

“Superior rheological and thermal properties of hybrid graphene and boron nitride epoxy nanocomposites at ultra low filler loading concentration”

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1. A B S T R A C T

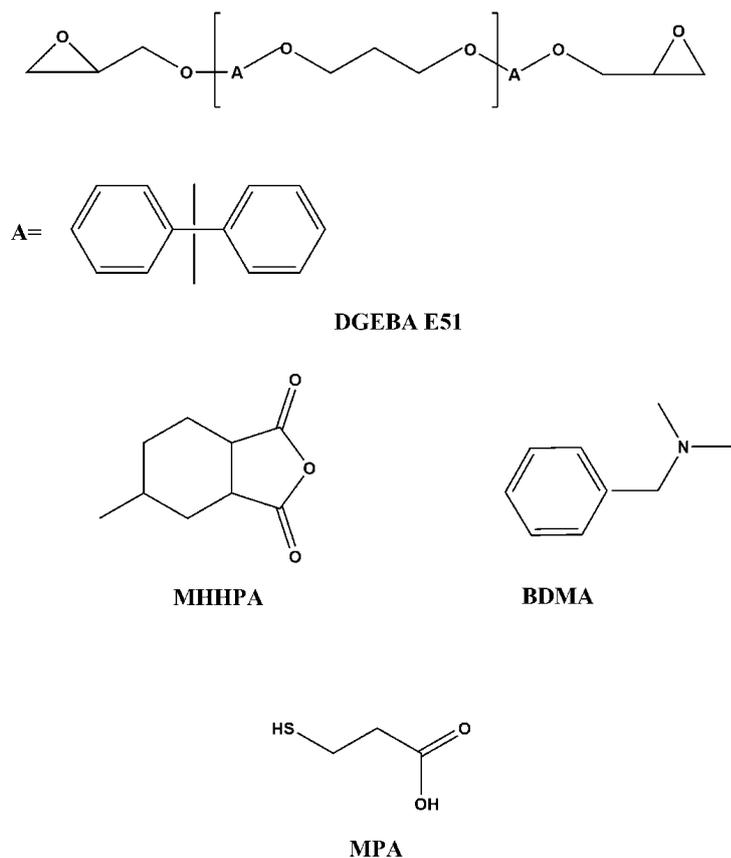
Graphene and boron nitride (BN) has been utilized quite often in polymer nanocomposites in high thermal properties like thermal conductivity and high glass transition temperatures for their use in different lightweight electronic industry[1-2]. Their high aspect ratio makes them potentially significant to augment the thermal conductivity of polymer composites independently. Whereas, the use of hybrid fillers of graphene and boron nitride nanoplatelets enhanced these properties greater than single filler epoxy nanocomposites. In our work, we prepared a unique microstructure of GNP-BN/epoxy nanocomposites by chemical exfoliation, sonication and mechanical mixing method. The structure includes the stacking of BN nanoplatelets onto the surface of GNP via van der Waal forces of attraction. Such hybrid surface modified GNP-BN/epoxy nanocomposites demonstrated a remarkably high thermal conductivity of ca. $0.53 \text{ W m}^{-1} \text{ K}^{-1}$ and a high electrical volume resistivity of ca. $7.37 \times 10^{16} \Omega \text{ cm}$ for a low filler loading of only 3 wt%. The high volume resistivity is mainly due to the fundamental electrical insulating properties of BN nanoplatelets which are stacked on the surfaces of GNP due to the van der Waals attraction hence acting as an obstacle against electron transportation between GNP. On the other hand, the unique microstructure plays an important role for connecting phonon transfer from graphene to BN and finally into the polymer chains of epoxy homogeneously, therefore the enhanced thermal conductivity is due

to the use of 3-mercaptoproionic acid (MPA), as surface modifying agent [3] and surfactant for the homogenous dispersion of fillers inside epoxy matrix of diglycidyl ether of bisphenol A (DGEBA). On the other hand, a prodigious upsurge in glass transition temperature, storage modulus and thermal stability was observed for the hybrid GNP-BN/epoxy nanocomposites. Hence, such hybrid nanocomposites with low filler loading provide an inimitable method for the electronic industry to enhance the thermal conductivity and the electrical insulation property of epoxy materials

2. EXPERIMENTAL

2.1 MATERIALS AND PREPARATION

In this research f-GNP and BN with an average particle size of 50 μ m and 50nm were used. The mixture of epoxy and hybrid fillers of BN and f-GNP with different weight content were stirred by high speed mechanical mixer to reach a homogeneous state. After degassing, the trapped air bubbles were removed. The curing agent MHPA, with 1wt % accelerator, *N,N*-benzyl dimethyl amine (BDMA), was then added into the epoxy mixture in a stoichiometric ratio and heated on an oil bath at 90 °C. The mixture was then mechanically stirred again before it was degassed in a vacuum oven. The mixture was thus, transferred into a preheated steel mould and cured at the following stepwise schedule of 90 °C for 30 min, 120 °C for 60 min, 140 °C for 30 min, and 160 °C for 120 min, respectively.



Scheme 1. Schematic presentation of the chemical structures of DGEBA E51, MHPA, BDMA, and MPA

2.2 RHEOLOGICAL, ELECTRICAL AND MECHANICAL TESTS:

Rheological properties of GNP-BN/epoxy nanocomposites were studied by was studied by differential scanning calorimetry (DSC, TA Instruments Q2000, U.S.A.) under nitrogen environment with a flow rate of 50 mL min⁻¹. Whereas, mechanical as well as rheological properties were investigated by Dynamic mechanical thermal analysis (DMTA, TA Instruments Q800, U.S.A.) accomplished in a single-cantilever mode. The thermal stability of materials was observed by thermogravimetric analysis (TGA, TA Instruments Q500, U.S.A.) under nitrogen atmosphere with a flow rate of 60 mL min⁻¹ from room temperature to 800 °C at a heating rate of 10.0 K min⁻¹. The thermal conductivity of materials was measured on a physical property measurement system (PPMS-9, American Quantum Design, U.S.A.) at different temperatures ranges respectively. A precision impedance analyzer (Avcitive Awia,

Agilent 4294A, U.S.A.) was used to bring out the dielectric spectroscopy measurements with frequency range from 40 Hz to 10^6 Hz.

3. RESULTS:

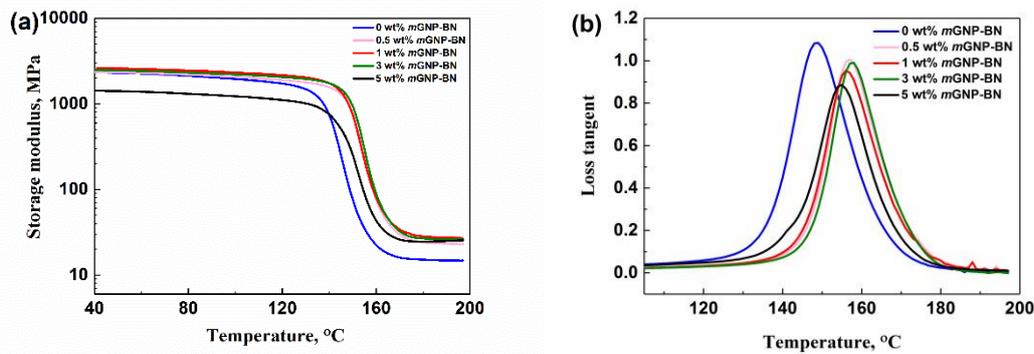


Fig.1 (a) Storage Modulus (b) trend in change in glass transition temperatures for various weight fraction of f-GNP/BN-epoxy nanocomposites

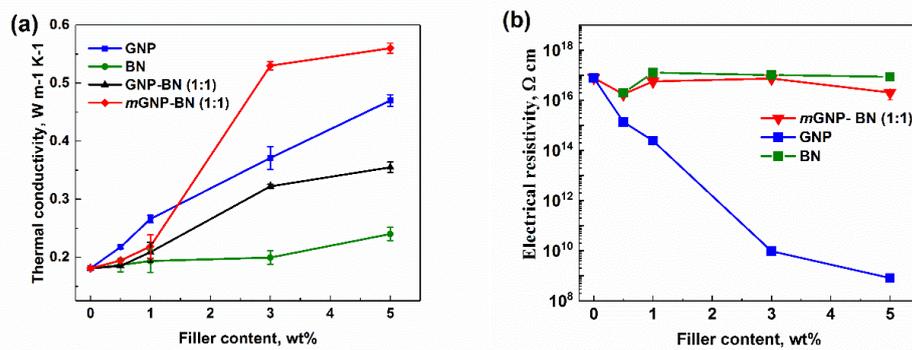


Fig.2 (a) Thermal conductivity (b) Electrical resistivity of different samples

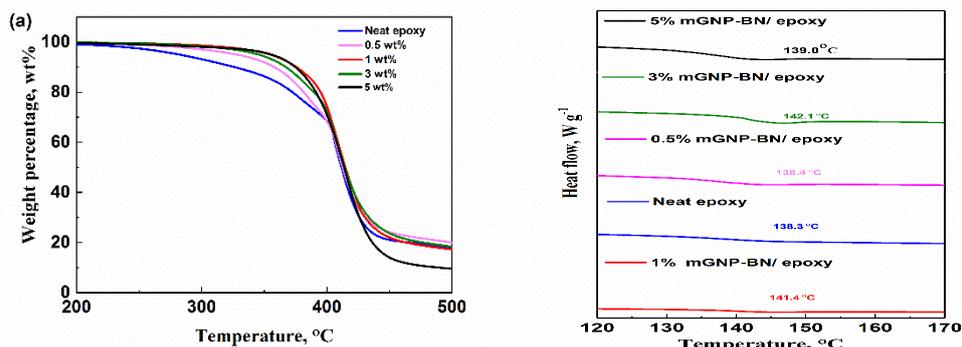


Fig.3 (a) Thermal stability and DSC curves of different samples

Filler content, wt%	T_g (DSC) (°C)	T_g (DMA) (°C)
Neat epoxy	138.3	148.5
0.5 BN	131.9	147.5
1.0 BN	135.6	145.5
3.0 BN	123.5	136.0
5.0 BN	130.0	130.7
0.5 GNP	137.7	146.0
1.0 GNP	127.9	146.8
3.0 GNP	121.7	142.5
5.0 GNP	133.2	155.6
0.5 <i>f</i> -GNP-BN	138.4	157.0
1.0 <i>f</i> -GNP-BN	140.1	156.0
3.0 <i>f</i> -GNP-BN	142.1	158.0
5.0 <i>f</i> -GNP-BN	139.0	155.0

Table 1. Change in glass transition temperatures for different filler loading in epoxy nanocomposites derived from DSC and DMA.

References:

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