Analysis of GNP based composite materials

A review on the application of various GNP-Rubber composite materials in high temprature applications

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Abstract - *Graphite Nano platelets (GNP) are wonder molecules that are used to make polymers with Fluoroelastomer, like all carbon based materials they have a tendency to improve the conductivity of material as the amount of GNP in the polymer increases, but it is keen to observe that at small levels not only the effect that GNP induces in the conductivity of material is minimal but also that it improves the strength of the material exponentially and as a result will improve its durability.*

***Key Words*: Graphite, Nanoplatelets; polymer, conductivity, durability etc.**

1. INTRODUCTION

The whole field of polymer science came about with the contribution of various folks from DuPont, with time various compounds were developed at DuPont from the early 40's but it took them two decades to find a polymer that is suitable for the industry. Polymers find a wide range of application in many industries but it is even more curious to note that they are the most common industrial sealants in use.

Polymers are used to make seal for sealing of tubes in chemical, petroleum industries, sealing reactors, sealing combustion chambers and so on. The paper here deals with the use of various polymers in heat sealing applications and also to determine the best materials for the same. Here we have compared the work of various researchers' so as to get an idea of the most suitable polymer composite for this application. Here we have chosen Graphite Nano platelets as the filler material and the purpose of this paper is to determine the best suitable material or substrate into which the GNP can be polymerized to produce good and durable heat sealants.

For the paper we have chosen Silicone rubber, epoxy, Fluoroelastomer (FKM).

2. EXPERIMENTAL DETAILS

2.1 GRAPHITE NANOPLATELETS

Graphite Nano platelets (GNP) are a form of Nano particulate form of carbon. They are basically stacks of Graphene. They are 1 to 15 thick stacks with diameters in the range from sub micrometer to a few 100 micrometers.[2]

GNP is a short bulk of single graphite layer called graphene. They are cost effective and it usually improves the tensile modulus of composite material [1]. They offer different geometric properties since they are a function of size and atomic number. Modification in specific surface area and aspect ratio may occur significantly because of its properties. The property improvement is induced with lower amount of Nano filler having good dispersion. Moreover GNP has good surface adhesion properties as a result polymerization is much easier. [7]

Sometimes problems in dispersion may occur because the large surface area of the GNP that causes an increase in van der Waals forces and strong π–π interaction, and hence induces in very thin Nano platelets a tendency to self-roll, also it has a relatively low specific surface area of 120–150 m2/g, due to which dispersion problems may occur [3].

2.2 Silicone Rubber

Silicone rubbers are often one- or two-part polymers, and may contain fillers to improve properties or reduce cost. Silicone rubber is generally non-reactive, stable, and resistant to extreme environments and temperatures from -55 °C to +300 °C while still maintaining its useful properties. Due to these properties and its ease of manufacturing and shaping, silicone rubber can be found in a wide variety of products, including: automotive applications; cooking, baking, and food storage products; apparel such as undergarments, sportswear, and footwear; electronics; medical devices and implants; and in home repair and hardware with products such as silicone sealants.

Silicone rubber (methyl-vinyl-silicone, MVQ 110-2) was purchased from Dongjue Silicone Group Co., Limited, China. It has average molecular weight Mw = 6.5 × 105, and contains 0.17 mol% vinyl groups on backbone chain.[1]

2.3 FKM

A fluoroelastomer (FKM) is a purpose synthetic rubber derived from fluorocarbon based synthetic rubber. It is seen that FKM has wide chemical resistance and superior performance, especially in high temperature application in different media.

Fluoroelastomer [Tecnoflon FOR 532, specific gravity1.81, Mooney viscosity (ML 1+10 at 1210C ; 45)] medium viscosity bisphenolic cured copolymer was procured from Synthetic and chemicals limited, Barielly, UP, India[2].

2.4 EPOXY

Epoxy resins, also known as polyepoxides, are a class of reactive prepolymers and polymers which contain epoxide groups. Epoxy resins may be reacted (cross-linked) either with themselves through catalytic homo polymerization, or with a wide range of co-reactants including poly functional amines, acids (and acid anhydrides), phenols, alcohols and thiols. These co-reactants are often referred to as hardeners or curatives, and the cross-linking reaction is commonly referred to as curing. Reaction of polyepoxides with themselves or with polyfunctional hardeners forms a thermosetting polymer, often with high mechanical properties, temperature and chemical resistance. Epoxy has a wide range of applications, including metal coatings, use in electronics / electrical components/LED, high tension electrical insulators, fiber-reinforced plastic materials and structural adhesives.

Epoxy resins are extensively used as coatings, adhesives, structural material, and composite matrix. Epoxy resin is naturally brittle, which make it susceptible to micro-cracks produced in service. Extensive research has been employed for the toughness of epoxy resin using rubbers, thermoplastics, and inorganic particles. Considerable amount of toughener (15–20 wt%) is required in rubber and thermoplastic toughening methods which causes loss of other desirable properties.[3]

2.5 Thermo gravimetric Machine

Thermo gravimetric analysis machine is a high degree of precision instrument. Therefore, the instrument has a pan balanced with very high precision, and a programmable furnace. The furnace can be programmed either for a constant heating rate, or for heating to acquire a constant mass loss with time.

The furnace is a small electrical furnace equipped with a thermocouple to monitor accurate measurements of the temperature by comparing its voltage output with that of the voltage-versus-temperature table stored in the computer's memory.

A reference sample can be placed on a similar balance that is placed inside a separate chamber. The atmosphere in the chamber is replaced with an inert gas to prevent oxidation or other unexpected side effects.

3. PROCEDURE

The method of preparation by each individual researcher is different, while polymerizing each researcher followed their own methods to make the polymer. But the method of manufacture has very minimal effect on property determination since most researchers have ensured that there is a uniform distribution of materials in the composite.

3.1 Thermo gravimetric Analysis

It is a unique method of thermal analysis where even the slightest change in physical and chemical properties of materials is measured as a function of increasing temperature, or time. It can also find details regarding physical phenomenon like sublimation vaporization and also chemical phenomenon like solid gas reaction, decomposition etc.

It is commonly used to determine selected characteristics of materials that exhibit either mass loss or gain due to decomposition, oxidation, or loss of volatiles. It is an especially useful technique for the study of polymers, like thermoplastic, elastomer, etc.

TGA can be used to evaluate the thermal stability of a material. In a desired temperature range, if a species is thermally stable, there will be no observed mass change. Negligible mass loss corresponds to little or no slope in the TGA trace. TGA also gives the upper use temperature of a material. Beyond this temperature the material will begin to degrade. Thus we compare the effect of temperature on the composite material and hence determine its suitability as sealant in high temperature applications.

The TGA instrument continuously weighs a sample as it is heated to temperatures of up to 2000 °C for coupling with FTIR and mass spectrometry gas analysis. As the temperature increases, various components of the sample decompose and the weight percentage of each resulting mass change can be measured. Results are plotted with temperature on the X-axis and mass loss on the Y-axis. The data can be adjusted using curve smoothing and first derivatives are often also plotted to determine points of inflection for more in-depth interpretations.

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4. RESULTS AND DISCUSIONS

The experiments were performed as mentioned above and following TGA graphs were plotted.

4.1 Epoxy GNP Composite

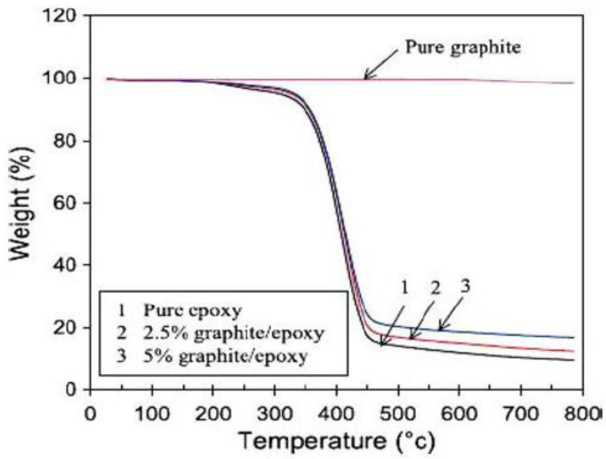

Fig 1: TGA curve of Epoxy GNP composite

TGA curve of pure epoxy and its composite with different graphite content are shown in Figure 4. Thus, reduction in thermal conductivity occurs at 0.3 wt%, which is also the electrical percolation threshold. The sudden increase in thermal conductivity was observed between 0.3 and 0.5 wt%. Interfacial layers were also created by the addition of filler in matrix, where reduction of heat flow occurred by phonon scattering. When filler content was 0.3 wt% this effect was dominant. Volume of filler when increased further than 0.3 wt% caused high thermal conductivity.

A reasonable explanation for larger raise of thermal conductivity of epoxy/GNP composite was the high intrinsic thermal conductivity of GNPs and increasing filler content. It has been acknowledged that the thermal conductivity of polymeric composite was mechanistically limited by polymer- filler interfacial thermal resistance.[3]

4.2 FKM GNP Composite

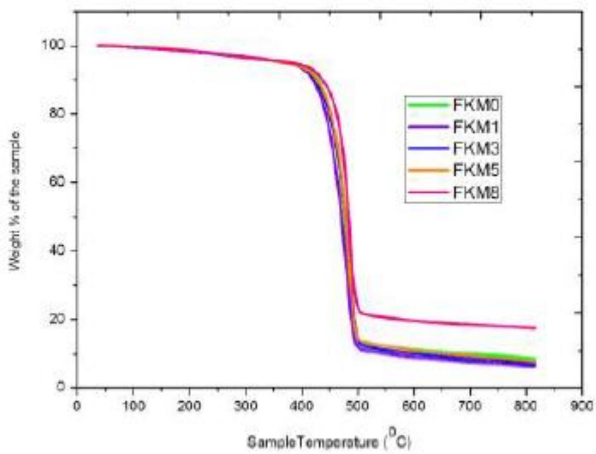

Fig 2: TGA curve FKM-GNP composite.

Thermo-gravimetric analysis gives the weight percentage of sample corresponding to the variation in temperature. The weight of the sample corresponding to the temperature is shown in the Fig 5. It is evident from the graphs that FKM 8 exhibits greater thermal resistance and is highly durable.[2]

4.3 Silicone Rubber GNP composite

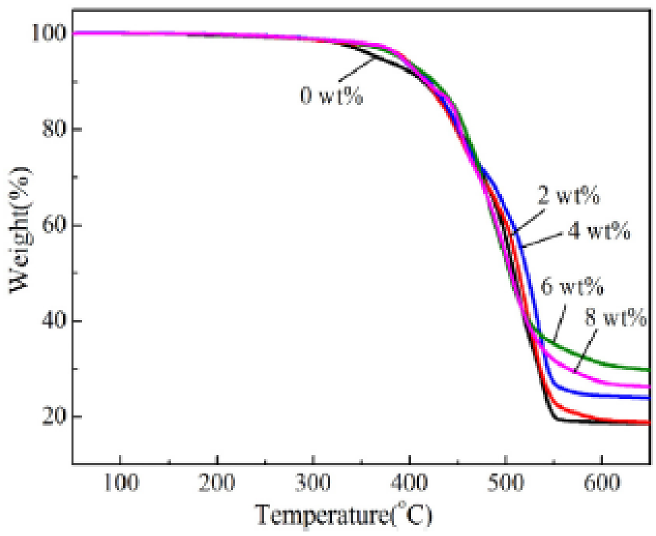

Fig 3 :TGA curve of Silicone GNP composite.

To study the thermal stability of the composites with different contents of GNP by weight is investigated by plotting TGA. The TGA curves are displayed in Fig. 9 at various wt% of GNP. The improvement of thermal stability of the composites filled with the GNP filler is due in part to the formation of a carbon char that acts as a barrier/isolator between the polymer's bulk and its surface, where heat is supplied. The results of TGA reveal the positive influence of GNPs on the thermal stability of the composites

The reason could be conducted as follows:

(i) The GNPs when heated forms a small layer of carbon, which prevents the transfer of mass and heat

(ii) GNP's have functional groups on their surfaces, the adhesion between GNPs and silicone rubbers restricted the motion of composite molecules towards the bulk from the surface.

Thus TGA curve illustrates the positive effect GNP has on silicone rubber. [1]

4.4 Silicone Rubber vs Polypropylene

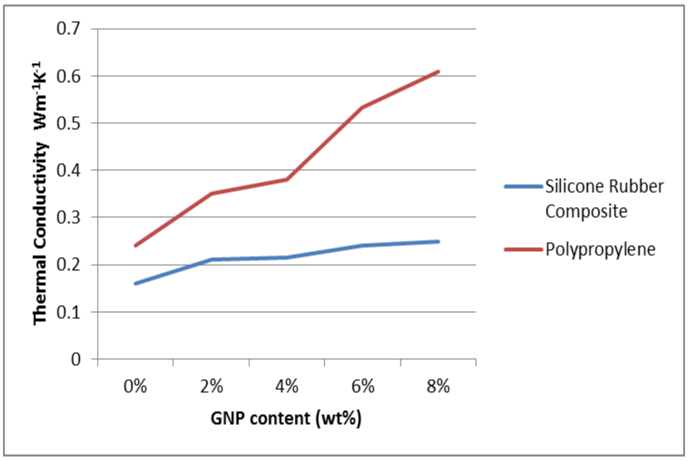

Fig 4 : Comparison of thermal conductivity of silicone rubber and polypropylene

From the above results it is evident that silicone rubber is a more favorable option in the use as a sealant in high temperature applications, based on the TGA curve analysis and hence a comparative study was done to determine the suitability of silicone rubber as a viable replacement of Polypropylene which is at present the most commonly used compound in high temperature applications [6].

5. CONCLUSIONS

The presence of GNP in the composite material has a tendency of improving the thermal conductivity of the material. This is because GNP or Graphite Nano platelets are derived from graphite which is a good conductor of heat and electricity; moreover it is similar to Carbon Nano Tube which is also a good conductor of heat and electricity.

This is the reason why GNP is a good conductor of heat and electricity. The composite material exhibits superior mechanical and high heat conductivity or negligible insulation property when compared to its base rubber at small quantities. It is seen that GNP will provide necessary reinforcing centers throughout the bulk of the matrix and also as a conduit for conduction virtually linking both the surfaces of the material to enable heat conduction.

At the same time it is also noted that GNP in small quantities provide the necessary reinforcing effects which is required of the composite but also there is minimal deviation from the conductivity of the base rubber which is desired and hence it is desired to make a composite material with very less GNP content so as to produce a composite with sufficient strength and negligible heat conductivity.

Hence from the result it is clear that silicone rubber exhibits the required behavior and hence it is required to produce a composite material with silicone rubber and 3% by wt. of GNP.

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REFERENCES

[1] Yingze Song, Jinhong Yu, Fakhr E, Alam, Wen Dai, Chaoyang Li,Nan Jiang, "Enhancing the thermal,electrical, and mechanical properties of silicone rubber by addition of graphene nanoplatelets", Materials and Design 88 (2015) pp 950–957.

[2] Anoop P, Dr. Soney C. George, Jithin Devasia, "Development and performance analysis of FKM-GNP nanocomposite material for critical engineering Application" in in Nation conference titled " ATATIME" in Caarmel Engg: College

[3] Zanib Anwar, Ayesha Kausar, Irum Rafique & Bakhtiar Muhammad, "Advances in Epoxy/Graphene Nanoplatelet Composite with Enhanced Physical Properties: A Review", Polymer-Plastics Technology and Engineering, 2016, VOL. 55, NO. 6, pp.643–662.

[4] Nasir, A.; Kausar, A.; Younus, "A. Polymer/graphite nanocomposites: Physical features, fabrication and current relevance." Polym. Plast. Technol. Eng. **2015**, *54*, 750–770.

[5] Bryning, M.B.; Islam, M.F.; Kikkawa, J.M.; Yodh, A.G.,"Very low conductivity threshold in bulk isotropic single-walled carbon nanotube-epoxy composites".Adv. Mater. **2005**, *17*, 1186–1191.

[6] K. Kalaitzidou, H. Fukushima and L. T. Drzal, "Multifunctional nanocomposites made of Polypropylene Reinforced with Exfoliated Graphite Nanoplatelets (xGnP)" NSTI-Nanotech 2006,vol 2 837-840

[7] Geim A.K.,Novoselov K.S., "The rise of graphene" Nat. Materials.2007,6,183-191.