# The Role of Filler Aspect Ratio in the Reinforcement of Polymers with Graphene and 2D Materials

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The mechanisms of reinforcement of an epoxy resin by the addition of graphene nanoplatelets (GNPs) has been studied in detail. It is found that the addition of GNPs increases both the stiffness and fracture toughness of the epoxy resin. The dependence of the flexural modulus upon the volume fraction of the GNPs has been modelled using a combination of the rule of mixtures and shear lag analysis [1] and it is shown that the reinforcement is controlled principally by the aspect ratio (length/thickness) of the GNPs. The dependence of the fracture energy upon the GNP volume fraction has also been modelled assuming failure takes place through the debonding of the GNP particles followed by their pull-out as shown in Figure 1. This behaviour is similar to that found for the toughening of elastomers by 2D materials [2]. It is again shown that the aspect ratio of the GNPs is a vital parameter in controlling the level of toughening. It is found that the mechanical behaviour can be modelled using a similar value of GNP aspect ratio to model both the flexural stiffness and fracture behaviour, demonstrating the importance of this parameter in controlling the mechanical properties of GNP/epoxy resin nanocomposites. The application of the above analysis to our understanding of the reinforcement of a wide range of polymers by 2D materials will be discussed in detail.

## References

[1] Young RJ, Liu M, Kinloch IA, Li S, Zhao X, Vallés C, Papageorgiou DG, The mechanics of reinforcement of polymers by graphene nanoplatelets, Composites Science and Technology, 154 (2018) 110-116.
[2] Liu M, Hui JH, Kinloch IA, Young RJ, Papageorgiou DG, Deformation and tearing of graphene-reinforced elastomer nanocomposites, Composites Communications, 25 (2021) 100764.

## Figures

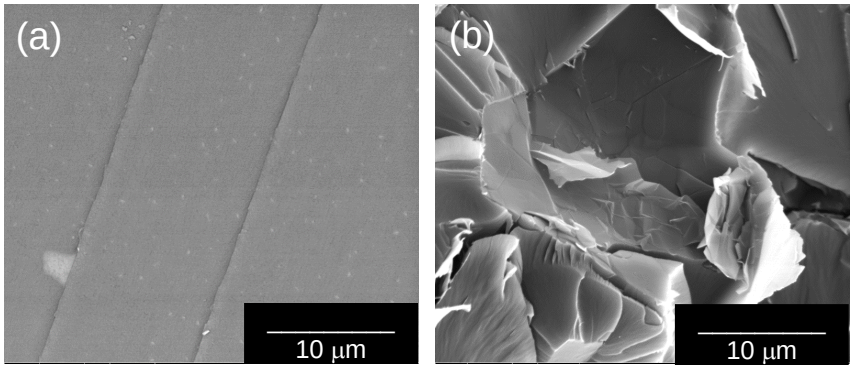


**Figure 1:** SEM micrographs of the fracture surfaces of (a) Pure epoxy and a nanocomposites with (b) 1 wt% GNPs, showing pulled-out GNPs and cavities.