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Editorial corner – a personal view

Multi-scale hybrid composites are making their way

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Polymer matrix composite materials are becoming increasingly common in everyday life. Today, there is also a strong effort to increase the performance of composites, *i.e.*, to create structural materials with higher strength and stiffness, which means that fewer materials are needed to make a product. Further increment in strength properties can be achieved by combining nanoparticles with microparticles to create multi-scale composites (https://doi.org/10.3144/expresspolymlett.2021.70). The presence of nanoparticles typically results in a 20–30% increase in strength properties, while they are present in a few percent by volume. Research to reduce the production costs of hybrid composites has now been successfully extended to cost-effective technologies, and hybrids will soon be economically competitive with conventional composites. Conventional composites are often handled as a three-phase system since the so-called interphase is created at the interface between the reinforcing material and the matrix material, which has properties significantly different from the other two phases. The molecules interact with the reinforcing material, and their mobility decreases, forming a bridge between the two phases. So the interphase affects the properties of the whole composite by its own properties. The presence of nanoparticles implies additional phases, and the specific surface area of nanoparticles is extremely large, so the role of interphase in hybrid composites is very dominant.

In an amorphous matrix hybrid composite, there are nanoparticles, microfibres, their individual interphases around them, and even the bulk matrix itself, which means five phases. In the semi-crystalline case, this is a real challenge, as the crystallites in the bulk matrix also have their own interphase; moreover, the reinforcing material can also be a nucleating agent (https://doi.org/10.1016/j.compscitech.2022.109489). Although these materials have excellent properties, they need to be made more designable to become more widespread in everyday life, but it is not easy to manage so many phases. There are two pathways to increase the designability of materials. On the one hand, the material's structure needs to be revealed as precisely as possible, and the role of the phases in the composite needs to be defined. The other way is modeling. Several research groups are working on molecular-level modeling and trying to build models that describe the role of the different structural units in hybrid composites well (https://doi.org/10.3144/expresspolymlett.2022.94). We believe that the meeting of the two paths is coming soon, and significant progress has been made on both fronts recently.

When nanoparticles were discovered, much was expected of them, especially in terms of mechanical properties. Interestingly, they have rather made their way through their functional property modification effects, such as electrical and thermal conductivity, gas barrier properties, *etc*. However, these functional properties can be combined with the reinforcing effect so that, for example, a material can be created that, in addition to good mechanical properties, also has good electrical conductivity (https://doi.org/10.1016/j.heliyon.2022.e10287). This multi-functionality allows for the production of more efficient structures.

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