

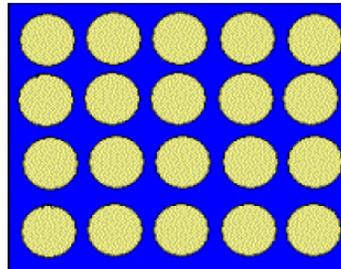
As per your suggestion I also try to calculate Thermal conductivity value. I had referred the Paper: **Effective Thermal Conductivity of Composite Solids** .

*Rayleigh's Derivation:*

$$\frac{k_{eff}}{k_0} = 1 + \frac{3\phi}{\left(\frac{k_1 + 2k_0}{k_1 - k_0}\right) - \phi + 1.569 \left(\frac{k_1 - k_0}{3k_1 - 4k_0}\right) \phi^{10/3} + \dots}$$

- Models heterogeneous solids for large volume fraction f as spheres embedded in the intersections of a cubic lattice

Figure 2: Spherical inclusions with a large volume fraction



**Notation:**

- $k_{eff}$ —effective thermal conductivity
- $k_1$ —thermal conductivity of embedded material
- $k_0$ —thermal conductivity of continuous phase
- $f$ —volume fraction of embedded material

The effective thermal conductivity for a composite solid depends on the geometry assumed for the situation.

If I follow the same procedure for my calculation Thermal conductivity value is increasing. But , for my simulation work I should use my continuous material as PMMA in cylindrical phase and Embedded material in spherical form. So the formula specified above is entirely different because of the Geometry is different. By using Comsol 4.3a I thought to calculate thermal conductivity value for different volume fraction of ALN material.

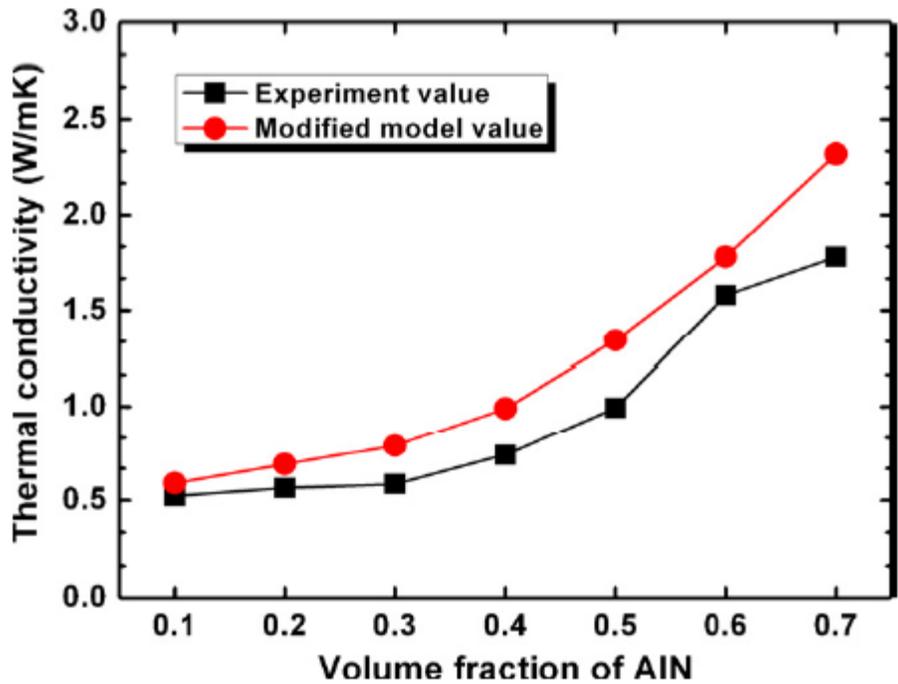


Fig. 6. Comparison of the experimental and simulation modified model values of the thermal conductivity from different volume fraction of the AlN/PMMA composites.

In the above fig.6 while using comsol software only , they calculated the thermal conductivity value for the corresponding volume fraction of ALN/PMMA and compared with their experiment work.

I am also looking for the similar kind of graph plot while using the comsol heat transfer module. I had a doubt- How to apply this volume fraction(VF) formula/ corresponding value in the model? How to plot the graph exactly between VF and Thermal Conductivity (ref. fig.6)? I am following one procedure for volume fraction value, could you tell is it correct or not?

In the paper they mentioned cylinder (i.e PMMA) radius=6.35mm , height of the Cylinder=2mm.

From that information I had calculated volume of cylinder =  $\pi \cdot r^2 \cdot h$

$$\text{volume of cylinder} = (3.14) \cdot ((6.35)^2) \cdot (2) \quad [\text{mm}^3]$$

$$\text{volume of cylinder} = 253 [\text{mm}^3] \quad \text{----- (1)}$$

**For calculating 1% volume fraction of ALN in PMMA**

I had calculated 1% volume of cylinder = volume of sphere(i.e ALN).

$$1\% \text{ volume of cylinder} = (4/3) \cdot (\pi) \cdot (r^3) \quad \text{----- (2)}$$

(from (1) , 1% volume of cylinder = 2.53 [mm<sup>3</sup>] ) -----(3)

Substitute (3) in (2),

$$2.53 \text{ [mm}^3\text{]} = (4/3) * (\pi) * (r^3)$$

By solving above equation we get radius of sphere,

$$r = 0.84 \text{ mm.}$$

**Could you help me whether I am following the correct procedure for applying volume fraction ratio or not ???**

**2<sup>nd</sup> Doubt**- Author mentioned ALN avg. particle size should be less than 5µm. I had constructed PMMA in mm dimension and if I need to construct ALN in µm its not visible in GUI because of 10<sup>-3</sup> dimension is very small. So I had constructed one Sphere for 1% volume of cylinder for my simulation and the thermal conductivity value which I got (8.3899\*10<sup>7</sup>)[(m<sup>4</sup> \*kg)/(s<sup>3</sup> \*K)] but we suppose to get 0.55[W/mK](see fig.6).

Basic properties of aluminum nitride powder (AlN) and polymethyl methacrylate (PMMA).

Materials	Density (g/cm <sup>3</sup> )	Average particle size (µm)	Thermal conductivity (W/(m K))	Coefficient of thermal expansion (1/°C)	Dielectric Constant (1 MHz)	Electrical resistivity (Ω cm)
AlN	3.235	<5	320	4 × 10 <sup>-6</sup>	8.7	>10 <sup>14</sup>
PMMA	0.18	-	0.18	82 × 10 <sup>-6</sup>	3.2	>10 <sup>16</sup>

And Is there any other way to apply in comsol 4.3a for calculating thermal conductivity and putting Volume fraction values/formula and get the plot between thermal conductivity and Volume fraction.