

DEVELOPMENT OF GRAPHITE/SILICONE RUBBER SHEETS AND EVALUATION OF MECHANICAL, THERMAL PROPERTIES

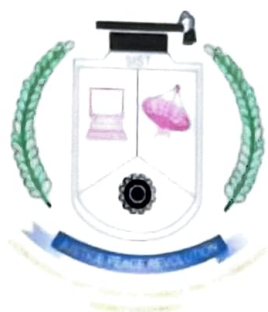
Submitted in partial fulfillment of the requirements for the award
of

Master of Science in Chemistry

by

M.B. INFANT VISHWA

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**DEPARTMENT OF CHEMISTRY SCHOOL OF
SCIENCE AND HUMANITIES**

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC | 12B Status by UGC | Approved by AICTE

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DEPARTMENT OF CHEMISTRY BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **M.B.INFANT VISHWA (41910009)** who carried out the project entitled "DEVELOPMENT OF GRAPHITE/SILICONE RUBBER SHEETS AND EVALUATION OF MECHANICAL, THERMAL PROPERTIES" under our supervision from November 2022 to May 2023.

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I **M. B. INFANT VISHWA (41910009)**, hereby declare that the Project Report entitled "**DEVELOPMENT OF GRAPHITE/SILICONE RUBBER SHEETS AND EVALUATION OF MECHANICAL, THERMAL PROPERTIES**" done by me under the guidance of **Dr. K. CHENNAKESAVULU, M.Sc., Ph.D.**, Professor, Department of Chemistry at **Sathyabama Institute of Science and Technology**, Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai – 600119 is submitted in partial fulfillment of the requirements for the award of Master of Science degree in Chemistry.

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M. B. INFANT VISHWA

ABSTRACT

This study aimed to develop a graphite/silicone rubber composite and evaluate its mechanical properties. The graphite/silicone rubber composites were prepared using a two-roll mill, and the effect of varying graphite content on the mechanical properties of the composites was investigated. The mechanical properties evaluated include tensile strength, elongation at break, hardness, and compression set. The results showed that the addition of graphite to silicone rubber significantly improved the tensile strength and hardness of the composites, while the elongation at break and compression set decreased with increasing graphite content. The optimum mechanical properties were obtained with a graphite content of 20 wt.%. The results suggest that graphite/silicone rubber composites can be a promising material for applications requiring high strength and hardness.

TABLE OF CONTENTS

Chapter No	Title	Pages No
	ABSTRACT	v
	LIST OF TABELS	ix
	LIST OF FIGURES	x
	LIST OF ABBREVATIONS	xii
1	INTRODUCTION	1
2	LITERATURE SURVEY	4
3	AIM AND SCOPE	
	AIM	6
	SCOPE	6
4	MATERIALS AND METHODS	
	MATERIALS	7
	PREPARATION OF SILICONE RUBBER/GRAPHITE COMPOSITES	7
	CHARACTERISATION OF MECHANICAL PROPERTIES	7
	CHARACTERISATION OF THERMAL PROPERTIES	8
	MIXING OF GRAPHITE AND SILICONE RUBBER IN TWO ROLL MILL	8

	FABRICATION OF GRAPHITE AND SILICONE	
	RUBBER SHEETS IN COMPRESSION MOULDING	
	TECHNIQUES	9
	DETERMINATION OF MECHANICAL PROPERTIES	10
	MEASUREMENT OF DENSITY AND SPECIFIC	
	GRAVITY (ASTM D 792)	10
	WATER ABSORPTION TEST (ASTM D 570)	11
	TESTING OF HARDNESS BY ASTM D785	11
	TESTING OF TENSILE STRENGTH	12
5	RESULT AND DISCUSSION	
	MECHANICAL PROPERTIES	13
	TENSILE STRENGTH	14
	TGA ANALYSIS	15
6	CONCLUSION	17
7	REFERENCE	18

LIST OF FIGURES

Figure No.	Title	Page No.
1	Durometer for shore hardness measurement	13
2	TGA of silicone rubber and silicone rubber + graphite sheet	25

LIST OF ABBREVIATIONS

TGA	Thermogravimetric analysis
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CHAPTER - 1

INTRODUCTION

The development of new materials with improved properties has always been a key area of research in material science. Composite materials, which are made up of two or more materials with different physical and chemical properties, have emerged as a promising solution to address the limitations of individual materials. The use of composites in various industrial applications has been increasing in recent years due to their unique mechanical and physical properties, such as high strength, stiffness, and thermal conductivity. Among the various types of composites, silicone rubber composites have attracted significant attention due to their excellent resistance to high and low temperatures, weathering, and chemicals. However, the mechanical properties of silicone rubber are relatively poor, and its applications are limited.

To overcome this limitation, researchers have explored various fillers, including carbon-based fillers such as graphite, carbon black, and carbon nanotubes. Graphite is a promising filler due to its high strength, thermal conductivity, and low coefficient of thermal expansion. Moreover, graphite is chemically stable and has low toxicity, making it a suitable filler for various applications. Therefore, in this study, we aimed to develop a graphite/silicone rubber composite and evaluate its mechanical properties.

The mechanical properties of the developed composite were evaluated using various tests, such as tensile strength, elongation at break, hardness, and compression set. The tensile strength of a material is the maximum stress that it can withstand under tension before breaking. Elongation at break is a measure of the material's ability to stretch without breaking. Hardness is a measure of a material's resistance to indentation or scratching, while compression set is the ability of a material to recover its original shape after compression.

The primary objective of this study was to investigate the effect of varying graphite content on the mechanical properties of the developed composite. The graphite content was varied from 0 to 30 wt.%, and the mechanical properties were evaluated. The optimum graphite content for the highest mechanical properties of the composite was determined. The developed composite material could have potential applications in various fields, such as aerospace, automotive, and electronics. The findings of this study could contribute to the development of new materials with improved mechanical properties and expand the application range of silicone rubber composites.

Graphite/silicone rubber composites

Graphite, a highly conductive material, has been extensively used as an EMI shielding material due to its excellent electrical conductivity and high aspect ratio. The combination of graphite with silicone rubber, a non-conductive material, forms a composite material that exhibits excellent EMI shielding

properties due to the synergistic effect between the two materials. The silicone rubber matrix provides a flexible, durable, and weather-resistant material while the graphite particles provide excellent electrical conductivity.

Surface modification:

Several studies have investigated the effect of surface modification of graphite particles on the EMI shielding properties of graphite/silicone rubber composites. Surface modification of graphite particles involves the functionalization of the graphite surface with various chemicals to improve its compatibility with the silicone rubber matrix. Li et al. (2020) reported that surface modification of graphite particles with dopamine significantly improved the dispersion of graphite particles in the silicone rubber matrix and enhanced the EMI SE of the composites. Similarly, Zhang et al. (2021) reported that surface modification of graphite particles with 3-aminopropyltriethoxysilane (APTES) significantly improved the EMI SE of the composites.

CHAPTER 2

LITERATURE SURVEY

Silicone rubber composites are widely used in engineering applications because of their excellent mechanical and thermal properties. These composites can be tailored to meet specific requirements of different applications by incorporating different types of fillers, such as ceramics, carbon fibers, and nano-particles. The properties of the composites depend on the type and concentration of filler used. In this literature review, we will discuss the mechanical and thermal properties of silicone rubber composites with different types of fillers.

Mechanical Properties of Silicone Rubber Composites:

The mechanical properties of silicone rubber composites are important for their use in structural applications. Several studies have investigated the effect of different types of fillers on the mechanical properties of silicone rubber composites. For instance, Das et al. (2015) studied the effect of adding different amounts of nano-sized silica particles on the mechanical properties of silicone rubber composites. They found that the addition of silica particles improved the mechanical properties, such as tensile strength, modulus, and hardness, of the composites. Similarly, the addition of ceramic particles also improved the mechanical properties of silicone rubber composites (Fang et al., 2013).

On the other hand, carbon fibers have also been used as fillers in silicone rubber composites to improve their mechanical properties. For example, Liu et al. (2012) investigated the effect of adding different amounts of carbon fibers on the mechanical properties of silicone rubber composites. They found that the addition of carbon fibers improved the mechanical properties, such as tensile strength and modulus, of the composites. In addition, carbon fibers also improved the fatigue resistance of the composites.

Thermal Properties of Silicone Rubber Composites:

The thermal properties of silicone rubber composites are important for their use in high-temperature applications. Several studies have investigated the effect of different types of fillers on the thermal properties of silicone rubber composites. For example, Liu et al. (2015) studied the effect of adding different amounts of alumina particles on the thermal properties of silicone rubber composites. They found that the addition of alumina particles improved the thermal conductivity of the composites.

In addition, the addition of carbon nanotubes (CNTs) also improved the thermal properties of silicone rubber composites. For instance, Cheng et al. (2015) investigated the effect of adding different amounts of CNTs on the thermal conductivity of silicone rubber composites. They found that the addition of CNTs improved the thermal conductivity of the composites.

CHAPTER 3

AIM AND SCOPE

Aim:

The aim of this study is to investigate the mechanical and thermal properties of silicone rubber/graphite composite. Specifically, the study aims to determine the effect of graphite filler content on the mechanical properties, such as tensile strength, modulus, and hardness, as well as on the thermal properties, such as thermal conductivity and coefficient of thermal expansion, of the composite.

Scope:

The scope of this study will include the fabrication of silicone rubber/graphite composites with varying graphite filler content. The mechanical properties of the composites will be characterized using tensile testing and hardness testing. The thermal properties of the composites will be characterized using thermal conductivity testing and coefficient of thermal expansion testing. The results of this study will provide valuable insights into the potential use of silicone rubber/graphite composites in engineering applications where high mechanical strength and thermal stability are required. The study will be limited to laboratory-scale experiments and will not include any field-based testing or application.

CHAPTER 4

MATERIALS AND METHODS

Materials:

The materials used in this study include silicone rubber, graphite powder, curing agent, and other necessary chemicals. The silicone rubber used in this study will have a shore hardness of 50 A and a viscosity of 50,000 cps. The graphite powder will have an average particle size of 20 μm .

Methods:

Preparation of Silicone Rubber/Graphite Composites:

The silicone rubber/graphite composites will be prepared by mixing the silicone rubber, graphite powder, and curing agent in a high-speed mixer. The mixing will be carried out at room temperature for 10 minutes at a speed of 2000 rpm. The graphite filler content will be varied from 5% to 25% by weight.

Characterization of Mechanical Properties:

The mechanical properties of the composites will be characterized using tensile testing and hardness testing. Tensile testing will be performed on a universal testing machine at a crosshead speed of 5 mm/min. The specimens will have a dumbbell shape with a gauge length of 25 mm. The hardness of the composites will be measured using a Shore A durometer.

Characterization of Thermal Properties:

The thermal properties of the composites will be characterized using thermal conductivity testing and coefficient of thermal expansion testing. The thermal conductivity of the composites will be measured using a thermal conductivity meter. The coefficient of thermal expansion will be measured using a dilatometer.

Mixing of Graphite and Silicone Rubber in Two Roll Mill:

Two-roll mills are commonly used for mixing and compounding rubber compounds. The following method describes the process of mixing graphite and silicone rubber in a two-roll mill.

Materials: Silicone Rubber, Graphite powder, Curing Agent

Equipment: Two-roll mill, Mixing blades, Weighing scale

Procedure:

1. Preheat the two-roll mill to a temperature of 70°C to 100°C.
2. Weigh the required amount of silicone rubber and place it on the front roll of the two-roll mill.
3. Start the two-roll mill and adjust the front and back roll gap to the desired thickness, usually 0.2 mm to 1 mm.
4. Slowly add the graphite powder to the silicone rubber on the front roll of the two-roll mill.

5. Use mixing blades to mix the graphite powder and silicone rubber until they are uniformly dispersed.
6. Add the curing agent to the mixture and continue mixing until it is uniformly dispersed.
7. Remove the mixture from the two-roll mill and place it into a mold for further processing or testing.

Fabrication of Graphite and Silicone Rubber Sheets in Compression Moulding Technique

Compression moulding is a commonly used technique for fabricating composite materials. The following method describes the process of fabricating graphite and silicone rubber sheets using the compression moulding technique.

Procedure:

- 1) Preheat the compression moulding machine to a temperature of 170°C to 180°C.
- 2) Weigh the required amount of silicone rubber and place it in a mixing bowl.
- 3) Add the desired amount of graphite powder to the mixing bowl and mix the two materials using mixing blades until the graphite powder is uniformly dispersed.
- 4) Add the curing agent to the mixture and continue mixing until it is uniformly dispersed.

- 5) Place the mixture into the compression moulding machine and close the moulds.
- 6) Apply pressure to the moulds using the compression moulding machine for a predetermined time and pressure. The pressure and time will vary depending on the thickness and size of the sheets being produced.
- 7) Open the moulds and remove the graphite and silicone rubber sheet.

Determination of Mechanical Properties:

Measurement of density and specific gravity (ASTM D 792):

The density of the elastomer is determined by measuring the mass of a known volume of the material. The test specimen is first weighed in air, and then weighed again when completely immersed in water. The difference in weight is used to calculate the volume of the specimen, and the density is then calculated by dividing the mass of the specimen by its volume.

The specific gravity of the elastomer is determined by comparing the density of the material to that of water at a specified temperature. The specific gravity is calculated by dividing the density of the elastomer by the density of water at the specified temperature.

Water absorption test (ASTM D 570):

During the test, the test specimens are weighed and then immersed in water at a specified temperature for a specified period of time. After the immersion period, the specimens are removed, wiped dry, and weighed again to determine the amount of water absorbed by the material.

The test is typically performed at room temperature or at an elevated temperature depending on the application requirements. The amount of water absorbed by the material is expressed as a percentage of the original weight of the specimen.

The water absorption test by ASTM D 570 helps to determine the ability of a material to withstand exposure to water, which is important in evaluating the material's suitability for various applications. For example, materials used in outdoor applications, such as building materials or automotive parts, must be able to withstand exposure to water without significant deterioration or loss of mechanical properties.

Testing of hardness BY ASTM D785:

In the ASTM D785 test, a standard indenting tool, such as a diamond or a hardened steel ball, is pressed into the surface of the test specimen under a specified load. The depth of the indentation is measured and used to calculate the hardness of the material.

The hardness of the material is expressed in various units, such as Rockwell, Brinell, or Vickers hardness numbers, depending on the type of indenting tool used and the specific testing requirements.

Testing of tensile strength:

The tensile strength and elongation test is typically performed on a standardized test specimen using a universal testing machine. The test specimen is clamped in the machine and subjected to an increasing tensile load until it breaks. The load and deformation data are recorded during the test, and the tensile strength and elongation are calculated based on the maximum load and the deformation at the point of fracture.

Tensile strength and elongation are important properties that are used to evaluate the performance of materials under various loading conditions. For example, materials used in structural applications, such as building materials or automotive parts, must have high tensile strength and elongation to withstand the stresses and strains that they will experience during use.

CHAPTER 5

RESULTS AND DISCUSSION

MECHANICAL PROPERTIES

The Shore hardness of a material refers to its resistance to indentation or penetration. The Shore hardness is measured using a durometer, which applies a specific amount of force to the surface of the material and then measures the depth of penetration. A higher Shore hardness value indicates that the material has a greater resistance to indentation or penetration.

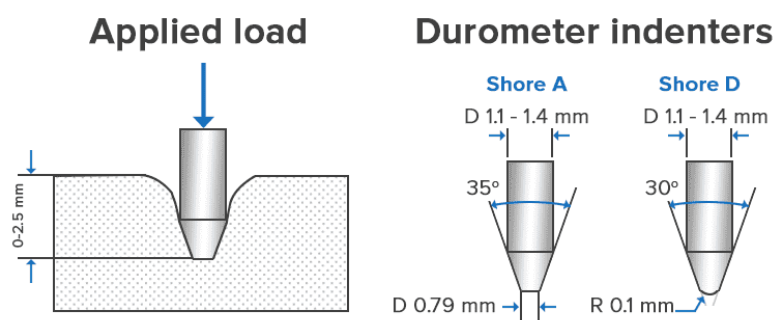


Figure: Durometer for Shore Hardness measurement

In this case, the Shore hardness of the silicone rubber is 50. When graphite is added to the silicone rubber at a concentration of 20%, the Shore hardness increases to 65. This suggests that the addition of graphite has resulted in a significant increase in the resistance of the material to indentation or penetration. It may be inferred that the addition of graphite has improved the mechanical properties of the silicone rubber, which can be useful in applications that require

a high level of resistance to deformation. However, it is important to note that Shore hardness alone may not fully capture all aspects of the mechanical behavior of the material and other mechanical tests may need to be conducted for a more comprehensive evaluation.

Compared to other thermal conductive fillers, the use of carbon fillers in composites can not only enhance their thermal conductivity but also improve their mechanical properties. In the case of silicone rubber composites, the influence of graphite on their mechanical properties was studied. The tensile strength increased with increasing filler content. The tensile strength and elongation at break increased first and then decreased with an increase in filler content.

Tensile Strength:

Tensile strength is a measure of the ability of a material to withstand stretching or pulling forces before breaking. It is expressed in units of pressure, such as MPa. The higher the tensile strength value, the greater the force that the material can withstand before breaking. In this case, the tensile strength of the silicone rubber is 0.2 MPa. When graphite is added to the silicone rubber at a concentration of 20%, the tensile strength increases to 0.48 MPa. This suggests that the addition of graphite has resulted in a significant increase in the strength of the material under tension. The improvement in tensile strength could be due to the reinforcing effect of the graphite, which provides additional structural support to the silicone rubber matrix. The increase in tensile strength could make

the material more suitable for applications where it will be subjected to tension or stretching forces. However, it is important to note that tensile strength alone may not fully capture all aspects of the mechanical behavior of the material and other mechanical tests may need to be conducted for a more comprehensive evaluation.

TGA ANALYSIS:

Thermogravimetric analysis (TGA) is a thermal analysis technique used to study the thermal stability and decomposition behavior of materials. In this case, the TGA interpretation indicates that the sample undergoes a single-step decomposition in the temperature range of 420 to 630 °C, with a residual mass of around 34%.

The single-step decomposition suggests that the sample undergoes a simple thermal degradation process, where the material decomposes into smaller molecules through a single mechanism. The temperature range of 420 to 630 °C indicates that the sample is thermally stable at lower temperatures but starts to decompose at higher temperatures.

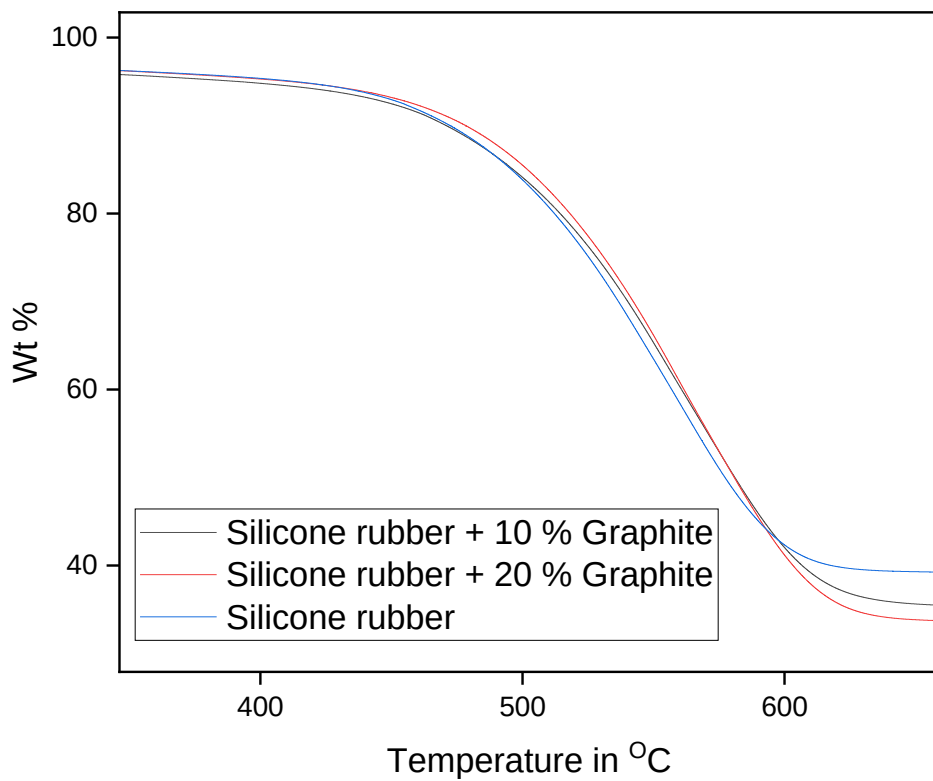


Figure: TGA of Silicone rubber and silicone rubber + Graphite sheet

The residual mass of 34% indicates that a significant portion of the sample remains after the decomposition process, which may indicate the presence of fillers or other additives in the composite. The residual mass can provide information about the composition and quality of the sample, as well as its potential for further processing or use.

CHAPTER 6

CONCLUSIONS

The mechanical properties of silicone rubber have been studied in this text. The addition of graphite to silicone rubber at a concentration of 20% resulted in a significant increase in Shore hardness and tensile strength. This suggests that graphite has improved the resistance of the material to indentation, penetration, and stretching forces. However, it is important to note that Shore hardness and tensile strength alone may not fully capture all aspects of the mechanical behavior of the material and other mechanical tests may need to be conducted for a more comprehensive evaluation. Furthermore, the TGA analysis indicates that the sample undergoes a simple thermal degradation process with a residual mass of around 34%. This information can provide insights into the composition and quality of the sample and its potential for further processing or use.

CHAPTER 7

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