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Mechanical Properties of Aluminium Nitride Particles Filled Polyester Composites

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Abstract*— *In this investigation, a new class of polymer composites with polyester as a matrix material and micro-sized aluminium nitride as a filler material is developed. The effect of filler content on different mechanical properties of the prepared sample is studied. The various mechanical property evaluated are tensile strength, tensile modulus, flexural strength, flexural modulus, compressive strength and hardness. From the experimental results, it is found that aluminium nitride filled polyester composites possess high modulus, compressive strength and hardness. Against that, the tensile strength and flexural strength of the composite decrease with an increase in filler content in the fabricated composites.

Keywords*—*Polymer matrix composites, polyester, aluminium nitride, mechanical properties.

I. INTRODUCTION

For microelectronic packaging application, dielectric materials with suitable dielectric constant, low dielectric loss, high thermal conductivity and good thermal stability are required. At present, such materials are mainly ceramics, which have the drawbacks such as high brittleness, low dielectric strength, high processing temperature and high density. In contrast, polymers have the advantages of easy processing, high flexibility, high dielectric strength and low density. Ceramic/ polymer composites can combine the better aspects both of polymers and ceramics and have been seen as a group of materials which are suitable for functional and demanding electronic products. Apart from thermal and dielectric behaviour, any developed material should be tested for its mechanical properties.

The amount of filler that is incorporated inside the matrix is considered to be the most significant factor which can alter the performance of the composite system. It has been shown by many researchers that dramatic improvement in mechanical properties can be achieved by the incorporation of either micro or nano-particles since rigid inorganic particles generally have a much higher stiffness than polymer matrices [1]. The effect of CaCO3 volume fraction on the notched Izod impact toughness of high-density polyethene (HDPE)/CaCO3 composites is shown by Liu et al. [2]. Cho et al. [3] underlined the interest in replacing micro-scale particles with its nano-scale counterparts smaller particle size yields higher fracture toughness.

As far as tribological behaviour is concerned, it has been seen that the incorporation of certain particles enhances the wear resistance of polymers. Wetzel et al. [4] study the effect of micro and nano-sized ceramic particulates on an epoxy resin. They study the effect of SiC and TiO2 particles for different particle loading and particle size as well as with surface modification of particles and observed that with an increase in filler loading and decrease in particle size, the specific wear rate decreases whereas modification of particles has only a little effect on the wear performance. However, Zang et al. [5] reported that grafting PAAM onto nano-silica increases the interfacial interaction between the particles and the matrix through chemical bonding. Antunes et al. [6] found that increasing the average particle dimension tends to decrease the volume removed by wear in the composite and increase it in the antagonist body. Recently, Anjum et al. [7] studied the specific wear rate of SiO2 filled glass-epoxy composite. Likewise, the incorporation of hard particles i.e., SiC, ZrO, Ti3SiC2 has led to enhancement in wear resistance [8-10].

Many investigations are reported on optically transparent polymer composites because of their wide industrial applications, such as optical fiber sensors, packaging products and medical devices [11]. Other than the difference in refractive indices of both the phases, supplementary parameters like filler concentration, particle size and affinity between filler-matrix also influence the composite transparency [12]. Zhou and Burkhart [13] studied the effect of the inclusion of SiO_2 on three different polymers i.e., polycarbonate (PC), polystyrene (PS) and PMMA, which are all amorphous thermoplastics and are often used as an alternative to glass. Yuan et al. [14] studied the effect of particle size of LaB6 particles on the optical properties of LaB6/ PMMA composites. They further reported that modification of LaB6 by adding a silane coupling agent enhanced the property to a great extent by increasing the light absorption strength of composites. Li et al. [15] evaluated the dynamic mechanical properties of particulate composites using high-precision ultrasonic testing technology. Against this background, an attempt has been made in this research work to develop aluminium nitride-basedpolyester composites using a simple hand lay-up technique and to study their mechanical behaviour under controlled laboratory conditions.

II. MATERIALS AND METHODS

A. *Material considered*

The presently used matrix is a thermoset polymer polyester along with its accelerator and catalyst.The polyester resin is procured from Carbon Black composites, Mumbai, India.Aluminium nitride is an aluminium-based ceramic material used as one of the filler materials in the present work. The used aluminium Nitride has been procured from Souvinier Chemical, Mumbai, India. The particle size analysis of the material provides the information that the average sizes of particles are about 60-70 microns.

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B. Composite Fabrication

A simple hand lay-up technique is used in the present investigation for the fabrication of aluminium nitride particles in a polyester matrix. This method is considered the simplest technique for composite fabrication. The fabrication of composite using the hand lay-up method involves the following steps:

1. First the room temperature curing polyester resin is added with the given percentage of AlN micro-particulates and mixed well through hand-stirring.
2. Later 1 wt. % of the cobalt accelerator is added into the mixture and mixed well through hand stirring.
3. This is followed by the addition of 1 wt. % MEKP catalyst and the combination is mixed properly through hand stirring over a period of around one minute.
4. A coating of silicon spray is mandatory over the mould before pouring the mixture into it, a silicon spray is done over the mould so that it will be easy to remove the composite after curing. The uniformly mixed dough is then slowly poured into the mould.
5. The cast is then cured for 2 hours before it was taken from the mould.

Composites were fabricated with different weight fractions of filler ranging from 0 wt. filler i.e. neat polyester to 40 wt. % AlN filler. The composite fabricated under the investigation is given in table 1.

TABLE I: POLYESTER COMPOSITES FILLED WITH ALUMINIUM NITRIDE

S.No.	Composition
1	Neat Polyester
2	Polyester + 10 wt % Aluminium Nitride
3	Polyester + 20 wt % Aluminium Nitride
4	Polyester + 30 wt % Aluminium Nitride
5	Polyester + 40 wt % Aluminium Nitride

C. Mechanical Characterization

The tensile properties, flexural properties and compressive strength of the composites are measured with a computerized Tinius Olsen universal testing machine Affri LD250 hardness measuring instrument is used to determine the micro-hardness of the fabricated composite.

III. RESULTS AND DISCUSSION

A. Tensile properties

The variation in the value of tensile strength with varying content of aluminium nitride in the polyester-based composite is shown in figure 1. From the figure, it is clear that with an increase in the content of aluminium nitride in the polyester matrix, the tensile strength of the combination decreases. The tensile strength of neat polyester is 33.5 MPa which decreases to 31.8 MPa at a loading of 10 wt. % of micro-size AlN which is a decrement of 5.07 %. The rate of decrement increases with an increase in filler content and for maximum filler loading of 40 wt. %, the tensile strength of composites decreased to 28.3 MPa. This decrement is attributed to 15.52 %.

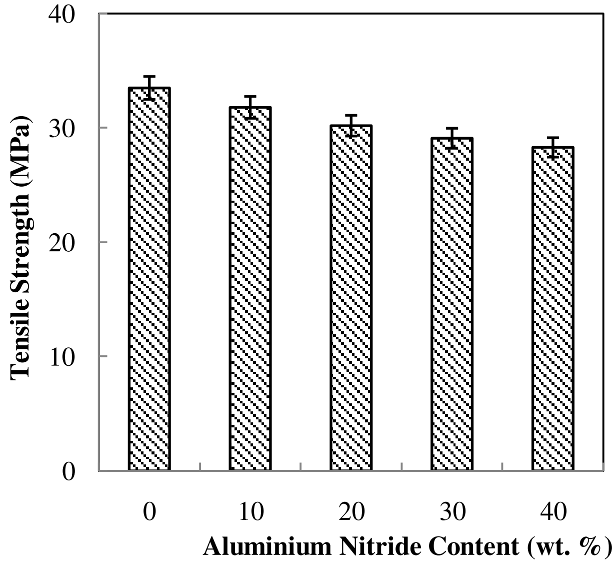

Fig.1:Tensile strength of polyester/aluminium nitride composites

The tensile modulus of the polyester composites filled with micro-sized aluminium nitride composites as a function of filler content is shown in figure 2. It can be observed from the figure that the tensile modulus of the composite increases with filler content. The highest tensile modulus obtained is for polyester/40 wt. % AlN. The tensile modulus obtained for the combination is 1321 MPa with an increment of around 20.09 %.

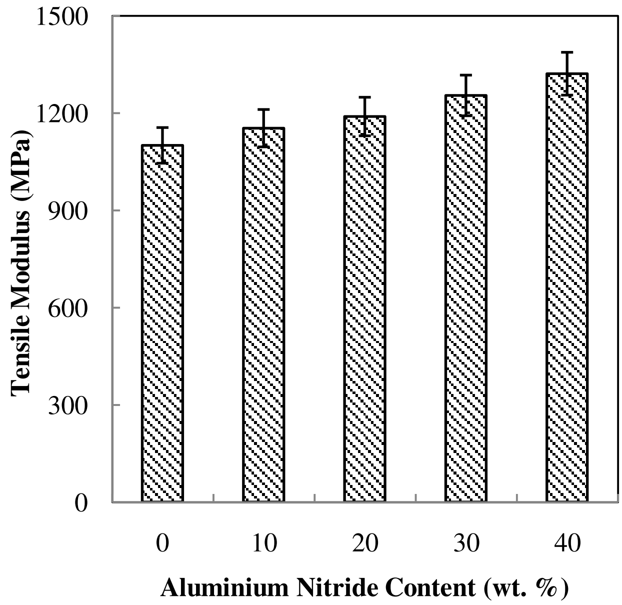

Fig. 2Tensile modulus of polyester/aluminium nitride composites

B. Flexural properties

The variation in the value of flexural strength with varying content of aluminium nitride in the polyester-based composite is shown in figure 3. From the figure, it is clear that with an increase in the content of aluminium nitride in the polyester matrix, the flexural strength of the combination decreases. The flexural strength of neat polyester is 40.6 MPa which decreases to 39.1 MPa at a loading of 10 wt. % of micro-size AlN which is a decrement of 3.69 %. The rate of decrement increases with an increase in filler content and for maximum filler loading of 40 wt. %, the flexural strength of composites decreased to 34.8 MPa. This decrement is attributed to 14.28 %.

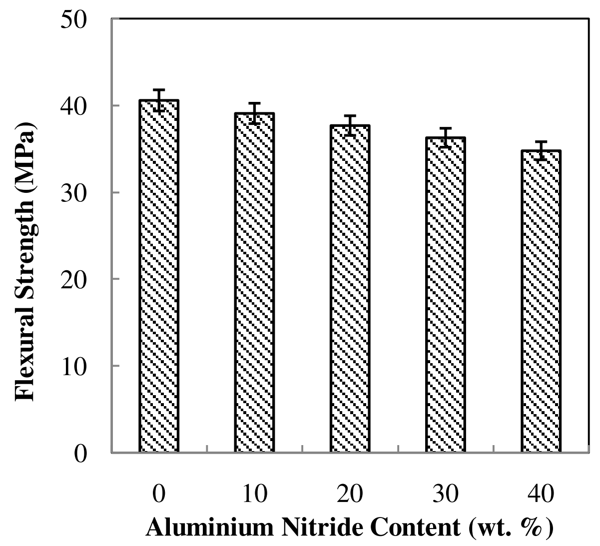

Fig. 3 Flexural strength of polyester/aluminium nitride composites

The flexural modulus of the polyester composites filled with micro-sized aluminium nitride composites as a function of filler content is shown in figure 4. It can be observed from the figure that the flexural modulus of the composite increases with filler content. The flexural modulus of neat polyester is 1530 MPa. The highest flexural modulus obtained is for polyester/40 wt. % AlN. The flexural modulus obtained for the combination is 1854 MPa with an increment of around 21.17 %.

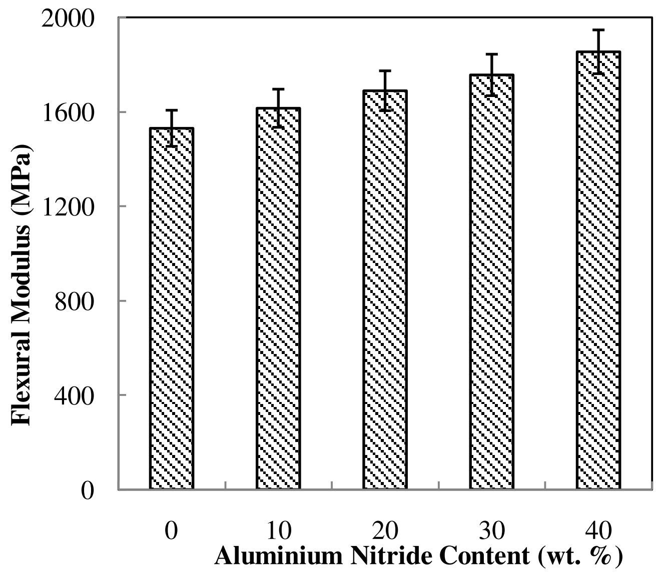

Fig. 4 Flexural modulus of polyester/AlN composites

C. *Compressive strength*

The dependence of compressive strength of polyester composites filled with aluminium nitride with different filler content is shown in figure 5. It can be seen from the figure that with an increase in AlN content, the compressive strength of the composites increases. The increasing behaviour is obvious as AlN has very high compressive strength as compared to the polyester matrix and hence the combination delivers higher compressive strength. The compressive strength of neat polyester is 72.8 MPa which increases to 77.1 MPa at a loading of 10 wt. % of micro-size AlN. This is an appreciable increment of 5.9 %. This increment is further increased when higher loading of AlN is used in a polyester matrix. With 40 wt. % of AlN, the combination delivers compressive strength of 89.8 MPa which is an increment of 23.35 %.

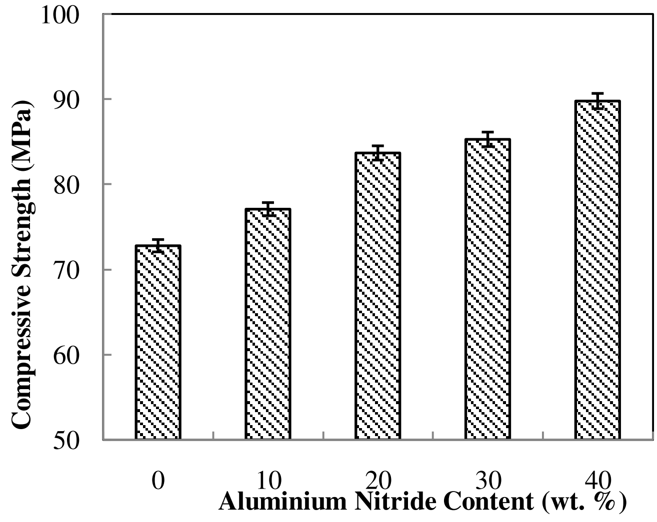

Fig. 5Compressive strength of polyester/AlN composites

D. *Micro-Hardness*

Figure 6 shows the variation in the value of hardness of the composite material for different content of aluminium nitride in the polyester matrix.

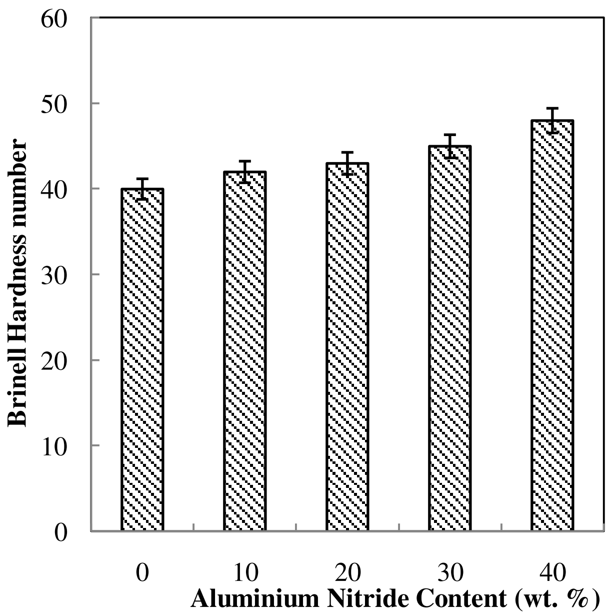

Fig. 6Micro-hardness of polyester/AlN composites

It can be seen from the figure that the incorporation of aluminium nitride particles imparts interesting changes in the value of hardness of the polyester matrix. It is evident from the figure that with the addition of fillers, the micro-hardness of the composites improved and this improvement is mainly a function of the filler content. The increment is obvious because of the high hardness value of AlN as compared to the polyester matrix. For 40 wt. % AlN content, hardness of the composite body increases from 48 Brinell hardness number against the virgin polyester having 40 Brinell hardness number which is an increment of 20 % over neat polyester.

IV. CONCLUSIONS

This experimental investigation has led to the following specific conclusions:

1) The tensile strength of polyester/AlN composites decreases with an increase in the content of AlN. The tensile strength of neat polyester is 33.5 MPa which reduces to 28.3 MPa for maximum filler loading of 40 wt. %. The tensile modulus of polyester/AlN composites increases with an increase in filler content. The tensile modulus of neat polyester is 1100 MPa which increases to 1321 MPa for polyester filled with 40 wt. %.
2) The flexural strength of polyester/AlN composites decreases with an increase in the content of AlN. The flexural strength of neat polyester is 40.6 MPa which reduces to 34.8 MPa for maximum filler loading of 40 wt. %. The flexural modulus of polyester/AlN composites increases with an increase in filler content. The tensile modulus of neat polyester is 1530 MPa which increases to 1854 MPa for polyester filled with 40 wt. %.
3) The compressive strength of the composites increases with an increase in filler content. The compressive strength of neat polyester is 72.8 MPa which increases to 89.8 MPa for a loading of 40 wt. %.
4) Micro-hardness of the composites improved by the incorporation AlN filler. For 40 wt. % AlN content, hardness increases from 40 Brinell hardness number to 48 Brinell hardness number.

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