Potential of thermally conductive polymers based on carbon allotropes in the development of new heat management components on board a car

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Thermally conductive polymer nano-composites based on carbon allotropes (graphite, graphene and nanotubes) offer new possibilities for replacing metal parts in several applications, including power electronics, electric motors and generators, heat exchangers etc. The polymer brings in advantages such as light weight, corrosion resistance and ease of processing; the nanofiller, to be distributed according to a perculating network enabling phonon transfer, ensures sufficient thermal conductivity (a few W/mk).

In the automotive sector, the tremendous challenge of reduction of CO_2 emissions, forces car manufacturers to improve drastically the heat recovery chain as more than 60% of the fuel energy gets actually lost. A survey of all the potential applications of carbon-based conductive polymers will be offered relying on the expertise of a large car manufacturer. Several heat exchangers systems offer indeed good application opportunities, including intercoolers, air conditioning condensers and evaporators as well as novel radiators hosted in the car chassis to substitute those based on frontal air intake which affect significantly the vehicle aerodynamics.

Unusually high thermal conductivity, in the range of a few thousands of W/mK [1], makes graphene and carbon nanotubes the best promising candidate material for thermally conductive composites. However, our experimental results, arising from the EU project Thermonano [2] and reviewed in this presentation, show that it is not trivial to reach the desired heat conductivities 3. The bottleneck is the large interfacial thermal resistance between the nanoparticles, which hinders the transfer of phonon dominating heat conduction in carbon materials. In order to overcome this limitation, the aspect ratio and platelet-like nature of graphene are beneficial, owing to the higher overlap obtainable with graphene compared to CNT. The best compromise between cost and performance was found by a combination of different allotropes, the carbon nanotubes bridging graphene or graphite platelets [4].

The compounding method and the plastic moulding process was found to have a significant importance in ensuring the desired nanostructure. In this context, the graphene low apparent density poses specific challenges and plays against a facile inclusion in the polymer matrix. Functionalisation of graphene platelets may help in this context. Furthermore, to maximise the efficiency of particle/particle thermal contact, the exploitation of self-structuring of nanoparticles in polymer blends is envisaged, based on the excellent results recently obtained by this research group on micronic graphite-based polymer composites [4].

In the presentation the complete development line of a prototype plate heat exchanger obtained by injection moulding for an intercooler application will be disclosed and benchmarked against current heat exchangers enlightening considerable economic margins.

Finally, some ideas will be discussed to functionalize the nanofilled polymer heat exchangers with sensing capabilities or increased surface conductivity. Graphene-based materials can indeed be solubilized and transferred into nanoparticle-based inks or deposited through layer-by-layer deposition [5].

References

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