

THERMAL AND ELECTRICAL PROPERTIES OF SILICONE RUBBER

Submitted in partial fulfilment of the requirements for the award of

Bachelor of Science in Chemistry

by

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DEPARTMENT OF CHEMISTRY
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SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)

Accredited with Grade "A" by NAAC | 12B Status by UGC |
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BONAFIDE CERTIFICATE**

This is to certify that this Project Report is the bonafide work of **BABY SHALINI C (39030003), SHANMUGA PRIYA M (39030032)** who carried out the project entitle **"THERMAL AND ELECTRICAL PROPERTIES OF SILICONE RUBBER "** under our supervision from December 2021 to April 2022.

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ABSTRACT

Silicone rubber's special features such as "organosiloxanes polymer" has been originated from its unique molecular structure that they carry both inorganic and organic properties unlike other organic rubbers. In other words, due to the Si–O bond of silicone rubber and its inorganic properties, silicone rubber was superior to ordinary organic rubbers in terms of heat resistance, chemical stability, electrical insulating, abrasion resistance, weatherability and ozone resistance. With these unique characteristics, silicone rubber has been widely used to replace petrochemical products in various industries like aerospace, munitions industry, automobile, construction, electric and electronics, medical and food processing industry. Recently, these scopes of silicone applications have been expanding at a great speed by the demand of industries that want more reliable elastomer. This paper reviews on synthesis, general properties, applications and nanocomposites of silicone rubber. Here we explained about Silicone rubber, Structures, Types, Thermal properties , Mechanical properties, characterization techniques,Results.

TABLE OF CONTENT

CHAPTER			TITLE	Pg.No.
1			Introduction	1
	1.1		Silicone rubber	1-2
	1.2		History of silicone rubber	2
	1.3		Types of basic silicone	3
		1.3.1	Silicone fluid	3
		1.3.2	Silicone resin	3
		1.3.3	Silicone rubber	3-4

	1.4		Types of silicone rubber	4-5
		1.4.1	Solid silicone rubber or High temperature vulcanized	4
		1.4.2	Liquid silicone rubber	5
		1.4.3	Room temperature vulcanized	5
		1.4.4	Fluoro silicone rubber	5
	1.5		Properties of silicone rubber	5-6
	1.6		Physical Properties	6-7
		1.6.1	Hardness	6
		1.6.2	Electrical conductivity	6
		1.6.3	Thermal conductivity	6
		1.6.4	Application	6-7
	1.7		Advantages of silicone rubber	7-8
2			Literature survey	8-9
3			Aim and scope	10
4			Materials and methodology	11
	4.1		Materials	11
	4.2		Characterization techniques	11

		4.2.1	Thermal Conductivity	11
		4.2.2	Hardness	12
		4.2.3	Electrical Conductivity	13
5			Results and discussion	14
		5.1.1	Hydraulic bending machine	14
		5.1.2	Thermal Conductivity	15
		5.1.3	Hardness	16
	5.2		Electrical Conductivity	17
		5.2.1	Volume resistivity	17
		5.2.2	Surface resistivity	17
6			Conclusion and References	18
	6.1		Conclusion	18
	6.2		References	19-20

LIST OF ABBREVIATION

FTIR	Fourier Transform Infrared Spectroscopy
BET	Braeuer-Emmette-Teller

LIST OF FIGURES

FIGURE	TITLE	Pg.No
Fig 1.1	Specific heat of graphite vs temperature at one atmosphere	5
Fig 1.2	Thermal vibrational amplitude of graphite crystal	7
Fig 1.3	Young's modulus of graphite crystal	8
Fig 1.4	The faces of a graphite crystal	9
Fig 4.1	Fourier transformer infrared spectrometer	12
Fig 4.2	Braeuer-Emmette-Teller	13
Fig 4.3	Raman Spectroscopy	14
Fig 4.4	Gas Pycnometer	15

Fig 5.1	FTIR spectrum of graphite	16
Fig 5.2	Raman spectrum of graphite	17
Fig 5.3	BET surface area plot	18

LIST OF TABLES

TABLE	TITLE	Pg.No
1.1	Theoretical and thermal properties of graphite	5
1.2	Specific heat of selected elements	6
5.1	Data of BET	18
5.2	Data of Density test	19
5.3	Data of electrical conductivity	19

CHAPTER 1

INTRODUCTION

1.1 SILICONE RUBBER:

Silicone or polysilicone is a polymer made up of siloxane. Silicone rubber is a strong and high strength elastomer composed of silicone containing silicon as well as other molecules such as carbon, hydrogen and oxygen. Its structure always consists of a siloxane (silicon-oxygen chain) framework and an organic part bonded to silicon.

Silicone rubber is one of many types of industrial rubbers. Taking traits such as flexibility and temperature resistance from both plastic and rubber, material comes in sheets, tubes, liquid, and other forms that allow it to be used in applications ranging from aerospace to medical to construction purposes. Silicone is sometimes mistakenly referred to as silicon, which is a chemical element and a crystalline metalloid widely used in computers and other electronic equipment. And they have totally different physical and chemical properties.

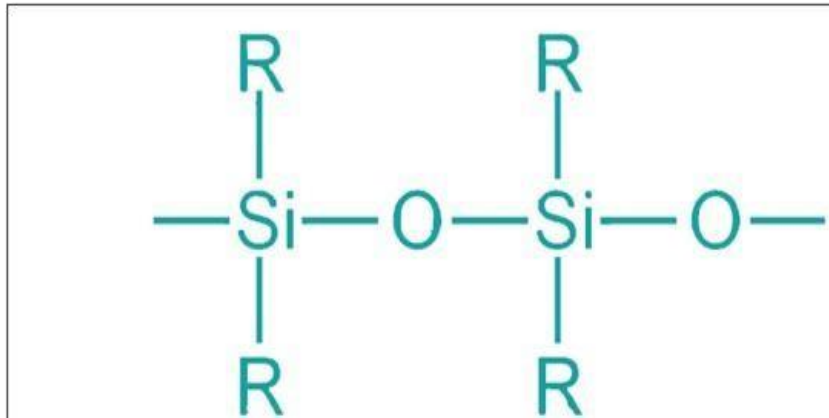


Fig:1.1. Structure of silicone rubber

The methyl group is called MQ. These are basic silicone rubbers developed for the first time. The methylvinyl group, which exhibits good compressive properties, is called VMQ.

These are the most commonly used silicone rubbers because vinyl helps to cure. The methyl phenyl group (MPQ) and methyl phenyl vinyl (PVMQ) are used to increase the low temperature ability of the rubber.

The fluorine, vinyl and methyl groups(FVMQ) are chemically more resistant to oils, fuels and solvent Liquid silicone rubber has the smallest molecular chain of the three, giving its polymers a low molecular weight.

It can be extruded or injection molded using specialized machinery. This silicone rubber is more weather resistant and transparent. RTV Silicone Rubber(Room Temperature Vulcanization) may be one or a mixture of two components and cures at room temperature to soft or medium hardness.

It is commonly used for making potting, mastic and packing. Silicone rubber molds are also made from RTV silicone rubber. Solid silicone rubber or HTV(High Temperature Vulcanization) contains the heaviest molecular weight long chain polymers. This is usually in its unprocessed form and must be vulcanized at the same temperature as more traditional rubbers..

1.2 HISTORY OF SILICON RUBBER:

F. S. Kipping and Matt Saunders coined the term silicone in 1901 and described the polydiphenylsiloxane by analogy with its formula Ph_2SiO ($\text{Ph C}_6\text{H}_5$) and the ketone benzophenone Formula Ph_2CO (originallysiliketone). Kipping recognized that polydiphenylsiloxane is a macromolecule, while benzophenone is a monomer.

The discovery of the structural difference between the kipping molecule and the nomenclature ketone is that, according to modern chemists'silicone is no longer the correct term (although it remains in the general usage of), it is called siloxane. Means a team.

1.3 TYPES OF BASIC SILICONE:

- Silicone fluid
- Silicone resin
- Silicone rubber

1.3.1 Silicone Fluid:

Silicone fluids principally consist of chains of alternating silicon and oxygen atoms with two alkyl groups usually methyl groups, in special cases can also phenyl. high order of thermal stability :used as heat –exchange fluid in lab. Water repellency due to hydrophobic nature. no colour and odour and low volatile in nature. Chemical resistant but are attacked by concentrated mineral acid.

1.3.2 Silicone Resin:

Silicone resin is produced by hydrolysis of alkyl tri-chlorosilanes for the final product to be cross-linked. Cross-linking takes place at elevated temperature in presence of catalyst.

- Highly water repellent.
- Good insulator.
- High Flexibility and Low-temperature flexibility.

1.3.3 Silicone Rubber

- Silicone rubber compound consists of long-chain polysiloxanes and various fillers, such as pyrogenic silica. They can be cured to form silicone elastomers.
- They are classified according to the curing method, the viscosity of the base polymer, and whether they cure at high or room temperature.
- Good thermal stability, can operate from –100 to 30.
- Good UV resistance.
- Highly inert and does not react with most chemicals.
- Non toxic and can be used with food products and in medical applications.
- Tensile strength is 11 N/mm².
- Used in plastic surgery and cosmetic surgery and in pipes used for medical purpose.
- Used in cookware industry as ice cube trays, baby products
- Used in day to day stuff like bands, mobile covers, keyboard protector.

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Fig.1.2.Silicone rubber image

1.4 TYPES OF SILICONE RUBBER:

1.4.1 Solid Silicone Rubber Or High Temperature Vulcanized (HTV):

Solid silicone rubber contains polymers with a high molecule weight and relatively long polymer chains. They are available in an uncured form and require traditional rubber processing techniques. (heat curable)

1.4.2 Liquid Silicone Rubber:

Liquid silicon rubber contains polymers of lower molecule weight and hence shorter chains. It has better flow properties. It is processed on specially designed injection molding and extrusion equipment. Liquid silicone rubber is a low viscosity and purity thermoset elastomer that maintains properties over a wide range of temperature.

1.4.3. Room Temperature Vulcanized:

Rtv silicon is a type of silicon rubber made from one part or two components

Systems where their hardness range of very soft to medium.

1.4.4. Fluorosilicone Rubber:

Fluorosilicone rubber is a long lasting elastomer that is stable, typical applications include aerospace fuel system components, seals and o rings.

1.5. PROPERTIES OF SILICONE RUBBER:

Silicone rubber has high heat resistance and chemical stability that helps it to supply higher electrical insulation. it's high physical property and squeezability yet as wonderful resistance to cold temperatures. synthetic rubber is immune to a large temperature vary. It provides wonderful resistance to extreme temperatures, which may vary from minus a 100 F to and 500° F. This rubber is used indefinitely at 150 C that doesn't result in any modification within the properties of synthetic rubber. It will stand up to temperatures of 200° C for 10,000 hours or a lot of.

Some polymer rubbers will stand up to temperatures of up to 350 C for brief periods of your time. synthetic rubber has wonderful oil resistance to high temperatures. Of the opposite common varieties of caoutchouc, nitril rubber and butadiene rubber have somewhat higher oil resistance at temperatures below a 100 ° C however at higher temperatures, synthetic rubber is superior to any or all alternative varieties of rubber.

Silicone rubber has exceptional weather resistance. Ozone generated by halo discharge does not deteriorate silicone rubber. Therefore, silicone rubber can be exposed to wind, rain and UV rays for a longer time without any change in its physical properties. The tensile strength, tear strength, elongation and compressibility of silicone rubber are far superior to those of ordinary rubbers. Silicone rubber has a higher thermal conductivity than most other rubbers. High thermal conductivity silicone rubber is used to manufacture products such as thermal interface plates and thermal rollers.

Silicone rubber has excellent resistance to moisture and steam. It can be soaked in cold, hot or boiling water for a long time with a water absorption of about 1%. This does not affect its mechanical strength or electrical properties. When exposed to steam under normal pressure, silicone rubber does not degrade. However, high pressure steam at temperatures

above 15°C can degrade the siloxane polymer and reduce rubber properties. This metal is traceable. It glows in the dark. Silicone rubber is also a conductor of electricity. In addition to being oil resistant, silicone rubber is also resistant to chemicals, acids and gases. Silicone rubber is flame retardant and has low smoke emission properties.

1.6 PHYSICAL PROPERTIES:

1.6.1. Hardness:

Silicone materials use comparative scales known as Shore hardness to characterize their hardness. Two commonly used Shore scales for silicon are Shore for silicon porous products and Shore A for dense products.

1.6.2 Electrical Conductivity:

Silicones in their original state are very insulating. Therefore, they are often used in applications requiring high dielectric strength. What's unique about silicone is that it accepts high loads and retains its handling.

1.6.3 Thermal Conductivity:

Silicones in their initial state are very thermoelectric. As a result, they are often used in applications requiring low heat transfer, such as in piping for fluid transfer in food handling or oven applications. What's unique about silicone is that it accepts high loads and retains its handling.

1.6. APPLICATION :

This rubber can be extruded into tubes, strips, solid wire or any custom configuration. Silicone rubber can also be molded into custom designs and shapes.

This form of neoprene is available for molding to be poured, brushed or sprayed on. extruded into tubes, strips, solid wire or any custom configuration.

Silicone rubber can also be molded into custom designs and shapes. This form of neoprene is available for molding to be poured, brushed or sprayed onto the model.

Suitable for casting low-melting metal alloys such as lead, tin, powder. Also used in molding plastic production. alloy like lead, pewter, pewter. Also used in molding plastic production.

1.7 ADVANTAGE OF SILICONE RUBBER:

- Excellent resistance to high and low temperature.
- Resistant to ozone and sunlight.
- Permeable to gas.
- Fine electrical properties .

USES:

Electronics applications use some of the most highly purified silicone rubber for insulating tape, sealant, varnish, lubricants, keyboards, and housings. High thickness rubber can be injection molded into insulators and arrestors.

Aerospace silicone rubber is used in spacesuit fabrics, tooling materials, seals and gaskets, as well as other products used in aircraft manufacturing and maintenance.

Construction uses silicone rubber for adhesives, sealants, and coatings, thanks to its weathering properties and ability to bond to metal.

Automotive applications include vibration and weather resistant parts as well as coatings and varnishes, but only the most heat, oil, and fuel resistant types are used for these purposes.

Medical silicone rubber can be found in tubing, adhesives, and defoamers.

Consumer products that use this material include anti-stick bakeware, food containers, utensils, toys, and jewelry including silicone rubber band bracelets. However, it can also act as an ingredient in shampoo, laundry soap, cosmetics, and deodorant.

CHAPTER- 2

LITERATURE SURVEY

1.TITLE: Properties of silicon rubber

AUTHOR : Gianqian zhu, zhenhao wang,hui zeng, Hun-Sik Kim, Seong-Hun Jung, Jin-San Yoon

JOURNAL AND YEAR: Journal of applied polymer science 2021.

INFERENCE: Silicon rubber using for thermal properties studied and sample using characterization techniques like thermal conductivity.

2 . TITLE: Mechanical properties of rubber ,polymers

AUTHOR: Louise van Tonder, Frederick Johannes Willem Jacobus Labuschagné

JOURNAL AND YEAR : Journal of Polymers, 2020 .

INFERENCE: The high-temperature resistance of silicone rubber was often affected by the type and content of high-temperature resistant additives and material preparation technology.

3. TITLE: Mechanical and thermal properties of high-performance silicone rubber

AUTHOR : Bratati Pradhan, Suneel Kumar Srivastava

JOURNAL OF YEAR: Polymers, 2013.

INFERENCE: Considering the properties of silicon rubber this blend had thermal conductivity and good mechanical properties (hardness).

4. TITLE: Silicone rubber properties

AUTHOR: Magdalen Lipinska

JOURNAL OF YEAR: Mechanical Properties, Elastomers, , (2017).

INFERENCE: To improve the mechanical properties and solvent resistance of silicone rubber (SR) without reducing its thermal insulation, it is proposed to use molybdenum disulfide (MoS₂) nanosheets. to reinforce SR. The MoS₂ nanopanel was prepared by lithium ion intercalation, and then MoS₂ was modified with 3mercaptopropyl trimethoxysilane(KH58) to improve the compatibility and interface interactions between the MoS₂ nanopanel and the substrate. The structure and morphology of KH58 – MoS₂ are characterized by Fourier transform.

5. TITLE: Mechaical and thermal properties of silicone rubber.

AUTHOR: Magdalen Lipinsk, Bratati Pradhan, Suneel

JOUNAL AND YEAR: Mechanical Properties, Elastomers, , (2017).

INFERENCE: The high-temperature resistance of silicone rubber was often affected by the type and content of high-temperature resistant additives and material preparation technology. Commonly used high-temperature additives mainly include metal oxides (CeO₂, Fe₂O₃, Al₂O₃), metal hydroxides (Ce(OH)₄, FeO(OH), Al(OH)₃), carbon nanomaterials (carbon black, CNTs, graphene nanosheets, graphene), and other high-temperature resistant functional additives.

CHAPTER 3

AIM AND SCOPE

3.1 AIM:

The main aim of the project is to characterize to silicone rubber. silicone rubber characterized with the help of thermal conductivity ,hardness and electrical conductivity.

3.2 SCOPE:

- Characterization of silicone rubber by thermal conductivity.
- Characterization of silicone rubber by mechanical properties of hardness.
- Conformation of electrical conductivity test..

CHAPTER 4

MATERIALS AND METHODOLOGY

4.1 MATERIALS:

Materials used in silicon rubber sheet, carbon nanotube.

4.2 CHARACTERIZATION TECHNIQUES:

4.2.1 Thermal conductivity:

Thermal conductivity refers to the ability of a given material to conduct/transfer heat. It is generally denoted by the symbol 'k' but can also be denoted by 'λ' and 'κ'. The reciprocal of this quantity is known as thermal resistivity. Materials with high thermal conductivity are used in heat sinks whereas materials with low values of λ are used as thermal insulators. Fourier's law of thermal conduction (also known as the law of heat conduction) states that the rate at which heat is transferred through a material is proportional to the negative of the temperature gradient and is also proportional to the area through which the heat flows. The differential form of this law can be expressed by the following equation: $q = -k \nabla T$ Where ∇T refers to the temperature gradient, q is the heat flux or heat flow, and k refers to the thermal conductivity of the material in question.

Thermal conductivity is expressed in terms of the following dimensions:

- Temperature, length, mass and time.
- The SI unit of this quantity is the Watt per Kelvin meter or $Wm^{-1}K^{-1}$.
- It is usually expressed as power (length * temperature). These units describe the rate at which heat is conduction through a material of unit thickness and for each Kelvin of the temperature difference.

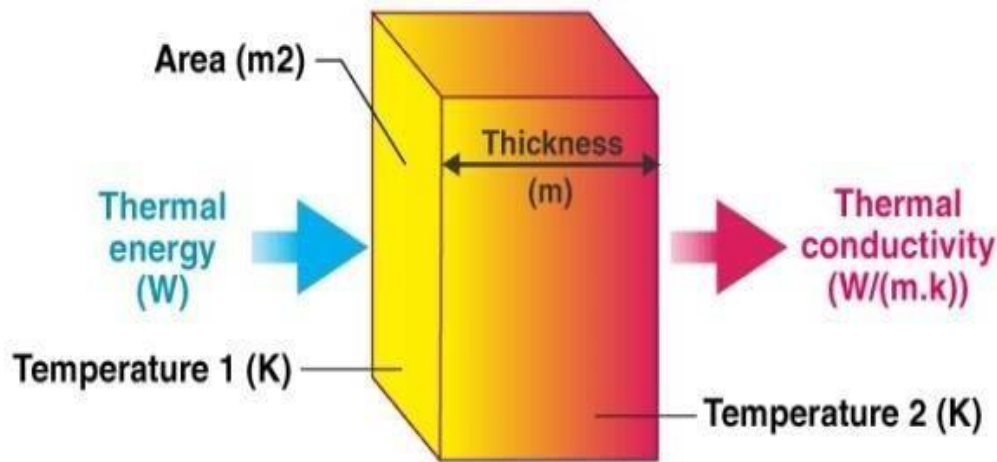


Fig 4.1 Thermal conductivity

4.2.2. Hardness

Hardness is nothing more than a measure of a certain material's hardness or its ability to resist permanent dents. It is measured by the depth of an indentation made in the material with a specified force. The measuring instrument is essentially a durometer, but the Shore Hardness is named after its inventor Albert Shore. Accordingly, there are different Shore hardness scales to measure the hardness of different materials with different properties, such as rubbers, polymers and elastomers. In fact, there are up to 12 different scales depending on the intended use, and each scale translates to a value from 0 to 100. You can safely assume that higher values indicate higher hardness and vice versa. However, you will find that only two of these scales are most commonly used to measure the hardness of rubber compounds. Scale A for the softest and scale D for the hardest.

The Shore A hardness scale is used to measure the hardness of mold rubber. They can vary in hardness from very soft and malleable, to medium and slightly ductile, to hard with almost no ductility. Accordingly, Shore A clearly specifies extremely soft and viscous rubbers. While semi-rigid plastics will be measured at the higher end of the

Shore A scale. The Shore D hardness scale is dedicated to measuring the hardness of hard rubbers, semi-rigid plastics and hard plastics. The most popular are Shore Durometer A for soft elastomers and Shore Durometer D for hard elastomers. Each test gives a hardness value from 0 to 100. Shore A test is commonly used to measure the hardness of silicone - most of our silicon is between 25 and 80 Duro Shore A.

4.2.3 Electrical Conductivity

Volume Resistivity

Conductive silicone rubbers contain electrically conductive Volume resistivity and carbon black content materials such as carbon. A range of products are available, with resistance varying from $0.01\Omega\cdot\text{m}$ to $10\Omega\cdot\text{m}$. Their other properties are basically the same as general purpose silicone rubbers. Conductive silicone rubbers are thus used extensively as a material for keyboard contact points, components used in heaters, an antistatic material, and high-voltage cable shielding.

Surface Resistivity

The surface resistivity and quotient cancel are generally measured in Ohms, however because the electrodes' four points form a square some test results use Ohms per square due to its more descriptive nature. This measurement does not take physical dimensions such as thickness and diameter into consideration. Since it only determines the surface's resistivity, only one physical measurement is required. In applications involving static electricity dissipation such as electronics manufacturing, low surface resistivity is ideal. In their base format rubbers and plastics have high levels of surface resistance. To increase conductivity, manufacturers will add carbon black or a surface treatment agent.

CHAPTER 5

RESULT AND DISCUSSION

5.1 CHARACTERIZATION OF SILICON RUBBER:

5.1.1 Hydraulic Bending Machine:

Hydraulic Bending Machine belongs to forging machineries. The main role is in the metal processing industry. Then, its products are widely used in light industry, aviation, shipbuilding, metallurgy, instrument, electrical appliances, stainless steel products, steel structure construction and other industries.



Fig 5.1 Hydraulic bending machine

5.1.2 Thermal Conductivity

Thermal conductivity refers to the ability of a given material to conduct/transfer heat. It is generally denoted by the symbol 'k' but can also be denoted by ' λ ' and ' κ '.

The reciprocal of this quantity is known as thermal resistivity. Materials with high thermal conductivity are used in heat sinks whereas materials with low values of λ are used as thermal insulators. Fourier's law of thermal conduction (also known as the law of heat conduction) states that the rate at which heat is transferred through a material is proportional to the negative of the temperature gradient and is also proportional to the area through which the heat flows. The differential form of this law can be expressed by the following equation: $q = -k \nabla T$ Where ∇T refers to the temperature gradient, q is the heat flux or heat flow, and k refers to the thermal conductivity of the material in question.

Thermal conductivity is expressed in terms of the following dimensions:

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5.1.2 Hardness

Hardness is nothing more than a measure of a certain material's hardness or its ability to resist permanent dents. It is measured by the depth of an indentation made in the material with a specified force. The measuring instrument is essentially a durometer, but the Shore Hardness is named after its inventor Albert Shore. Accordingly, there are different Shore hardness scales to measure the hardness of different materials with different properties, such as rubbers, polymers and elastomers. In fact, there are up to 12 different scales depending on the intended use, and each scale translates to a value from 0 to 100. You can safely assume that higher values indicate higher hardness and vice versa. However, you will find that only two of these scales are most commonly used to measure the hardness of rubber compounds. Scale A for the softest and scale D for the hardest.

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S.no	TEST NAME	TEST METHOD	UNIT	TEST VALUE OBTAINED
1	Thermal conductivity at 55c mean temperature	ASTM E 1530	W/mK	0.326
2	Shore A hardness	ASTM D 2240	-	56.0

Table 5.1 Mechanical properties of silicone rubber

5.2 ELECTRICAL CONDUCTIVITY

5.2.1 Volume Resistivity

Conductive silicone rubbers contain electrically conductive Volume resistivity and carbon black content materials such as carbon. A range of products are available, with resistance varying from $0.01\Omega \cdot m$ to $10\Omega \cdot m$. Their other properties are basically the same as general purpose silicone rubbers. Conductive silicone rubbers are thus used extensively as a material for keyboard contact points, components used in heaters, an antistatic material, and high-voltage cable shielding

5.2.2 Surface Resistivity

The surface resistivity and quotient cancel are generally measured in Ohms, however because the electrodes' four points form a square some test results use Ohms per square due to its more descriptive nature. This measurement does not take physical dimensions such as thickness and diameter into consideration. Since it only

determines the surface's resistivity, only one physical measurement is required. In applications involving static electricity dissipation such as electronics manufacturing, low surface resistivity is ideal. In their base format rubbers and plastics have high levels of surface resistance. To increase conductivity, manufacturers will add carbon black or a surface treatment agent.

S.no	Test name	Test method	unit	Test value obtained
1	Volume resistivity	ASTM D 257	ohm.cm	Less than 1.411
2	Surface resistivity	ASTM D 257	ohm	Less than 4.296

Table 5.2 Electrical properties of silicone rubber

CHAPTER 6

CONCLUSION

6.1 CONCLUSION

The thermal conductivity of silicone rubber composites was always greater than that of silicone rubber composites under the same content of fillers. There were decrease trends for volume electrical resistivity and breakdown strength, but they were still very large and far beyond electronic packaging materials requirements. It was proved that by biological modification of silicone rubber, thermal resistance of h-BN in silicone rubber reduced, and the interfacial compatibility between h-BN and silicone rubber increased so that the thermal conductivity of silicone rubber increased. Unlike some traditional methods with low grafting rate, DA bio-modified h-BN had the virtue of simple process, rapid modification, and high grafting rate, which deserved extensive utilization and could make silicon better exert its effect on various fields. In addition, compared with previous experiments, the amount of silicone rubber required for the dispersion of ultrasonic-assisted h-BN in the experiment was much less, which reduced the cost of the experiment. Nevertheless, the high cost of DA was still a big problem for us. In the future, we can focus on improving synthetic DA Technology to reduce the cost of DA.

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