

An Analytical Study of the Thermal Behaviour of Epoxy Resins Containing Boron Nitride

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Abstract: An epoxy-thiolic system filled with boron nitride (BN) in the shape of 80 m agglomerates has been tested in order to achieve better thermal conductivity. The effect of BN content on cure reaction kinetics was evaluated by differential calorimetric scanning (DSC) and the thermal conductivity of the healed samples was calculated by a temporary hot bridge check. The reaction heat and the glass transition temperature of the fully cured samples are both independent of the BN content, while the cure reaction kinetics is not: with a rise in BN content, the reaction first occurs and then is delayed, this activity is more apparent than with the same system with 6 m BN particles that was previously tested.

Keywords: Epoxy, Thiol, Boron nitride, Differential scanning calorimetry (DSC), Thermal conductivity.

1. Introduction

Current microelectronic computer architecture requires rising miniaturization and activity at higher speeds than before, contributing to higher power densities and, as a result, a higher probability of failure due to problems with thermal management. For eg., the device failure rate was estimated to double with any 10 C shift in the chip junction temperature [1], whereas for LEDs, the thumb law is that every 10% rise in the operating temperature will decrease the operational life by 50 percent [2]. It is also clear that the thermal dissipation from these devices is of important importance Boron Nitride Benefits

Thanks to its properties, hexagonal boron nitride (BN) offers major possibilities for use.

The structure of the micro plate of boron-nitride provides exceptional sliding, lubrication and separation capabilities for this material.

The boron nitride is graphite-like, but pure. This is also known as "pure graphite," for this reason. Boron nitride, organic boron-nitrogen crystalline resin, a small but effective industrial ceramic substance, primarily used in electrical insulation systems and cutting devices. This is composed of hexagonal boron (H-BN) and cubic boron nitride (C-BN), two crystallographic types.

Comparison of the graphite (left) and boron nitride hexagonal systems, BN (right).

Nitride: Nitride in boron

Since the number of valence electrons (eight) is the same as

the number of bonded Carbohydrate atoms, boron nitride is said to be Processes for processing H-BN require heating boric oxide with ammonia (NH₃). H-BN is rendered using various methods. It is a flat powder made up of sheets of hexagonal circles, at the molecular stage, which move quickly over each other. Similar to the carbon graphite (Figure) this composition renders H-BN a strong lubricant; but H-BN is noted for its low power conductivity and high thermal conductivity, as distinct from graphite. H-BN is also formed and then pushed hot into shapes such as electrical insulators and crevices. This may also be added to metallurgical, ceramic, or chemical manufacturing equipment as a temperature-resistant covering.

Comparison of graphite (left) and boron nitride hexagonal systems (right).

Comparison of graphite (left) and boron (right) hexagonal systems.

C-BN is typically formed by putting H -BN under exceptionally high pressure (6-9 Gigapascals) and temperature (1500 ° C to 2.000 ° C or 2.730 ° to 3.630 ° F) as tiny crystals. It is second to diamonds with a hardness of 10 on the Mohs hardness index (they are sometimes added to a metallic or metal ceramic device to handle hard steel as a fake diamond). It often operates with toughness diamonds. It has a far higher operating temperature than diamonds, oxidizing over 800 ° C or 1.475 ° F, owing to the elevated oxidation temperatures (over 1.900 ° C or 3.450 ° F).

Boron nitride has a very strong thermo-conductivity that contributes to excellent thermal shock behaviour, along with low density and extremely low thermo-expansion. We give a number of qualities with different mechanical strengths.

- Excellent resistance to thermal shock
- Small Thermal Efficiency
- Best tolerance to temperature
- Wetting just
- Lubrication
- Excellent electrical isolation
- Can be machined with traditional instruments
- Farb: ivory

PolymersClad 2018[4], 10,000 Bergquist, usually around 3.0 W/mK² of 18 in thermal conductivity, opposed to about 0.2 W/mK for standard circuit board manufacturing.

Lower and lower degrees of thermal conductivity than the previous values.

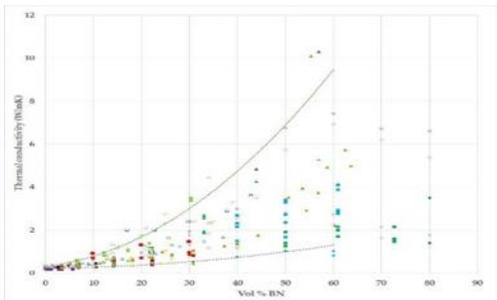


Fig. 1. Dependence of thermal conductivity of epoxy-boron nitride (BN) composites on vol % of BN

It is clear that all these findings represent the same general trend, except that there is always substantial dispersion, since nearly all effects are in the upper and lower trend curves seen in the diagram. There are several potential reasons for this dispersion linked to the processing of these epoxy-BN composites. The most significant factors were: the interaction between the particles and the matrix where the particles may be used, on the one hand, to adjust the surface area or the binding agent; and (ii) the density of the particles, or the distribution of the size or even the combination of particles of different dimensions.

In figure 1, composites in which either surface particles or coupling agents have been used are labeled as filled points, while untreated particle composites with no coupling agent are defined as open points. There is no obvious tendency to pursue the higher trend and to pursue the lower trend curve at accessible locations, as is the case when there is a substantial advantage in changing the BN surfaces by using a connection agent. Nevertheless, some writers notice that thermal conductivity improves substantially, if not always greatly, if a

coupling agent is used a gain of 12 to 45 per cent. Kim and Kim, on the other side, note a rise in OH therapy but a decrease in silane treatment, whereas other authors notice only a marginal improvement, usually less than 5%, as a consequence of surface therapy, at least to very low BN levels [6].

As far as the influence of the BN particle size is concerned, thermal conductivity decreases by the same BN volume percentage as the particle size increases. There are exceptions, however: Hong et al. indicate higher thermal conductivity for 1 m particles compared to 5 m particles in a 60 vol percent BN composite; Permal et al. indicate that there is no disparity in thermal conductivity for samples produced with 1 or 5 m particles in 30 Wt percent BN; and Wattanakul et al. report that the sounding reduces the agglomerate thickness, increasing t. For example, Gaska et al. [10] have discovered that larger particles, namely 25 m spherical agglomerates, have a higher thermal conductivity than smaller particles, i.e. 13 meter platelets. Improved thermal conductivity, with the BN particle size shown by Huang et al., can also be attributed to the various particle sizes, the smaller ones (1 m), the circular ones and the larger ones (5-10 m) of the flakes, although this shape influence is the opposite of the one proposed by Gaska et al. [10].

2. Materials and Methods

A. Materials

The epoxy resin used was bisphenol-A diglycidyl ether (DGEBA) with thiol, pentaerythritol tetrakis (3-mercaptopropionate), thiol (Sigma-Aldrich, Saint Louis, MO, USA, 488.66 g / mol, 1.28 g / cm³ density) as a cross-linking part. A powder-like latent epoxy initiator was used to trigger the connection between epoxy and Thiol, encapsulated imidazole LC-80 (Technicure, A&C Catalysts, Linden, NJ, USA). Different forms of BN filler have been used: hexagonal plates with an average particle size between 6 and 2 m and nearly spherical platelet agglomerates with an average particle

Table 1
 Composition of samples: parts by mass, wt % BN and the approximate vol % BN

Samples	Parts by mass				wt % BN	vol % BN
	Epoxy	BN filler, 80 m	Thiol	LC-80		
ETL	100.0	0		66.7	2.0	0
ETLBN80-10	90.0	10.0		60.0	1.8	3.7
ETLBN80-30	70.0	30.0		46.7	1.4	12.9
ETLBN80-50	50.0	50.0		33.3	1.0	25.7
ETLBN80-60	40.0	60.0		26.7	0.8	34.2
80/6 hybrids		80 m	6 m			
ETLBN80/6-10	90.0	10.0	3.3	60.0	1.8	4.9
ETLBN80/6-30	70.0	30.0	10.0	46.7	1.4	16.5
ETLBN80/6-50	50.0	50.0	16.7	33.3	1.0	31.6
ETLBN80/6-60	40.0	60.0	20.0	26.7	0.8	40.9
80/2 hybrids		80 m	2 m			
ETLBN80/2-10	90.0	10.0	3.3	60.0	1.8	4.9
ETLBN80/2-30	70.0	30.0	10.0	46.7	1.4	16.5
ETLBN80/2-50	50.0	50.0	16.7	33.3	1.0	31.6
ETLBN80/2-60	40.0	60.0	20.0	26.7	0.8	40.9

size between 80%. Hey, Benmayor S.A. The 6 m specimens were kindly supplied. Both of these BN particles were obtained from Saint Gobain Boron Nitride (Amherst, NY, USA) (Barcelona, Spain), 80 m agglomerate (PCTL5MHF) and 2 m platelets (PCTP2), both of which were rendered in white powder shape and used as given without surface treatment.

Details of the different epoxy-BN composite items have been developed. The initiator was mixed with thiol in the smallest component, which was developed in a proportion of 2.0 parts per 100 resins (phr) to preserve a stoichiometric ratio with epoxy resin (approximately 60:40 epoxy/thiol by mass). The solvent of the epoxy was then

This has led to the preparation of Epoxy-BN composite clear mixtures of 80 m particles on their own, as well as the preparation of combinations with a combination of 80 and 2 m particle sizes; 80 and 6 m. It was intended to use smaller platelets to fill the holes in larger spherical agglomerates. In all hybrid schemes, the density of the smaller particles was one third of the density of the 80 m agglomerate, the latter being added in the same proportion as for the simple mixtures.

Table 1 offers a detailed description of all the formulations used. The manufacturer values for epoxy resin and thiol densities, as mentioned above, were used to estimate the volume amounts, taking into account volume additivity, while the BN density was estimated to be 2.1 g/cm³.

3. Results and Discussion

A. Fracture Morphology of Composite Materials

Figure 2 displays the SEM photos of the cross-sections of broken samples with a different CTBN material. You will see that the BN filler is spread in the resin matrix. Composite content without CTBN (Figure 2a) reveals a standardized distribution of BN and a fairly smooth fracture surface. Upon the introduction of CTBN (Figure 2b – d), the fracturing surface comprises of two separate layers, the epoxy resin is a continuous layer, while the CTBN is a distributed process, which is randomly scattered throughout the matrix to create a "island" shape. When the volume of CTBN decreases, the average scale of the CTBN particles rises. Nevertheless, as the volume of CTBN begins to rise (Figure 2e – f), when the viscosity of the product decreases, the agglomeration of the CTBN induces the distortion of the standardized morphology, which has a significant effect on the intensity of the compound. Various mechanisms for rubber tightening have been documented and are assumed to function alone or synergistically when epoxy resins are hardened. Figure 2g – I display the split CTBN particles and the tension whitening line. The whitening of tension is caused by the reflection of visible light from the reflection middle sheet.

In this scenario, the nullity of the dispersion core is attributed to the cavitation of the CTBN particles. This is an essential energy dissipation process when CTBN is applied to the epoxy

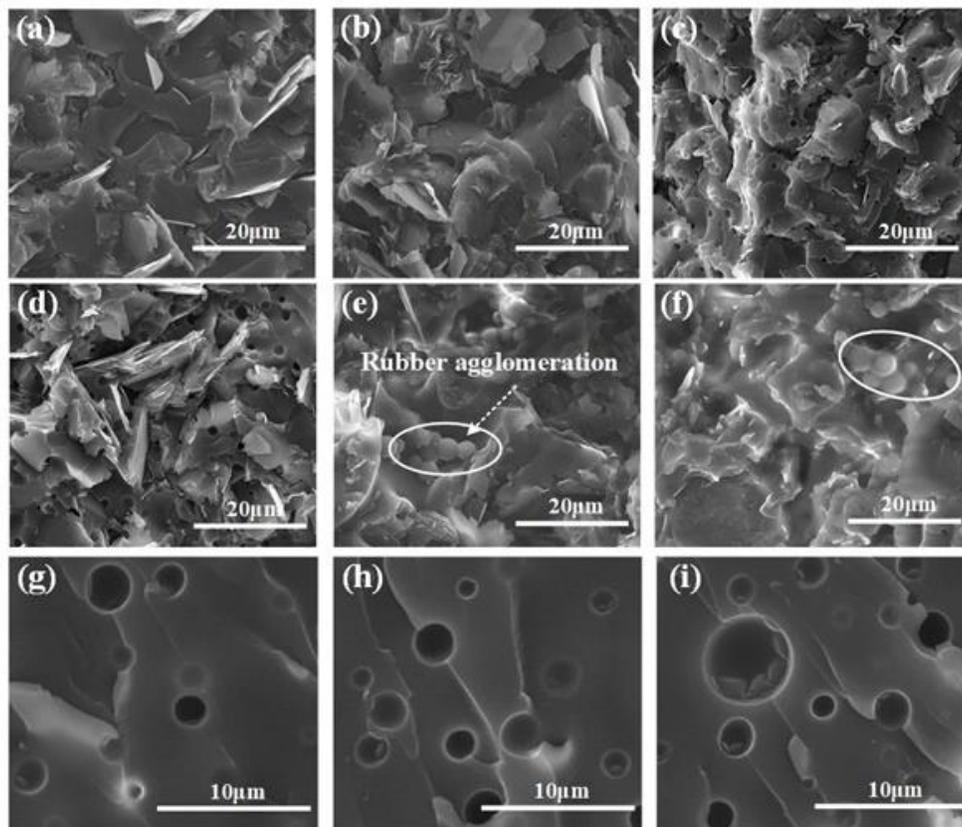


Fig. 2. SEM images of epoxy composites. (a) 0 wt.% CTBN; (b,g) 5 wt.% CTBN; (c,h) 10 wt.% CTBN

paste, and can absorb energy at the time of fracturing, so rubber bridging and shear yield are also appropriate.

4. Conclusion

Electronic thermal management requires materials that can absorb heat effectively. There have been a range of interesting materials discovered lately, but diamonds appear to be the most thermally conductive bulk substance. Chen et al. found out that ultra-high thermal conductivity isotopically pure cubic Boron Nitride is 75% diamond. The crystal movements that transmit heat will travel more easily through the substance utilizing either boron-11 or boron-10. This can be used to control the temperature of high performance instruments more effectively.

References

- [1] Huang, X.; Jiang, P.; Tanaka, T. A review of dielectric polymer composites with high thermal conductivity. *IEEE Electr. Insul. Mag.* 2011, 27, 8–16.
- [2] Xiao, M.; Du, B. Review of high thermal conductivity polymer dielectrics for electrical insulation. *High Volt.* 2016, 1, 34–42.
- [3] Li, S.; Yu, S.; Feng, Y. Progress in and prospects for electrical insulating materials. *High Volt.* 2016, 1, 122–129.
- [4] Li, Q.; Chen, L.; Gadinski, M.R.; Zhang, S.; Zhang, G.; Li, H.; Haque, A.; Chen, L.; Jackson, T.N.; Wang, Q. Flexible high-temperature dielectric materials from polymer nanocomposites. *Nature* 2015, 523, 576–579.
- [5] Lin, Y.; Huang, X.; Chen, J.; Jiang, P. Epoxy thermoset resins with high pristine thermal conductivity. *High Volt.* 2017, 2, 139–146.
- [6] Yu, J.; Mo, H.; Jiang, P. Polymer/boron nitride nanosheet composite with high thermal conductivity and sufficient dielectric strength. *Polym. Adv. Technol.* 2015, 26, 514–520.
- [7] Zhou, W.; Zuo, J.; Zhang, X.; Zhou, A. Thermal, electrical, and mechanical properties of hexagonal boron nitride-reinforced epoxy composites. *J. Compos. Mater.* 2014, 48, 2517–2526.
- [8] Chen, C.; Jian, J.; Yen, F. Preparation and characterization of epoxy/aluminum oxide nanocomposites. *Compos. Part A Manuf.* 2009, 40, 463–468.
- [9] Hou, J.; Li, G.; Yang, N.; Qin, L.; Grami, M.E.; Zhang, Q.; Wang, N.; Qu, X. Preparation and characterization of surface modified boron nitride epoxy composites with enhanced thermal conductivity. *RSC Adv.* 2014, 4, 44282–44290.
- [10] Huang, X.; Iizuka, T.; Jiang, P.; Ohki, Y.; Tanaka, T. Role of Interface on the Thermal Conductivity of Highly Filled Dielectric Epoxy/AlN Composites. *J. Phys. Chem. C* 2012, 116, 13629–13639.
- [11] Jeong, S.H.; Song, J.; Kim, K.L.; Choi, Y.H.; Lee, H. Enhanced thermal properties of epoxy composite containing cubic and hexagonal boron nitride fillers for superconducting magnet applications. *Compos. Part B Eng.* 2016, 107, 22–28.
- [12] Jiang, Y.; Shi, X.; Feng, Y.; Li, S.; Zhou, X.; Xie, X. Enhanced thermal conductivity and ideal dielectric properties of epoxy composites containing polymer modified hexagonal boron nitride. *Compos. Part A Manuf.* 2018, 107, 657–664.
- [13] Zhang, Y.; Gao, W.; Li, Y.; Zhao, D.; Yin, H. Hybrid fillers of hexagonal and cubic boron nitride in epoxy composites for thermal management applications. *RSC Adv.* 2019, 9, 7388–7399.