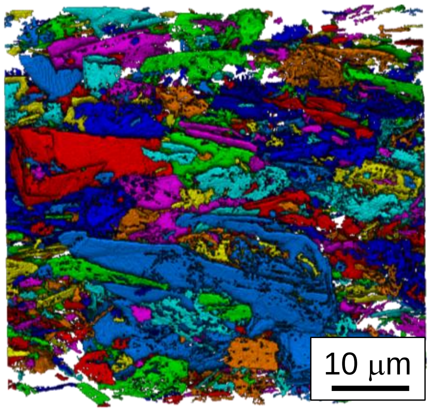

Figure 1: Artificially-coloured image of a CT scan of a natural rubber nanocomposite [2] containing M25 GNPs nanoplatelelets.

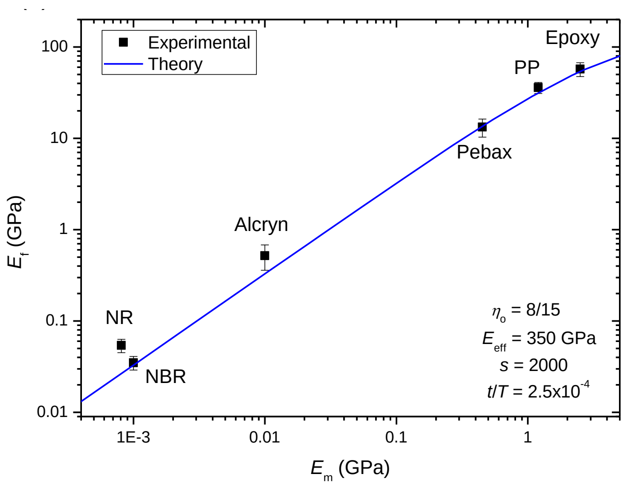

Figure 2: Variation of E_f with E_m for the M25 GNPs reinforcing a series of polymeric matrix different materials with different values of matrix modulus, E_m. The solid line is the behaviour predicted with the parameters indicated.