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Hybrid nanocomposites: an effective way to enhance properties of electrical devices

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Summary

A novel core-shell material has been proposed and manufactured by means of a polymer derived ceramics route and a carbothermal reduction and nitridation process. The obtained fillers are made of a standard material which is covered by the high thermally conductive shell. Additionally a new class of a hybrid graphene-silica functional epoxy resin composite is presented. Such an unique structural design combines advantages of both, graphene and silica.

The obtained both types of hybrid nanocomposites exhibited a significant enhancement of thermal conductivity, represented by a 60% relative increase. Additionally the mechanical and dielectric measurements were performed showing a high potential for the novel hybrid nanocomposites to be applied as electrical insulation with enhanced thermal conductivity.

Motivation and results

Filled epoxy composites are broadly used in electronic and power devices as an electrical insulation [1,2]. The heat generated during operation of power products can lead to malfunctioning or even damage of equipment. Therefore an effective evacuation of excess heat is an important technical problem to be solved. In this work two approaches are presented.

Firstly, a novel core-shell material has been proposed and manufactured by means of a polymer derived ceramics route and a carbothermal reduction and nitridation process. The obtained fillers are made of a standard material which is covered by the high thermally conductive shell [3]. It was shown that application of the core-shell filler, especially alumina with aluminum nitride shell (Al2O3@AlN), lead to an improvement of the effective thermal conductivity of filled epoxy composite as shown in Figure 1. The enhanced thermal conductivity (up to 63%) of the system with a novel core-shell filler can open the way for more affordable epoxy composites suitable for application as a proper material for thermal management in electrical devices. Analysis of the obtained results by means of theoretical models indicated the lack of an adequate model for accurate estimation of the effective thermal conductivity of the composites filled with core-shell particles.

Secondly, a new class of a hybrid graphene-silica functional epoxy resin composite is presented. Such an unique structural design combines advantages of both, graphene and silica. Thermal conductivity of the epoxy composite was enhanced significantly by incorporation of graphene nanoparticles (see Figure 2). Mechanical properties were also enhanced in relation to the reference system. Dielectric properties were not much influenced. Hybrid graphene nanocomposites with low amount of GNPs can work as electrical insulation. Low amount of GNPs can open way for a more affordable epoxy composites for thermal management in electrical devices.

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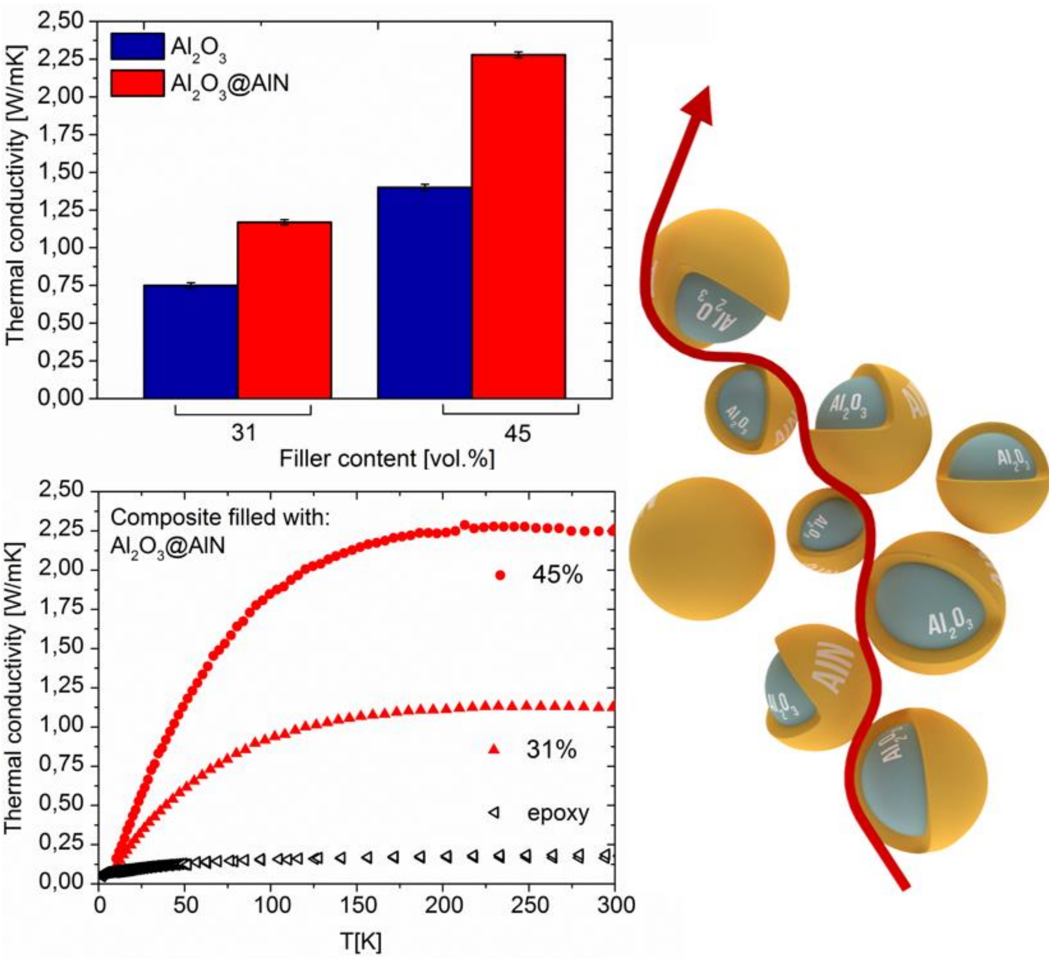

Figure 1. Thermal conductivity of composites measured at 300K (top left), and relative increase of thermal conductivity for composites with core-shell fillers in relation to standard system (bottom left). Schematic representation of heat transport mechanism along the HTC shells of the modified core-shell fillers (right).

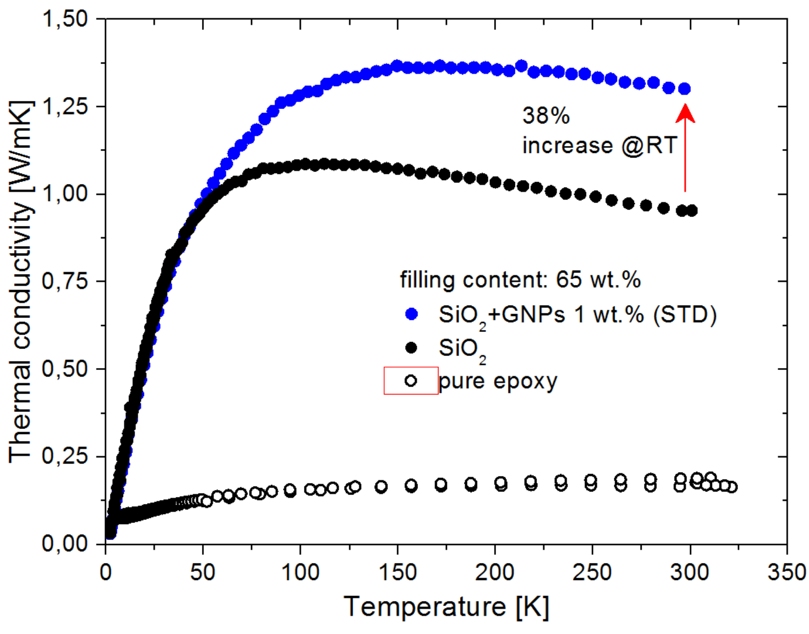

Figure 2. Thermal conductivity measurements as a function of temperature in wide range 10÷400 K.