

Editorial corner – a personal view

Is it possible to strengthen rigid polymers by adding low aspect ratio nanofillers?

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When polymer nanocomposites emerged over twenty years ago, represented by the application of clay/nylon-6 nanocomposites at Toyota Central R&D Labs, they were considered as revolutionary alternative to microcomposites. As the interface between nanofillers and matrix would constitute large area within the bulk material, properties of polymer nanocomposites were expected to be greatly improved. With growing experience, however, it seems that enhancement of mechanical properties of rigid polymers (which are so named to distinguish them from rubbers and gels) resulting from addition of low aspect ratio nanofillers (e.g., clay, nanoparticles, etc.) is not so easy as people imagine. In general, stiffening characterized by increase of modulus can be acquired due to the inherent rigidity of inorganic nanofillers. Toughening is also possible when nanofillers are capable of highly mobile under applied stress, which leads to greater ability of energy dissipation and hence higher ductility of nanocomposites. The strategy has been evidenced by nanoclay/poly(vinylidene fluoride) or polystyrene (Adv. Mater., DOI: [10.1002/adma.200400984](https://doi.org/10.1002/adma.200400984)), nano-SiO₂/polypropylene or polystyrene (Adv. Mater., DOI: [10.1002/adma.200602611](https://doi.org/10.1002/adma.200602611)), and carbon nanotubes/polypropylene (J. Mater. Chem., DOI: [10.1039/C1JM14474J](https://doi.org/10.1039/C1JM14474J)). Nevertheless, the reported strengthening effect is far from satisfactory no matter how the composites are prepared. The poor load-bearing capability of the low aspect ratio nanofillers should take the main responsibility.

It is worth noting that the results of our recent exploration indicate that the problem might be hopefully solved (J. Mater. Chem., DOI: [10.1039/C2JM16097H](https://doi.org/10.1039/C2JM16097H)).

We found that when nano-SiO₂ is present in drawn polypropylene, the aligned chains in amorphous regions can be tied by the well distributed nanofillers to share the stress together. Above the critical content of nanoparticles or drawing ratio, the nanoparticles form percolated network throughout the matrix, facilitating stress transfer in the amorphous phases during tensile test. Additionally, the nanoparticles favor microfibrillation of matrix polymer in the late stage of tensile testing (note: the microfibrils are mainly constituted by the crystalline phases). As a result, the high strength covalent bonds of macromolecules in both amorphous and crystalline phases are brought into full play. The matrix acts as the key load-bearer, while nano-SiO₂ gives indispensable assistance. This is different from the mechanism involved in conventional fiber/polymer composites.

Our approach is not a total solution for the aforesaid problem and needs optimization for specific polymers, but it demonstrates the possibility of strengthening rigid linear polymers with low aspect ratio nanofillers. Continuous efforts are needed in this aspect to find out new strengthening mechanism.



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