

Synthesis and Characterization of Bis(4-cyanato-3,5-dimethylphenyl)anisylmethane/Epoxy/Glass Fiber Composites

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ABSTRACT: Bis(4-cyanato-3,5-dimethylphenyl)anisylmethane was prepared by treating CNBr with bis(4-hydroxy-3,5-dimethylphenyl)anisylmethane and blended with commercial epoxy resin in different ratios and cured at 120°C for 2 h, 180°C for 1 h, and postcured at 220°C for 1 h using diamino diphenyl methane as curing agent. Castings of neat resin and blends were prepared and characterized. The composite laminates were also fabricated with glass fiber using the same composition. The tensile strength of the composites increased with increase in cyanate content (3, 6, and 9%) from 322 to 355 MPa. The fracture tough-

ness values also increased from 0.7671 kJ/m², for neat epoxy resin, to 0.8615 kJ/m², for 9% cyanate ester-modified epoxy system. The 10% weight loss temperature of pure epoxy (358°C) was increased to 390°C by the incorporation of cyanate ester resin. The incorporation of cyanate ester up to 9% in the epoxy resin increases the T_g from 143 to 147°C. © 2009 Wiley Periodicals, Inc. *J Appl Polym Sci* 112: 2579–2587, 2009

Key words: cyanate ester; toughening of epoxy; mechanical and thermal properties of composite

INTRODUCTION

Improved performance coupled with cost savings associated with reduced weight of components has been the key reason for using composites extensively in a variety of space applications. Composite material provides the designer the opportunity to tailor properties such as modulus, strength, and coefficient of thermal expansion.¹ High-modulus graphite/epoxy composites have been the material of choice for space applications because of the desirable properties such as high tensile strength and modulus, good thermal and electrical properties, excellent chemical and solvent resistance, outstanding adhesion to various substrates, and easy process ability under various conditions. However, their brittleness and moisture absorption pose problems during service as does the coefficient of thermal expansion. The absorbed moisture decreases the T_g of the polymer matrix by acting as a plasticizer.² The epoxy resins need to be modified by some means to improve the aforementioned properties. There are reports on the toughening of this resin system with amine-terminated butadiene-acrylonitrile (ATBN), carboxyl-terminated butadiene-acrylonitrile (CTBN), and other

elastomers but always with a decrease in modulus and T_g .^{3–6} A large number of studies were undertaken on the inclusion of thermoplastics such as polysulfones, polyether sulfones, and polyether imides to epoxy networks.^{7,8} These studies show good improvement in thermal and mechanical properties.⁹ However, these polymers show poor solubility in organic solvents leading to difficulties in processing.

Cyanate esters are inherently tough, and they have much higher T_g in comparison with epoxy and very low thermal coefficient of expansion and moisture absorption. These properties make them suitable candidates for advanced composite applications. However, when compared with epoxies, they are very expensive.¹⁰ There have been reports on the chemical reaction between cyanate esters and epoxies,^{11,12} making them highly compatible blends. Among the various materials, cyanate esters are anticipated to provide improvement in the properties of epoxy resins. Hence, in this investigation, a new cyanate ester has been synthesized and blended with epoxy resin, and the effects of loading level on mechanical and thermal properties of castings and composites were evaluated.

EXPERIMENTAL

Materials

Cyanogenbromide, anisaldehyde, 2,6-dimethyl phenol, toluene, *p*-toluene sulfonic acid, acetone (HPLC

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grade), and triethylamine were obtained from SRL (Mumbai, India). Commercial epoxy resin LY 556 and diamino diphenyl methane (DDM) were obtained from Hunts-man (Chennai, India). All the chemicals were used as purchased.

Synthesis of monomer precursor

Synthesis of bis(4-hydroxy-3,5-dimethyl phenyl)anisylmethane

2,6-Dimethyl phenol (32.98 g, 0.27 moles), 19.2 g (0.12 moles) of anisaldehyde, 2.34 g (0.012 moles) of *p*-toluene sulfonic acid monohydrate, and 38 mL of toluene were charged into a three-necked flask equipped with a condenser, a Dean-stark water separator, and a nitrogen inlet. The reaction mixture was refluxed at 132–134°C for 5 h under nitrogen atmosphere. Water produced by the reaction was successively removed from the system by azeotrope with toluene. After completion of the reaction, the solution was cooled to 80°C, and then 5.2 g of 10% aqueous solution of sodium hydroxide was added to the resulting solution. The solid formed was filtered and recrystallized from methanol/water (3 : 1 v/v) to produce light brown crystals.¹³ The molecular formula of the prepared bis-phenol is C₂₄H₂₆O₃. Yield 90%, elemental analysis C (79.55) 80.55, H (7.18) 7.47; FTIR: 3511 cm⁻¹ (OH stretch), 2923 cm⁻¹ (CH₃ stretch); ¹H-NMR: 4.4 ppm (OH). The reaction scheme is shown in Figure 1.

Synthesis of monomer

Synthesis of bis(4-cyanato-3,5-dimethyl phenyl)anisylmethane

The bis(4-cyanato-3,5-dimethyl phenyl)anisylmethane (BCAM) was prepared by reacting bis(4-hydroxy-3,5-dimethyl phenyl)anisylmethane (1 mole) with cyanogen bromide (2 moles) and triethylamine (2 moles) in acetone medium at -10 to 5°C. Triethylamine was added dropwise over a period of 45 min to the mixture of bis(4-hydroxy-3,5-dimethyl phenyl)anisylmethane and cyanogen bromide, and then

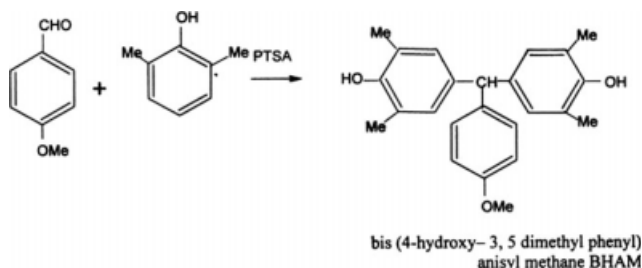


Figure 1 Synthesis of bis(4-hydroxy-3,5-dimethyl phenyl)naphthyl methane: BHAM.

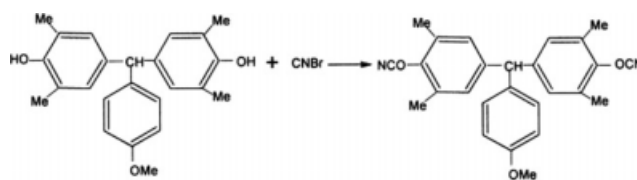


Figure 2 Synthesis of bis(4-cyanato-3,5-dimethyl phenyl)naphthyl methane: BCAM.

the reaction was continued for another 90 min at the same temperature. The reaction mixture was precipitated in cold water, filtered, and dried.¹⁴ The molecular formula of the monomer is C₂₆H₂₄O₃N₂. Yield 90%, melting point 90°C, elemental analysis C (75.73) 74.52, H (5.83) 6.02, N (6.79) 6.59; FTIR: 2245 cm⁻¹ (OCN stretch), 2923 cm⁻¹ (CH₃ stretch); ¹³C-NMR: 108.1 ppm (OCN). The reaction scheme is shown in Figure 2.

Fabrication of neat and blended resin castings

Employing the compositions given in Table I, different formulations of BCAM with EP and DDM were made. The blends were thoroughly mixed and melted at 90°C in an oil bath and degassed to remove air bubbles. The homogenous liquid was then transferred to a preheated open mold at 100°C coated with silicone-based release agent to facilitate the release of cured samples. All the castings were cured at 120°C for 2 h, 180°C for 1 h demolded and further postcured at 220°C for 1 h.¹⁵

Fabrication of composites

The laminate composites were fabricated from E-glass fiber plain woven fabric and epoxy resin/cyanate-modified epoxy resin by hand lay-up technique. Plain woven glass fibers with an aerial density of 200 g/m² were used as the reinforcement for composite laminate. The liquid epoxy was taken in a beaker, which was heated to 90°C to lower the resin viscosity, and then the desired amount of cyanate was added into the resin. The cyanate loading was varied between 0, 3, 6, and 9% by weight of epoxy resin. The mixture was degassed in a vacuum oven followed by the addition of DDM (curing agent) in

TABLE I
Blend Formulation

S. No.	EP (g)	BCAM (g)	DDM (g)
1.	100	–	27
2.	100	3	27
3.	100	6	27
4.	100	9	27

27% by weight of epoxy and stirred for 3 min at 90°C.

A steel mold plate was coated with silicone release agent, and then a layer of the resin was applied using a brush. Then, the first layer of the fiber (160 mm × 160 mm) was placed on the resin and consolidated using rollers. This process was repeated to construct a 14-ply laminate. Necessary precautions were taken to keep the fabric well aligned. A 15- μ m thick Teflon release film was inserted in the mid-plane of the laminate as an initial crack for the mode I fracture toughness test.¹⁶ The fabricated sheet was then cured at 120°C for 1 h and 180°C for 1 h in a hydraulic press. The sheet was then demolded and postcured at 220°C for 1 h.

Measurements

Elemental analysis of monomer precursors and monomers were carried out on Thermo Finnigan FLASH EA 1112 CHNS analyzer with a sample weight of 1.2 mg. A Perkin-Elmer FTIR spectrometer model 20 D × B was used to record the IR spectrum (400–4000 cm^{-1}) of cured samples. Analysis was done using solid KBr pellets. ¹H- and ¹³C-NMR spectra were used to obtain the chemical structure of the monomer precursors and monomers synthesized. Samples were dissolved in deuterated chloroform (Aldrich, CDCl_3 , 99.8% containing 0.03% v/v tetramethylsilane TMS) at concentration of 2–10% solid content. NMR spectra were recorded on an AMX-400 NMR spectrometer at 400 MHz.

The fiber volume fraction by acid digestion method was evaluated as per ASTM D-3171 procedure B. The tensile and flexural properties were investigated by using universal Testing Machine (Model H50K-S, Hounsfield Test Equipment, UK). The crosshead speed was 1 mm/min. The span length of the specimen was 150 mm. Tensile modulus studies were evaluated as per ASTM D-3039. The flexural strength and flexural modulus of the blends and composites were studied as per ASTM D-790. The crosshead speed was 1.0 mm/min. The unnotched Izod impact strength of the castings was measured according to ASTM D-25688. The double cantilever beam (DCB) test samples for G_{IC} fracture toughness measurements were prepared according to the ASTM D-5528 (dimension 125 mm × 25 mm × 3 mm) with a preinitiated crack of 50 mm. Aluminum hinges were attached to the surfaces of the specimens to facilitate crack propagation. Measurements of load and crack displacement were taken at the initial crack propagation, at 1-mm interval for first 5 mm, at 5-mm interval up to a total crack length of 45 mm, and at 1-mm interval for the last 5 mm giving a total of 19 readings. Three methods of data reduction were applied using software pro-

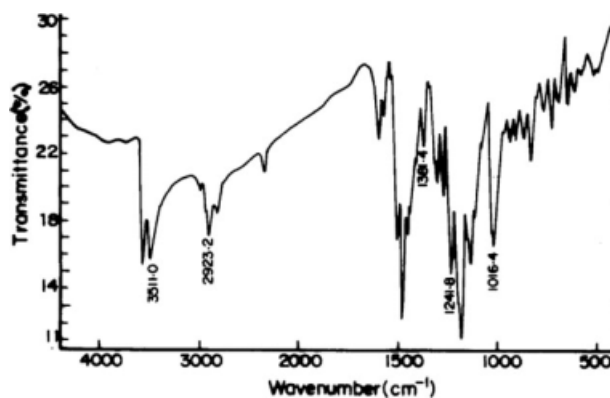


Figure 3 FTIR spectrum of bis(4-hydroxy-3,5-dimethylphenyl)naphthyl methane: BHAM.

grams; the data quoted being those obtained by compliance method at peak load.¹⁶ The displacement of crack was observed using a camera, and the test was carried out in universal testing machine.

The thermal stability of the blends was studied by thermogravimetric analysis using TA-SDT Q 600 at a heating rate of 10°C/min in a nitrogen atmosphere. The cure characteristics of neat resin and blends were studied using DSC (TA Instruments, USA) in the temperature range between 50 and 250°C at a heating rate of 10°C/min in air. The glass transition temperatures of the composites were evaluated by DMA in the temperature range between 50 and 300°C at a heating rate of 10°C/min and a frequency of 2 Hz.

Morphological studies were conducted by using scanning electron microscopy (JOEL, JSM 840 A). Microphotographs were taken on the surface, which was made by breaking the specimen by impact testing machine and then coating with gold powder. Photographs were taken on Polaroid film at the magnification of 1000 \times .

RESULTS AND DISCUSSION

Spectral analysis

The structure of the prepared bisphenol and the dicyanate were confirmed by FTIR and NMR techniques. The FTIR spectrum of the bisphenol (Fig. 3) synthesized show disappearance of absorption band at 1750 cm^{-1} characteristic of aldehyde and appearance of the absorption band at 3511 cm^{-1} characteristic of —OH group confirming the structure. The presence of —OH group is further confirmed by the presence of absorption bands at 1381 and 654 cm^{-1} because of the in-plane and out-of-plane bending of OH group, respectively.¹³ The monomer precursor shows absorption around 2923 cm^{-1} because of the C—H stretching vibration of CH_3 group. ¹H-NMR spectrum of the monomer precursor is shown in

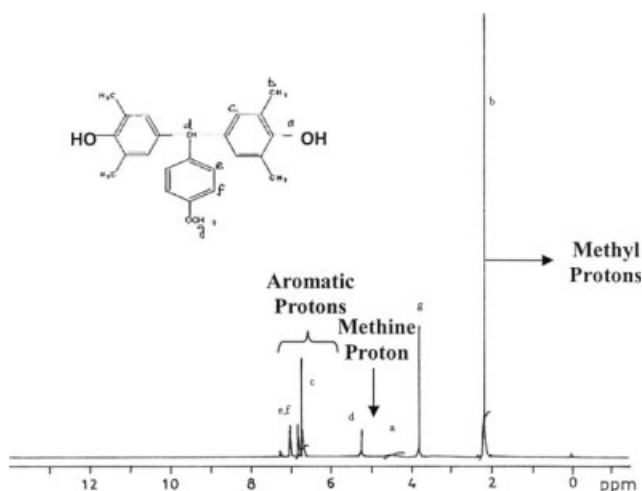


Figure 4 ^1H -NMR spectrum of bis(4-hydroxy-3,5-dimethyl phenyl)naphthyl methane: BHAM.

Figure 4. The bis-phenol shows a signal around 4.4 ppm (singlet) corresponding to the $-\text{OH}$ protons. The methyl protons of the monomer precursor resonate around 2.2 ppm (singlet).^{17,18} The aromatic protons resonate around 6.8–7.2 ppm.

The FTIR spectrum of the cyanate ester (Fig. 5) shows a band at 2245 cm^{-1} because of the $-\text{CN}$ stretching vibration confirming the formation of the cyanate ester group.¹⁷ ^{13}C -NMR spectrum of the monomer (Fig. 6) shows distinct signals for all the different carbon atoms. All the methyl carbon atoms resonate at 16.1 ppm. The $-\text{OCN}$ group present in the monomer shows a distinct signal around 108.1 ppm further confirming the formation of dicyanate.^{19,20} The aromatic carbons resonate between 120 and 160 ppm. All the spectroscopic data obtained agree well with the expected structure.

The disappearance of absorption band at 2245 cm^{-1} and the appearance of new absorption bands at 1567 and 1368 cm^{-1} in the FTIR spectrum of the

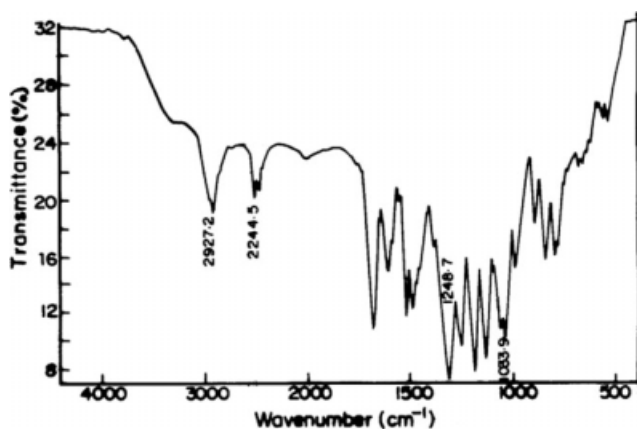


Figure 5 FTIR spectrum of bis(4-cyanato-3,5-dimethyl phenyl)naphthyl methane: BCAM.

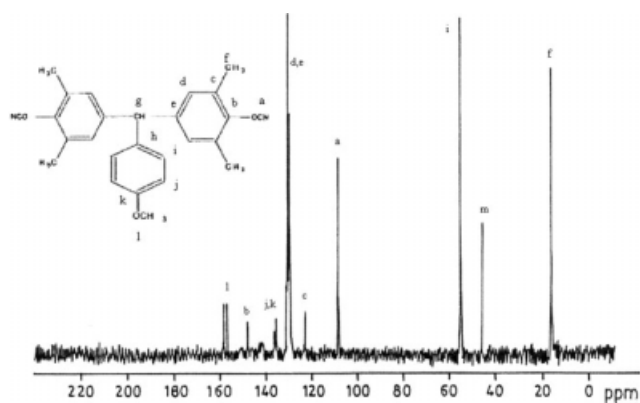


Figure 6 ^{13}C -NMR spectrum of bis(4-cyanato-3,5-dimethyl phenyl)naphthyl methane: BCAM.

cured resin confirms the formation of cyanurate ring after curing (Fig. 7).

The cyanate and epoxy resins when blended together react chemically as reported earlier.^{11,12} The cyclotrimerization of the cyanate ester groups among themselves and formation of oxazolidinone and oxazoline by reaction between cyanate and epoxy take place in the blend, as reported by other authors. The FTIR spectrum of DDM-cured cyanate ester-epoxy system (Fig. 8) shows an absorption band at 1750 cm^{-1} confirming the formation of oxazolidinone group. The intensity of absorption at 1537 and 1370 cm^{-1} due to cyanate are found to decrease in the cyanate-epoxy blend further confirming the coreaction.¹⁸

Thermal properties of neat epoxy and cyanate-modified epoxy blends

The thermal characteristics of the blends and neat epoxy resin were studied by thermogravimetric analysis. The thermograms of the epoxy and cyanate-modified epoxy blends are shown in Figure 9. The 10% weight loss temperature and the char yield

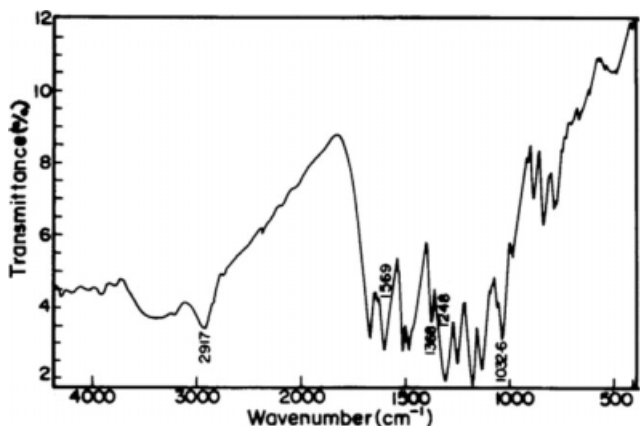


Figure 7 FTIR spectrum of cured cyanate ester resin.

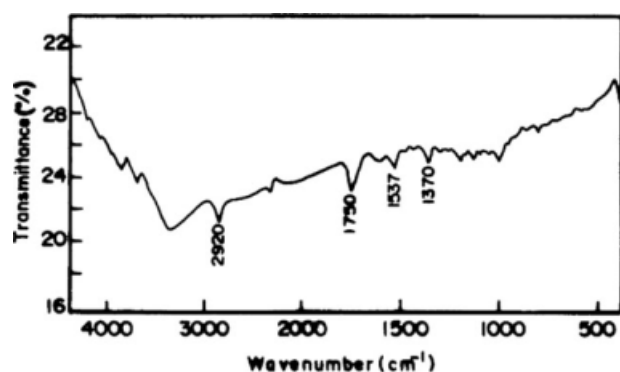


Figure 8 FTIR spectrum of epoxy/cyanate ester resin blend.

of pure epoxy and cyanate-modified epoxy blends are presented in Table II. The T_{10} for pure epoxy and cyanate-modified epoxy are 358 and 390°C, respectively. The blends clearly show their superior thermal stability over epoxy resin by about 32°C in T_{10} value. The incorporation of cyanate into epoxy resin improves the temperature of 10% weight loss and enhances the degradation temperature. This is because pure cyanate ester resin degrades at a temperature greater than 400°C, irrespective of the chemical structure.¹⁵ From the figure, it is observed that the T_{10} values of cyanate-modified epoxy blends are more or less the same around 390°C. The upward shift in decomposition temperature for cyanate-modified epoxy system may be due to the triazine ring formed as a result of curing of cyanate ester resin. The anaerobic char yield of pure epoxy system is 18.15%. The char yield of cyanate ester-modified epoxy systems for 3, 6, and 9% are 21.04, 23.79, and 26.23%, respectively. The increasing trend of char yield with the incorporation of cyanate content is due to the increase in the aromatic content.^{14,15}

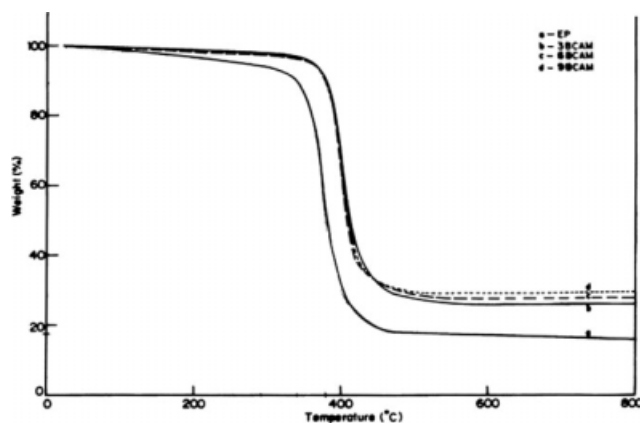


Figure 9 TGA curves of neat epoxy and cyanate-modified epoxy blends.

TABLE II
TGA Values of Epoxy and Cyanate-Modified Epoxy System

Composition	T_{10} value (°C)	Char yield (%)
EP	358	18.15
3 BCAM	390	21.0
6 BCAM	390	23.8
9 BCAM	390	26.2

Cure characteristics

The cure characteristics of the dicyanate BCAM and their 3, 6, and 9% blends were monitored by DSC analysis. The temperatures corresponding to the onset of cure, T_i , the maximum cure, T_p , and end of the cure, T_f , are presented in Table III.

From Table III, it is evident that the curing reaction peaks at 200°C for BCAM monomer. The peak maximum temperature is found to be higher than that of conventional cyanate ester (bis-phenol dicyanate) due to rigid and bulky ring structure, which requires high temperature to accomplish the curing reaction.²¹

It can be seen from Table III that cyanate ester-modified epoxy systems have a peak maximum temperature of 164, 165, 169°C, respectively, for 3, 6, and 9% (by weight of epoxy) of cyanate content. The decrease in peak maximum temperature of cyanate ester-modified epoxy system when compared with pure cyanate ester system is due to the fact that the major curing reaction is between epoxy resin and DDM (since the cyanate content is very low) whose cure temperature (peak maximum) is only 153°C (Table III). The reaction between epoxy and cyanate requires a higher temperature than that of pure epoxy but lower than that of pure cyanate. The peak maximum temperature of the blends lie between that of neat epoxy and neat cyanate ester resins as expected. The large exothermic peak obtained from cyanate ester epoxy systems is due to the following reactions:

- polycyclo trimerization of cyanate monomers,
- reaction of cyanate with amine, and
- reaction of cyanate with epoxide.

TABLE III
DSC Cure Characteristics of Neat Epoxy and Cyanate-Modified Epoxy System

Composition	T_i (°C)	T_p (°C)	T_f (°C)
BCAM	182	200	229
3 BCAM	126	164	242
6 BCAM	128	165	231
9 BCAM	131	169	236
EP	105	153	224

TABLE IV
Glass Transition Temperature of Epoxy and
Cyanate-Modified Epoxy/Glass Fiber Composites

Composition	EP (°C)	BCAM (°C)
100	142.7	–
3	–	143.5
6	–	144.6
9	–	147.1

The observed behavior correlates with the values reported by other authors.²² Based on the cure behavior observed from DSC studies, the processing temperature of the epoxy/cyanate blends and their composites was decided.

Glass transition temperature

Dynamic mechanical analysis (DMA) is a powerful technique measuring the glass transition temperature (T_g), particularly for polymers with rigid backbones.²³ The T_g is determined by the corresponding peak of the loss modulus curve. The T_g values of neat epoxy and cyanate-modified epoxy resin are tabulated in Table IV. The T_g of pure epoxy is 142.7°C and that of 3, 6, and 9% BCAM-modified epoxy system are 143, 144, and 147°C, respectively. From the results it is seen that on increasing the cyanate content, the T_g value is found to increase only moderately to 143 to 144 for 3 and 6% cyanate contents. However, with 9% cyanate the T_g has gone up to 147°C. With less amounts of cyanate, only oxazolidinone would be formed and hence thermoplastic character is introduced to some extent. However, for 9% system there is a slight increase in the T_g value by 4.4°C when compared with neat epoxy system. With 9% cyanate content *s*-triazine ring forma-

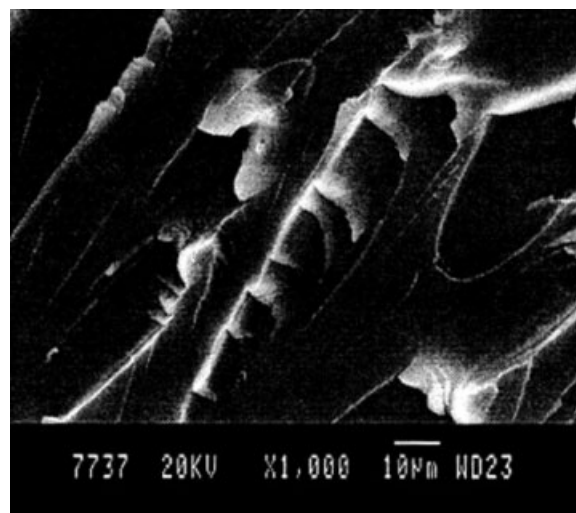


Figure 11 SEM micrograph of 3 BCAM.

tion becomes more probable and hence the T_g goes up to a higher value. The DMA curves with single T_g further indicate that the blend system is a single-component system.

SEM analysis

The phase separations brought about by the inclusion of cyanate into the epoxy system were studied by SEM analysis. The SEM micrographs of the fractured surface of pure epoxy and cyanate-modified epoxy at 1000× magnification are shown in Figures 10–13. The bright lines that emanate from the crack with the cut edges were observed in pure epoxy system (Fig. 10). The polymer ligament tear appears as straight cuts with sharp edges. This shows that the cured unmodified resin is brittle, whereas for the modified resins, the fractured surfaces shown in

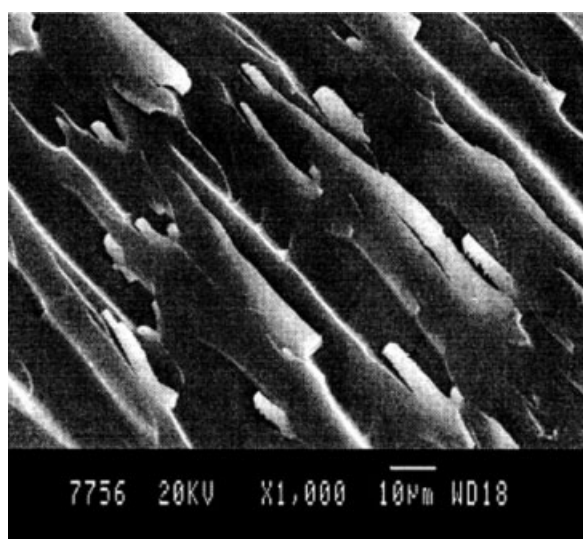


Figure 10 SEM micrograph of neat epoxy system.

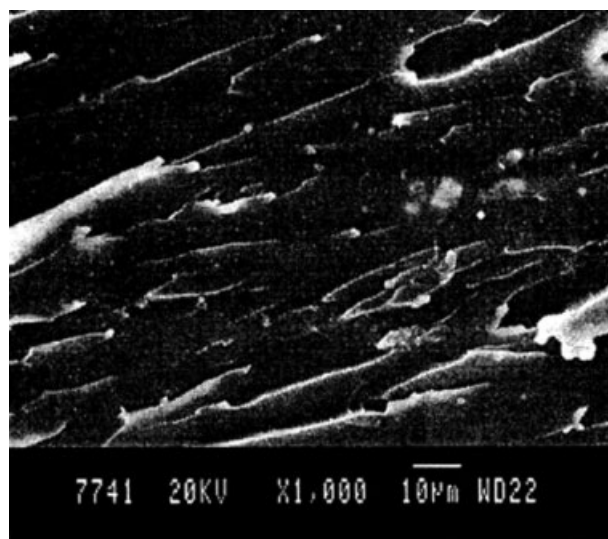


Figure 12 SEM micrograph of 6 BCAM.

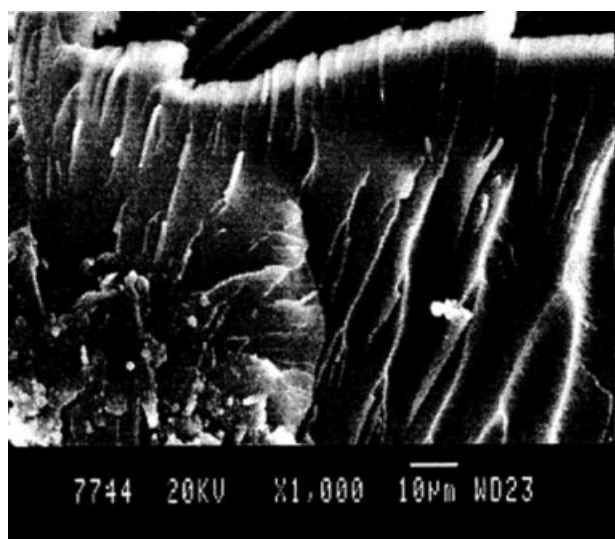


Figure 13 SEM micrograph of 9 BCAM.

Figures 11–13 appear as local shear deformation. Although few definite cut edges were seen at scattered points, the local yielding and shearing seems to be prevalent to some extent.²⁴

Mechanical properties of epoxy–cyanate blends

In this investigation, the mechanical properties like tensile, flexural, and impact properties of pure epoxy and cyanate-modified epoxy system were measured as per the ASTM standards and examined as a function of their composition and the results are compiled in Table V. From Table V it is observed that the introduction of 3, 6, and 9% (by weight) of cyanate ester into epoxy resin increases the tensile strength when compared with unmodified epoxy system. This may be explained due to the presence of rigid phenyl ring with the incorporation of cyanate ester into epoxy systems. As the composition of dicyanate is increased from 3% → 6% → 9%, the aromatic content also increases, resulting in the increased tensile strength. The tensile strength value for pure epoxy system is 52 MPa but for 3, 6, and 9% system, the values are 55, 63, and 76 MPa, respectively.²⁵

TABLE V
Mechanical Properties of Epoxy and Cyanate-Modified Epoxy Resins

Blend code	Tensile strength (MPa)	Tensile modulus (GPa)	Flexural strength (MPa)	Impact strength (J/cm)
EP	52	2.4	89	0.67
3 BCAM	55	2.5	96	1.3
6 BCAM	63	2.6	148	2.0
9 BCAM	76	2.6	169	2.7

The flexural behavior of pure epoxy system and cyanate ester-modified epoxy system are presented in Table V. The introduction of 3, 6, and 9% (by weight) cyanate ester into epoxy resin increases the flexural strength by 1.02, 1.7, and 1.9 times, respectively, for blends when compared with the unmodified epoxy system. The enhanced flexural properties are due to the increase in the interfacial shear strength as a result of the formation of a network structure between cyanate ester and epoxy matrix. The formation of aliphatic oxazolidinone exhibits more thermoplastic character, which imparts resistance to bending stress.²⁶

The impact behavior of unmodified epoxy is found to improve with the incorporation of cyanate ester into epoxy resin. The enhancement of impact strength with the increase in cyanate content is due to the reduced crosslink and a high percentage of flexible ether linkages in the network.

Mechanical properties of epoxy–cyanate glass fiber composites

Prior to the study of mechanical properties of composites, the fiber volume fraction and void content of the epoxy and cyanate/epoxy composite were determined by ASTM 3171 procedure B. The fiber volume fraction of the composites were found to be in the range $42\% \pm 2\%$.

Table VI represents the mechanical properties of epoxy/cyanate-modified glass fiber composites. With the incorporation of fiber into the polymer matrix, the strength of the composite is found to increase by about six times than that of resin blends. From the table it is seen that the tensile strength values of epoxy composite is 322 MPa, and for cyanate-

TABLE VI
Mechanical Properties of Epoxy–Cyanate/Glass Fiber Composites

S. No.	Composition	Tensile strength (MPa)	Tensile modulus (GPa)	Flexural strength (MPa)	Flexural modulus (GPa)	Fracture toughness G_{IC} (kJ/m ²)
1.	100% EP	322	3.8	404	8.5	0.7671
2.	3% BCAM	302	5.1	435	16.1	0.7782
3.	6% BCAM	310	4.6	450	10.3	0.7876
4.	9% BCAM	324	4.6	471	8.4	0.7944

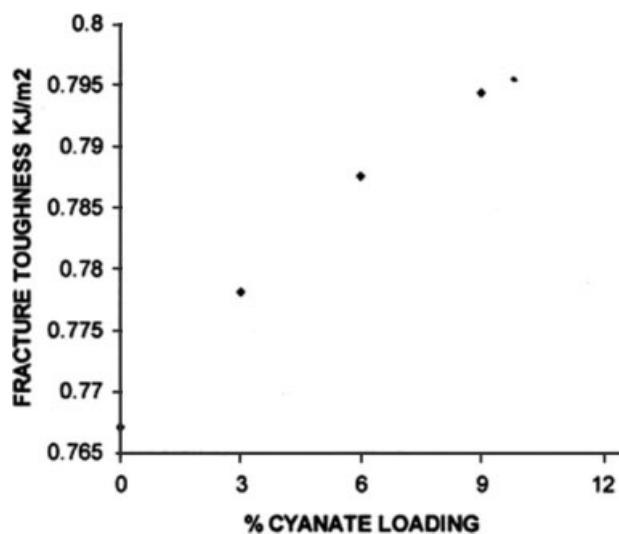


Figure 14 Fracture toughness vs. % cyanate loading.

modified epoxy composite, the values are 302, 310, 324 MPa, respectively, for 3, 6, and 9% loading. It is observed that the cyanate-modified epoxy has lower tensile strength when compared with epoxy composite. However, an increasing trend is observed with the tensile modulus values on increasing the cyanate content.

The flexural behavior of pure epoxy system and cyanate ester-modified epoxy glass fiber system are presented in Table VI. The introduction of 3, 6, and 9% (by weight) cyanate ester into epoxy resin increases the flexural strength by 8, 11, and 17%, respectively, for composites when compared with the unmodified epoxy system. The enhanced flexural properties are due to the formation of a network structure between cyanate ester and epoxy matrix. The formation of aliphatic oxazolidinone exhibits more thermoplastic character, which imparts resistance to bending stress.²⁶

The fracture toughness (G_{IC}) of pure epoxy composite and the blend composite were obtained by compliance method, and the values are shown in Figure 14 by plotting the fracture toughness against composition of resin. The G_{IC} of pure epoxy glass fiber composite is 0.7671 kJ/m^2 and that of 3 BCAM, 6 BCAM, and 9 BCAM are 0.7782, 0.7876, and 0.7944 kJ/m^2 , respectively. From the figure it is observed that the fracture toughness increases with the increase in cyanate content. The increase in fracture toughness with the cyanate content may be due to the presence of oxazolidinone and cyanurate ring, which imparts toughness to the resin system.

CONCLUSIONS

Novel cyanate ester, BCAM, was synthesized and characterized by spectral technique. The prepared

dicyanate ester resin containing anisyl moiety was blended with epoxy resin in 3, 6, and 9% loading levels. The thermal stability of cyanate epoxy blend shows a higher thermal stability over epoxy resin with a margin of about 40°C in the temperature of 10% weight loss. The T_g slightly increased from 142°C to 143°C for 3% loading and 144°C for 6% loading and then showed a slight increase of 147 for 9% loading. The very slight variation in T_g of 3% and 6% cyanate loading may be due to the formation of oxazolidinone ring which is formed as a result of epoxy–cyanate ester co-reaction in addition to cyanurate rings. But with 9% loading substantial amounts of cyanurate rings should have been formed thereby increasing the T_g to 147°C .

The mechanical properties like tensile modulus, flexural strength, and flexural modulus were observed to be greater for 3, 6, and 9% cyanate loading than the unmodified epoxy system. The trend in the aforementioned mechanical properties recorded for neat resin and cyanate-modified epoxy were apparently translated into the corresponding composites except for the tensile strength values. The fracture toughness of cyanate-modified epoxy system was found to increase by 4% for 9% loading. Thus, it is clear that the incorporation of cyanate upto 9% loading yields better toughness without leading to the degradation in other mechanical properties. From the results of blend castings and composites, the new cyanate-modified epoxy composites may have potential in engineering and aerospace applications to provide better performance.

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