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# Thermal Conductivity of Epoxy Compounds Enriched With Aluminium Nitride (Aln)

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## ABSTRACT

*Purpose of this thesis is Estimation of thermal conductivity of epoxy composites enriched with Aluminium Nitride(AlN) micro-fillers with analytical modeling. Thermal conductivity of epoxy composite is find out by measuring heat flow with the help of Unitherm TM Model. In analytical model, a mathematical model is developed to evaluate the effective thermal conductivity of the composites filled with fillers. The conductivity values measured and then compared with the analytical ones. These composites with AlN created and thermal conductivities of the samples were measured. Observations can be made with 25 % of volume AlN in epoxy matrix, thermal conductivity has elevated by 7 times while with 35% volume the thermal conductivity has elevated by 65 folds which is higher than epoxy matrix. A decision to draw from the measured values are in close to the proposed model upto fraction of 35 % of vol. at which quick rise is observed in the value of $K_{eff}$. This quick rise in effective thermal conductivity is because of overlap between filler particle which leads to the emergence of conductive chain. The % of volume after which this occurs is called percolation threshold.*

***Keywords : Epoxy Matrix, Thermal Conductivity, AlN***

## INTRODUCTION

In micro-electronic packaging, increasingly important integrate circuit plays role in the electronic and electrical technologies and also is source heat in circuits. The heat must be carried away quickly to avoid any breakage of elements, which requires that the materials used in electronic circuits should have good thermal conductivity besides having good electrical resistivity. These materials used for packaging must have low relative permittivity and low dielectric constant to reduce the heat transfer, which ultimately can provide better device performance.

The heat dissipation in microelectronic packaging which is more complex and integrated is highly required now-a-days. Conventional materials are incapable of giving intended results because low conductivity and high thermal expansion. Under this circumstance special thermal class materials are polymer composites. Polymer composites filled with particulate i.e polymers filled with highly conductive particulate are coming up to cope with such heat transfer issues with a cost effective way.

The imperative elements of the lattice are to exchange directional loads between the

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strengthening filaments/particles and to protect them from ecological harm though whereas the filaments/fillers in a composite enhances its physical properties, for example, quality, firmness and so forth. A composite is thusly a blend of more than one small scale constituents that vary in physical and chemical form and are insoluble in one another. The primary target is to exploit the predominant characteristics of both materials without trading off on the weak characteristics of either. Consequently in composites, materials are consolidated so as to empower us to improve utilization of their superior properties while diminishing some degree to the impacts of their inadequacies. This procedure of optimization can be advantageous for the imperatives related with the determination and assembling of ordinary materials. Making utilization of harder and lighter materials, with properties that can be mannered to suit specific prerequisites and on account of the strength with which complex shapes can be created, the complete of a built plan regarding composites can frequently prompt both less expensive and better arrangements. The properties of the composites depend essentially on volume fraction and type of fiber and/or molecule enriched in the lattice

## OBJECTIVE

The objectives of this work are given as follows:

- Fabrication of compounds filled with Aluminium nitride powder as the filler used for reinforcement with an aim of present work to improve the thermal properties of epoxy polymer compounds.
- Calculation of effective thermal conductivity (Keff) of these polymer compounds obtained experimentally.
- To study the effect of incorporation of micro sized AlN on the heat conductivity of epoxy.
- To validate the theoretical model by comparing the results with measured values.
- To identify the potential applications of these composite in relevant fields.

## MATERIALS AND METHODOLOGY

Metals, ceramics and polymers are most often used as matrix material for processing of composite. Most commonly used matrix material is polymer matrix since polymers are cheaper, easy to fabricate into complex part, show excellent properties at room temperature as compare to ceramic and metal matrix. Polymer matrix can be of two type viz. Thermoplastic and thermoset. Due to huge 3D cross link structure thermosets show good electrical insulation properties, outstanding thermal stability and better creep resistance.Keeping all above benefits in mind, for present model epoxy has been selected as matrix material.

### Analytical model analysis :

In analytical model, a cubical model of matrix material filled with reinforcement particulates is considered. The arrangement of thermal conductive sphere with various volume concentrations is assumed to be a network of thermal resistance consists of thermal resistors connected in series/parallel along the heat flow direction. The layer

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within the matrix which have no particulate filling and considering thermal contact resistance ($R_{int}$) in the model

***Rtotal= Rint + Σ Ri***

According to Fourier „s law of heat transfer , the heat flow rate across the element is

$$Q = K_{eff}\times a^{2}\times \ T/a = K_{eff}\times a\times \ T$$

where $K_{eff}$= effective conductivity of the composite a= side of the matrix cube

and the resistance of element is

$$R_{total}= 1/ K_{eff}\times a$$

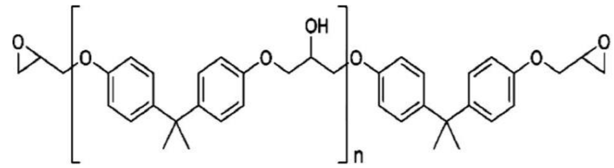
Considering thin layer of the spherical filler with thickness dy as long upward direction .

$$Qtotal=Qm + Qf$$

$Q_m$ and $K_m$= heat transfer and conductivity of matrix material $Q_f$ and $K_f$ = heat transfer and conductivity of filler material
Let side length of the matrix cube and particle radius is a & r respectively.
$Ø_f$= *volume fraction*

**Matrix Material:**

Epoxy is found in both liquid and solid form. Epoxy is formed by step growth polymerisation reaction between biphenol and epichlorohydrin. Thermal conductivity of epoxy alone is very low (0.363W/m. K).



Unmodified epoxy pre polymer resin chain.

**Filler material:-**

Aluminium Nitride (AlN) is a ceramic material that combines high thermal conductivity with high electrical resistivity. "Thermal conductivity" is the ability of a material to transfer heat on application of a temperature gradient across its surfaces. In AlN, heat transfer is through lattice vibrations in micro level. For heat dissipation applications, a high thermal conductive particle is needed to be reinforced with polymer material. The actual thermal conductivity is affected by factors that reduce the propagation of lattice vibration. Temperature distribution, impurities, particle size and distribution, grain size makes it a highly usable filler material for applications.

**Fabrication of composite by hand-lay-up method**

Effective thermal conductivity measurement of composite was done using Unitherm™ model 2022 tester. **ASTME-1530** standard is followed for this measurement.

**Operating principle of Unitherm-TM 2022:**

Test sample is held between two polished surfaced and compressive force applied to avoid any layer of air at interfaces. Temperatures different is applied across the test specimen. Heat flows from top, passes through the length of sample to bottom, and

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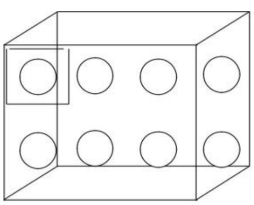
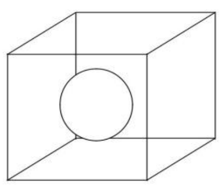
hence a temperature gradient is established along the length of the test specimen. Once the steady state is achieved temperature drop across the test sample is measured by temperature sensor. Thermal conductivity is then obtained.

## RESULTS AND DISCUSSION

## METHODOLOGY AND MODEL DEVELOPMENT :

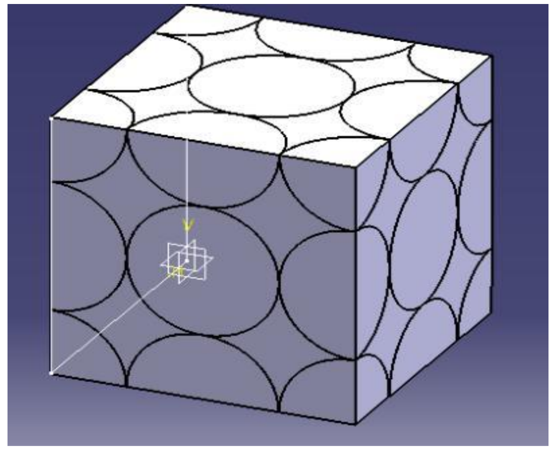
A particulate filled composite cube is shown in Figure 4.2 in 3-d model and a single element is taken under experiment for further study the heat transfer behavior as shown in Figure 4.3 compromising of the part of the matrix as a cube filled with a single spherical filler particle. The analysis carried out theoretically of the heat transfer in such a composite is based on the same assumptions that are taken for numerical analysis.



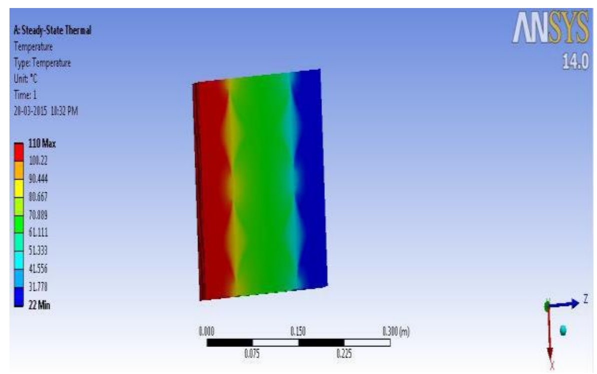


### Numerical Analysis

Here an ANSYS analysis is shown evaluating the temperature distribution of aluminium nitride filled epoxy composite in static thermal model. By taking different arrangemts of fillers in terms of volume fraction and assuming certain temperature along the side of the matric cube meshing is done. The heat flow is assumed to be uniform along the selected faces. Final model of temperature distribution is shown below.

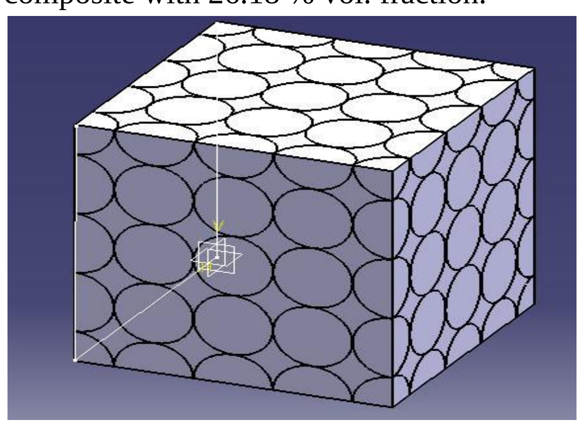


Analytical and ANSYS model of a epoxy cube filled with Aluminium




**Nitride Particulate**.

Volume fraction here is 26.18 %. Above shows the thermal distribution of epox composite with 26.18 % vol. fraction.



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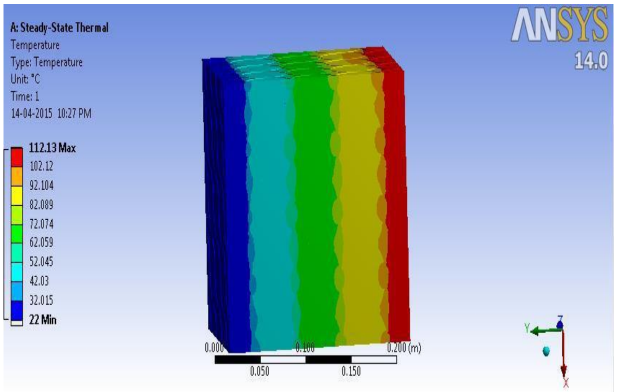


| SAMPLE NO. | VOL % OF AlN | Keff by analytical | Keff experiment | Error % |
|---|---|---|---|---|
| **1** | 0 | 0.463 | 0.34 | 5.2 |
| **2** | 18 | 3.13 | 1.92 | 28 |
| **3** | 32.16 | 32.86 | 21.33 | 41.6 |

## CONCLUSION

1.Successful manufacturing of ALUMINIUM NITRIDE filled epoxy polymer composite is possible by conventional Hand - layup method can be possible.

2.The expressions which have been developed in present work can be used to determine the effective thermal conductivity of composite material with different volume fractions.

3.The magnitude of effective thermal conductivity obtained from analytical model and that obtained from experimental investigation for various volume fractions are under agreement for volume percentage of particulate ranging from 0 to 32.16%.

4.Inclusion of AlN powder in epoxy polymer composite results in substantial increase in effective thermal conductivity of epoxy-AlN composite. For inclusion of 18 % of AlN by volume, effective thermal conductivity rises by 5 times. Similarly with the inclusion of 32.16 % of AlN by volume, corresponding increment in the effective thermal conductivity is found by 60 times.

5.This new developed epoxy-AlN composite can be employed for various applications like electronic packaging, glob top encapsulation, printed circuit board etc.

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