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Improving thermal conductivity in polyurethane sheets by incorporating three dimensional AlN nanofiber network through freeze-drying

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1) Introduction

The typical operation of electronic devices produces significant heat during continuous usage. In that case, it can result in malfunctions of electronic components, leading to a higher rate of failures and the risk of fires. Consequently, there is a need to create high-performance heat dissipation sheets for advanced electronic devices [1]. Hossain et al. prepared aluminum nitride (AlN) nanofibers (NFs) using polyvinyl alcohol (PVA)/boehmite precursor by electrospinning technique [2]. After adding polyurethane (PU) with AlN NFs, they made composite sheets of PU/AlN NFs, which showed excellent thermal conductivity (4.5–19.0 W/(m·K)) in the plane direction. However, it is very insignificant in the thickness direction (0.1–2.1 W/(m·K)). The Freeze-drying method has recently been prevalent for synthesizing three-dimensional (3D) NFs. This study explores using AlN as an inorganic filler in composites, leveraging its excellent thermal conductivity ranging from 70 to 270 W/(m·K) and its electrical insulation properties. For this reason, the authors tried to develop 3D AlN NFs through freeze-drying and heat-pressing techniques. The resulting composites exhibited significant thermal conductivity in thickness directions compared to electrospinning.

2) Experimental section

1 wt.% PVA aqueous solution and 1 wt.% boehmite nanoparticles dispersion liquid were mixed in a flask to give a PVA/boehmite=70/30 wt.%. PVA/ boehmite precursor NFs were prepared with liquid nitrogen for about 20 minutes and -50°C and 15 Pa pressure for about one week using a freeze-drying machine. PVA/boehmite precursor NFs were subjected to hot pressing under 120°C, 30 min, and 5 MPa. To remove organic components, PVA/boehmite precursor NFs will be calcinated at different heating temperatures, and finally, AlN will be obtained. The obtained AlN NFs were dropped into a 5 wt.% PU solution to produce a PU/AlN heat spreader sheet.

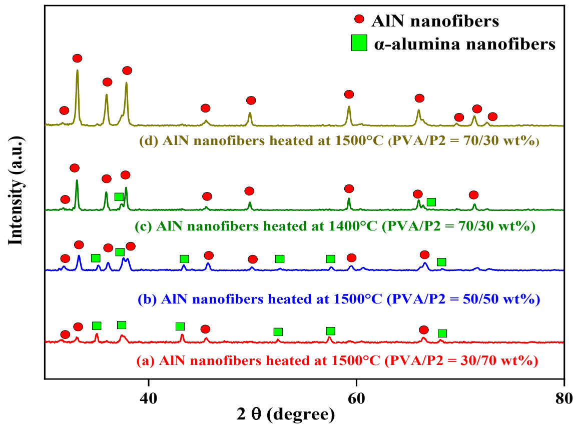

Fig. 1 XRD curves of AlN NFs at different heating temperatures

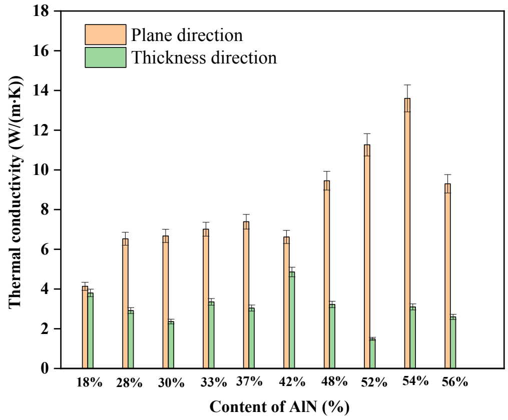

Fig. 2. Thermal conductivity of PU/AlN sheets

3) Results and discussion

Fig. 1 (a-d) presents the XRD curves of PVA/boehmite precursor NFs with varying mass ratios under a nitrogen atmosphere. PVA/boehmite precursor NFs with a 30/70 wt% and 50/50 wt% ratio exhibited the emergence of a few AlN NF peaks. At 1400°C, a notable abundance of AlN NF peaks was detected alongside numerous α-alumina peaks. PVA/boehmite precursor NFs with a 70/30 wt% ratio demonstrated complete conversion to AlN at 1500°C, as depicted in Fig. 1 (d), which is lower than AlN's theoretical (1664°C) formation temperature. Fig. 2 shows the thermal conductivity of hot-pressed PU/AlN heat-dissipating sheets at 120°C heating temperature with 5 MPa pressure. Thermal conductivity was observed in both planes (4.1–13.6 W/(m·K)) and thickness (1.5–4.9 W/(m·K)). Hence, the author tried to develop a thermally conductive but electrically insulating PU/AlN heat spreader sheet so electric devices can effectively eliminate generated heat.

4) Referrences

[1] Alawadhi EM, Amon CH. *IEEE Transactions on Components and Packaging Technologies* 2003;**26**:116–25.
[2] Hossain MS, Nakane K. *Journal of Materials Science* 2023; in press.

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