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Effect of Zeolite on Glass Fibre Reinforced Cyanate Ester Nano Composites

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Abstract. Cyanate esters are thermally resistant thermosetting resins with low dielectric constant, low moisture absorption, high glass transition temperature and can be tuned for different mechanical, thermal and electrical properties. In this work, different compositions (0%, 1%, 3% and 5%) of zeolite nanoparticles incorporated cyanate ester composites were synthesised by Hand Lay-Up method followed by compression moulding. Curing was done at 200^{0}C for half an hour. Mechanical properties like tensile strength, flexural modulus were measured using Universal Testing Machine. The thermal properties of the composites were studied by Thermogravimetric analysis (TGA). The decomposition occurred between 350^{o}C to 400^{o}C. The dielectric studies were carried out using LCR meter. All these studies supports that the chosen composite is a potential candidate for dielectric applications.

INTRODUCTION

With the growing needs in various industrial fields, thermosetting resins are finding an indispensable role. Cyanate ester resins are a class of thermally resistant thermosetting resin which plays a vital role in making composite materials suitable for aerospace and avionics applications, electronics industry etc. [1, 2]. The cutting edge properties that set a different place for cyanate ester resins among other thermosets like epoxy, bismaleimide and polyimide resins are relatively lower dielectric constant (ε) and tan δ values, lower moisture absorption, higher toughness [3,4,5], high glass transition temperature [6] etc. The applicability of cyanate ester resin can be improved if there is a reduction in its dielectric constant. Various organic - inorganic or inorganic materials with nanopores have been used to lower the dielectric constant of the cyanate ester resin [7,8,9]. In this work, zeolite was used as filler to make cyanate ester nanocomposite reinforced with E-glass fiber.

MATERIALS AND METHODS

Materials

Cyanate Ester was purchased from Lonza Group AG and the zeolite from Sigma Aldrich. Both are used as received. E - Glass fibre was kindly supplied by NIT, Calicut.

Methods

A weighed amount of cyanate ester sample was taken in a beaker and was subjected to probe sonication for 15 minutes. A preheated rectangular mould (110mm x 80mm x 2mm dimensions) coated with silicon oil was used for the fabrication. E glass fibre sheet of required dimension was laid on the mould by Hand Layup method and cyanate ester was uniformly applied on it. This process was repeated for four times. The mould was closed and kept at 90^{o}C for 30 minutes. It was then subjected to compression moulding at a temperature of 200^{o}C and a pressure of 2300 PSI

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for 30 minutes. The heated mould was opened and the glass fibre reinforced cyante ester laminate was taken out for further studies.

To study the effect of nanofillers in the cyanate ester glass fibre laminate, zeolite nanopowder was added in 1 wt % (ZCE 1%), 3 wt % (ZCE 3%) and 5 wt % (ZCE 5%) of cyanate ester. Firstly, to the weighed, sonicated, cyanate ester sample, 1 wt % of zeolite powder was added and further sonicated for 15 minutes. This sonicated mixture was applied on the mould by hand layup method and was subjected to compression moulding as mentioned earlier. The whole process was repeated for 3 wt % and 5 wt % of zeolite. The as prepared glass fibre reinforced cyanate ester laminates with and without zeolite powder was subjected to mechanical, thermal, electrical and morphological studies.

RESULTS AND DISCUSSIONS

Mechanical Studies

The mechanical studies included tensile strength and flexural analysis of the prepared cyanate ester nanocomposites using Universal Testing Machine.

Tensile Strength Studies

The tensile strength analysis of the prepared cyanate ester nanocomposites gave the following stress strain graphs as shown in fig 1. Figure 1 (a) represents the stress strain graph of neat cyanate ester resin and (b), (c) and (d) represents cyanate ester nanocomposites with 1%, 3% and 5% zeolite respectively. Maximum tensile strength was given by ZCE 1% which is ~ 1.8 MPa.

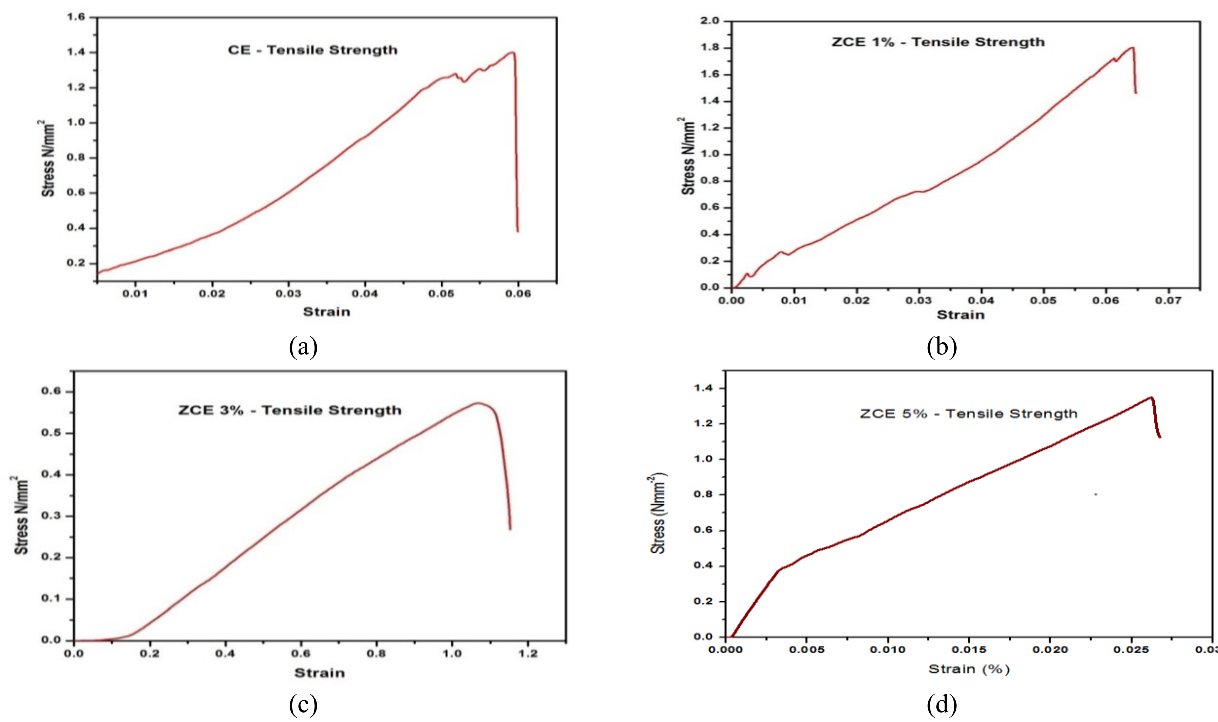


FIGURE 1. Tensile strength analysis of the glass fibre reinforced cyanate ester zeolite laminates (a) without zeolite (0 wt %) (b) 1 wt % zeolite (c) 3 wt % zeolite (d) 5 wt % zeolite

Flexural Strength Studies

The stress strain graph obtained from the flexural analysis of the prepared samples was also plotted in fig 2. Figure 2 (a) represents the stress strain graph of neat cyanate ester resin and (b), (c) and (d) represents cyanate ester nanocomposites with 1%, 3% and 5% zeolite respectively. The ZCE 3% showed remarkably lower flexural strength (~ 5 kPa) and maximum was for neat cyanate ester composite (54kPa).

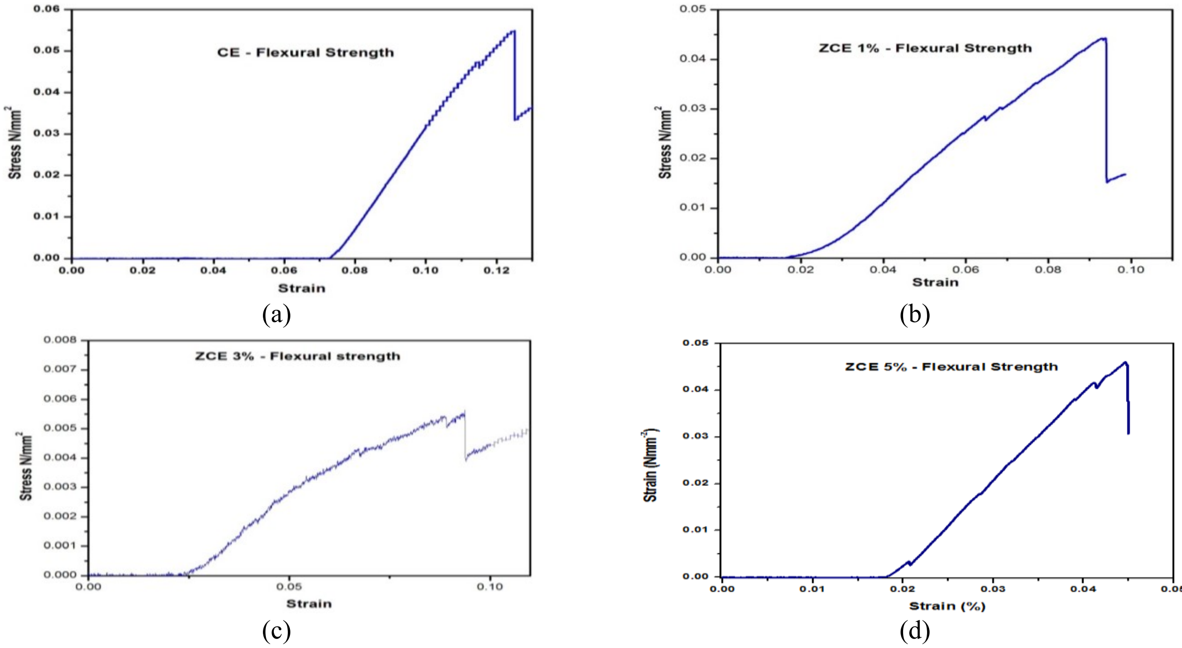


FIGURE 2. Flexural strength analysis of the glass fibre reinforced cyanate ester zeolite laminates (a) without zeolite (0 wt %) (b) 1 wt % zeolite (c) 3 wt % zeolite (d) 5 wt % zeolite

Thermal Studies

Thermogravimetric Analysis (TGA)

The thermogravimetric analysis of the glass fibre reinforced cyanate ester (CE) and ZCE 3% were done using the Perkin Elmer Thermogravimetric Analyser. The sample CE shows first decomposition around 440^{o}C and the corresponding weight loss was around 16%. Also the second decomposition occurred around 600^{o}C and the weight loss was 40%. In the case of ZCE 3%, decomposition started at 346.5^{o}C corresponding to a weight loss of 12%.

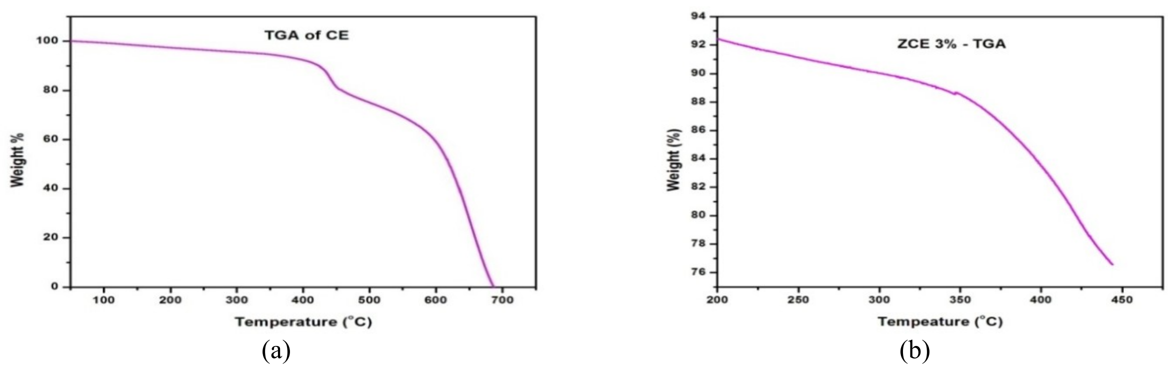
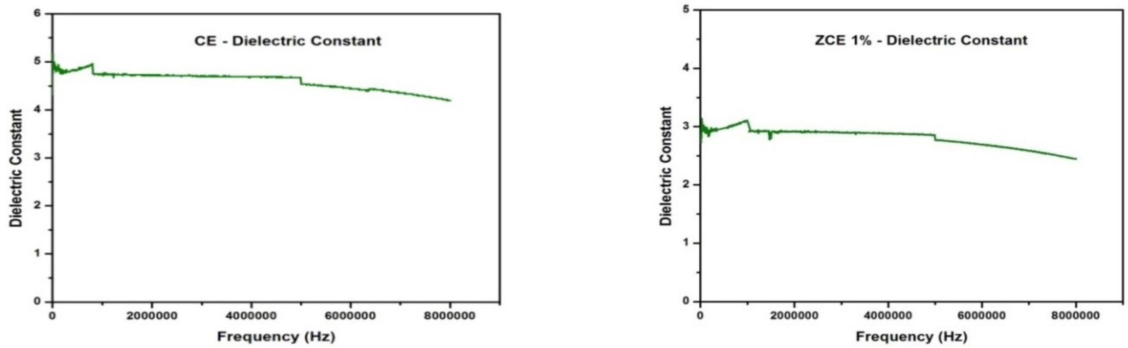


FIGURE 3. TGA of the glass fibre reinforced cyanate ester zeolite laminates (a) without zeolite (b) 3 wt % zeolite

Dielectric Studies

The applicability of the prepared nanocomposites in various fields depends on the dielectric properties along with other thermo-mechanical properties. The variation of dielectric constant of the samples CE and ZCE 1% with applied frequency was studied using HIOKI IM 3536 LCR Meter. Figure 4 (a) and (b) represents dielectric constant versus frequency (0 to 8MHz) graph of the samples CE and ZCE 1% respectively. In both cases, the dielectric constant remained almost a constant from 1MHz to 5 MHz. The CE sample gave a dielectric constant of 4.6 which was decreased to 2.8 on the addition of 1% zeolite.

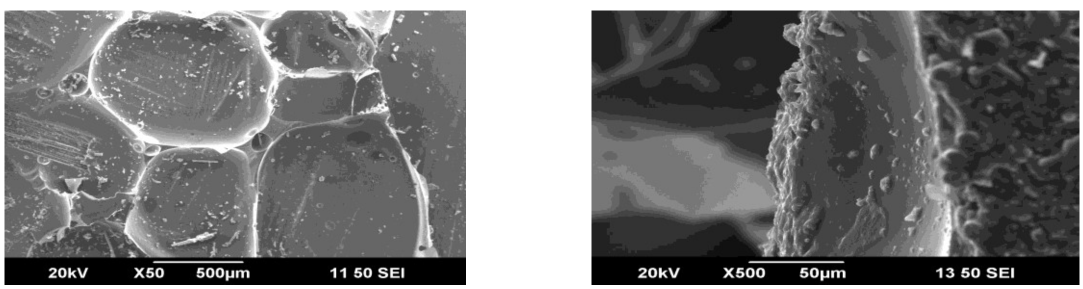


(a) (b)

FIGURE 4. Dielectric Studies of the glass fibre reinforced cyanate ester zeolite laminates (a) without zeolite (b) 1 wt % zeolite

Morphological Studies

The SEM analysis was carried out in JEOL Model JSM - 6390LV. Figure 5 (a) shows the SEM image of the glass fibre reinforced cyanate ester (CE) and 5 (b) shows the cross sectional image of the zeolite added sample ZCE 3%.



(a) (b)

FIGURE 5. (a) SEM image of the glass fibre reinforced cyanate ester zeolite laminates with 3 wt % zeolite (b) Cross sectional image

CONCLUSION

In this work, different compositions of Zeolites (0%, 1% and 3%) with Cyanate Ester were synthesized by Hand Lay - Up method reinforcing with E - glass fiber, followed by compression moulding. The as prepared samples were characterized mechanically (Tensile Strength and Flexural Strength), thermally (TGA), electrically (Dielectric Study) and morphologically (SEM). The dielectric constant of the cyanate ester reinforced with E glass fibre was reduced on the addition of 1 % zeolite. Also ZCE 1% sample gave maximum tensile strength of 1.8MPa.

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