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Boron Nitride/Vapour Grown Carbon Nanofibre/Rubbery Epoxy-based Hybrid Composites For Thermal Interface Applications

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Background

Thermal interface materials (TIMs) are vital for microelectronics packaging as they are responsible for improving interfacial contacts between the microchips and heat sinks, thus ensuring sufficient heat removal from chips [1]. Boron nitride (BN) is the most popular filler material for TIMs mainly due to its high thermal conductivity (300 W/m.K) and electrical resistivity. Recently, carbon nanofillers such as graphite nanoplatelets, carbon nanotubes and carbon nanofibres have been widely researched as fillers to produce polymer based composites due to their very high thermal conductivity [2, 3]. One solution to further improve the conducting and mechanical properties of carbon nanofiller based composites is to produce hybrid nanocomposites.

Aims of the study

The present work reports novel hybrid rubbery epoxy composites produced by dispersing inorganic filler, BN, and carbon nanofiller, vapour grown carbon nanofibres (VGCNF), with the aim of producing much better TIMs than conventional ones.

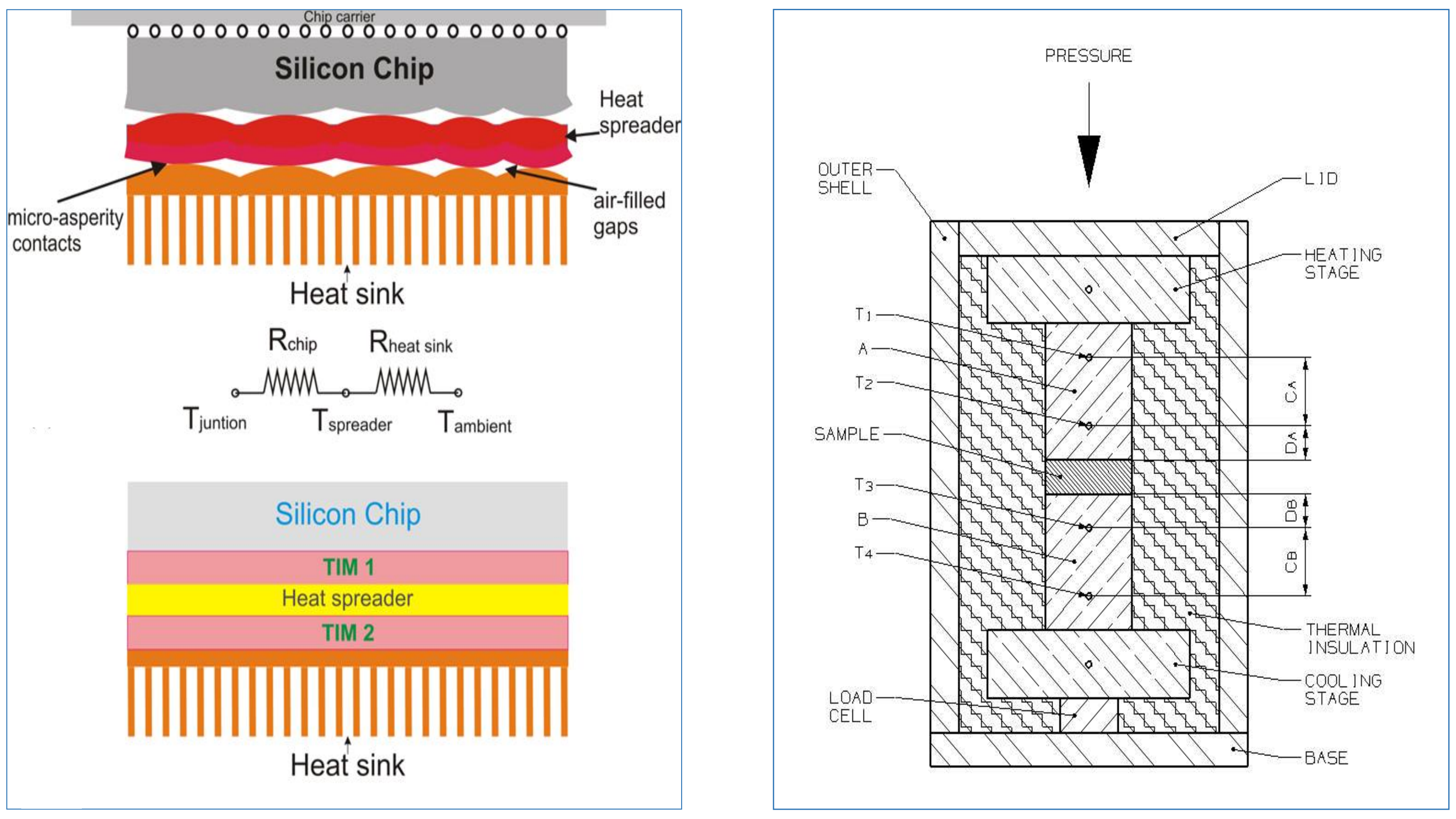

Fig. 1: Air gaps between chip (top, left) and TIM I and TIM 2 placed in the die (bottom left), Schematic of Thermal Contact Resistance Measurement Rig (right)

The total thermal resistance (R_T) of the coating joining the copper cylinders is proportional to the thickness of the coating .The total thermal resistance of the system shown in Fig. 1 is described as,

$$R_T = R_c + R_{int1} + R_{int2}$$

where R_c is the thermal resistance of the coating, and R_{int1} and R_{int2} are the geometric interface contact resistances between the copper cylinder *A* and the coating and cylinder *B* and the coating, respectively.

Results

SEM images of BN/VGCNF/Rubbery Epoxy Hybrid Composites

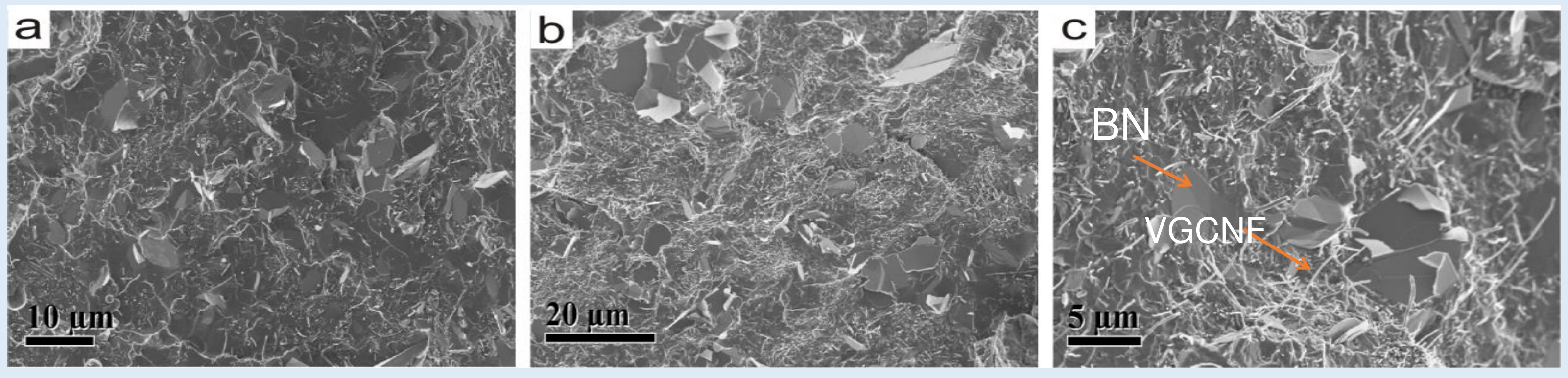

Fig. 2 (a) SEM images of (a) 6 wt.% BN/8 wt.% VGCNF/rubbery epoxy (b & c) 6 wt.% BN/12 wt.% VGCNF/rubbery epoxy composites produced by roll milling.

Thermal Conductivity and Thermal Contact resistance of BN/VGCNF/Rubbery Epoxy Hybrid Composites

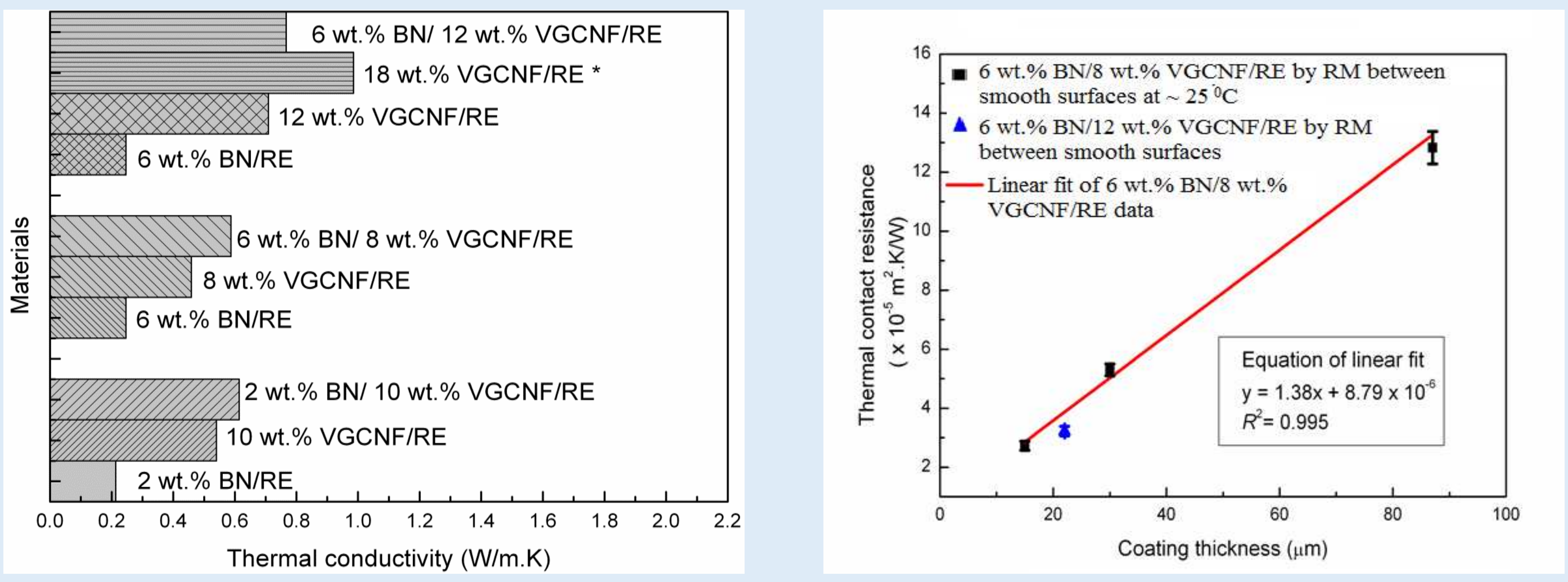

Fig. 3. Thermal conductivity of composites (left) and Thermal contact resistance of BN/VGCNF/epoxy composite coatings (right)

Experimental

Materials

Boron nitride (particle size 5-10 µm), VGCNF (diameters = 70-200 nm and lengths = 50-100 µm) were used as filler materials. Rubbery epoxy was used as matrix.

Composite Fabrication

The fillers were dispersed in epoxy resin by 3 roll mill. Composites dispersions were cured at 120 °C for 3 hr. Composites were produced with BN content fixed at 6 wt.% while VGCNF content was varied from 8 to 12 wt.%.

Characterisation

The morphology, thermal conductivity, electrical conductivity and compression properties of the resulting composites were studied. The interfacial thermal transport performances of selected hybrid composite coatings were studied as thermal interface adhesives according to ASTM D5470 (Fig. 1) [4]

Table 1. Comparison of Thermal Contact Resistance of BN/VGCNF/Rubbery Epoxy Composites with Commercial TIMs

Material	Bond line thickness (µm)	Thermal contact resistance (m².K/W)
Commercial TIM (Matrix II) paste	18	4.2×10^{-6}
45 wt.% BN/rubbery epoxy (RE) composite	18	2.28×10^{-5}
6 wt. % BN/8 wt. % VGCNF/RE composite	18	3.38×10^{-5}
15 wt.% VGCNF/rubbery epoxy	18	1.93×10^{-5}
45 wt.% BN/rubbery epoxy composite	95	8.82×10^{-5}
65 wt.% BN/silicone (EPM 2490) (Commercial TIM adhesive)	95	1.36×10^{-4}
6 wt. % BN/8 wt. % VGCNF/RE composite	95	1.39×10^{-4}

Conclusions

- SEM images show that both VGCNFs and BN are uniformly dispersed in the rubbery epoxy matrix.
- VGCNFs improved BN dispersion in the matrix but reduced the number of interconnects between BN plates.
- The hybrid combination of BN and VGCNF did not significantly increase the thermal conductivity of the composites .
- The incorporation of BN decreases the electrical conductivities of hybrid composites significantly compared with the corresponding BN-free composite. The electrical conductivity data suggest that inclusions of BN in the conducting networks of VGCNFs add significant resistance to the electron transport and reduce the efficiency of the conducting networks.
- The data suggest that the combination of BN and VGCNF (at the loadings studied in this work) neither improves the mechanical properties of the hybrid composites nor deteriorates them.
- The thermal contact resistance of 6 wt.% BN/12 wt.% VGCNF/rubbery epoxy coating is still 1.4× higher than that of the 15 wt.% VGCNF/rubbery epoxy composite coating. This again suggests that inclusion of BN in VGCNF-based coatings deteriorates their performance as thermal interface adhesives and that the non-hybrid coatings can perform much better than hybrid coatings.
- The thermal contact resistance of hybrid composite is almost similar to that of commercial BN-based adhesive but is achieved at 50 wt.% lower loading of filler.
- The incorporation of VGCNF in BN/Rubbery epoxy composite coating however can easily disssipate electrostatic charges.

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