International Journal of Advance Research in Engineering, Science & Technology(IJAREST),
ISSN(O):2393-9877, ISSN(P): 2394-2444,
Volume 2 ,Issue 4 , April- 2015

CONDUCTIVITY IN WHITE FILLED SILICONE RUBBER

[1]*Treena Topdar*, M.E Sem-IV, Rubber Technology, L.D College of engineering,

Email: treena.rockslife@gmail.com, Mo: +91-8460613103

[2]*Rupande Desai*, Associate Professor and Head, Rubber Technology Dept.,

L.D College of Engineering, Email: rupandendesai@yahoo.com

[3]*C.G Bhagchandani*, Associate Professor, Chemical Engg. Dept.,

L.D college of Engineering.

Abstract

The main objective of this review is to describe some of the important topics related to the use of silicone rubber for electrical conductivity purpose. The review aims at providing a thorough picture of state-of-the-art in improving electrical conductivity property in silicone rubbers. The properties of di-electric constant and volume resistivity of the polymer as well as the fillers play an important role in deciding the electrical conductivity properties. The purpose of using these inorganic fillers to get a coloured object other than that of black colour which can be used as an electrically conductive device.

Also certain disadvantages of carbon black are discussed in the review which is not desirable in many applications and it proves to be carcinogenic to human health. So inorganic/white fillers are taken as an alternative to make silicone rubbers conductive equally as carbon black. The values of volume resistivities of various inorganic fillers are discussed and compared among each other. If the filler gives lower volume resistivity it gives higher electrical conductivity as volume resistivity is inversely proportional to electrical conductivity.

KEYWORDS: *Silicone Rubber, Electrical Conductivity, Volume Resistivity*

1. INTRODUCTION:

Electrical conductivity is the measure of a material's ability to accommodate the transport of an electric charge. Polymer composites (particles dispersed in a polymer matrix) are of great interest because addition of fillers to a polymer matrix can enhance mechanical, thermal, barrier, and other properties. These composites have drawn great interest for its versatile applications in the field of electronic materials such as integrated decoupling capacitors, acoustic emission sensors, electronic packaging materials and angular acceleration accelerometers. [1,2] Many studies have been done on BaTiO3 due to their remarkable optical and electronic properties. The volume resistivity is the reciprocal of the electrical conductivity.

2. DEFINITION OF PROBLEM:

Black fillers such as carbon black impart high amount of electrical conductivity to the silicone rubbers but major disadvantage of carbon black is it gives black colour to the product outcome. Several products used in electrical conductivity purposes like sprays, paints, varnishes and other electrical appliances etc. which are desirable in other than black colour cannot be treated by carbon black.

Also carbon black proves to be possibly carcinogenic to humans and classified to be a group 2B carcinogen because there is a sufficient evidence in experimental animals with inadequate evidence in human epidemiologic studies.

Short term exposure to high concentration of carbon black dust may produce discomfort to the upper respiratory tract, through mechanical irritation.

2.1 Disadvantages of carbon black [5]:

- makes processing difficult
- requires previous drying
- conductivity achieved by carbon black depends on additive concentration and morphology of the product
- Slightly lower compression strength

3. PURPOSE OF WHITE / INORGANIC FILLERS [3]:

we can use other inorganic fillers which can impart equal amount of electrical conductivity to the silicone rubber and also can be used in different coloured products.

Some properties of the silicone rubber need to be improved to extend service life. the fillers are added to the polymer to promote specific properties and also to reduce cost. To improve the surface hydrophobicity, electrical conductivity, relative permittivity and thermal conductivity of polymeric materials, some micro/nano fillers can also be added.

Also there are several other disadvantages of carbonaceous fillers which can be avoided by using these inorganic fillers during processing.

Fillers which give electrical conductivity as below:-

- ZnO
- Carbon black
- Expanded graphite
- Multi walled Nano tube (MWNT)
- Nickel
- Iron
- Copper
- Zinc
- Aluminium
- BaTiO3

4. CONDUCTIVITY PROPERTIES OF SILICONE RUBBER:

4.1 Thermal conductivity:-

The thermal conductivity of silicone rubber is about 0.2 W/mΩ·K, a value higher than that of common organic rubbers. Some silicone rubbers contain a high proportion of special inorganic fillers to improve thermal conductivity (about 1.3 W/mΩ·K), and these are used to make products including thermal interface sheets and rollers.

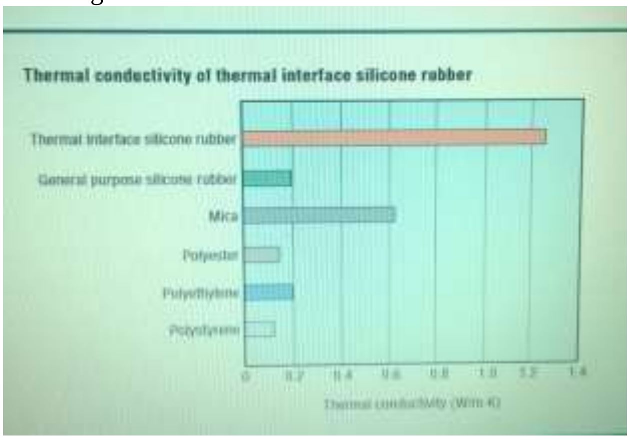

Fig.1. Thermal conductivity of thermal interface silicone rubber

4.2 Electrical Conductivity:-

Conductive silicone rubbers contain electrically conductive materials such as carbon. A range of products are available, with resistance varying from 0.01Ω·m to 10Ω·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.

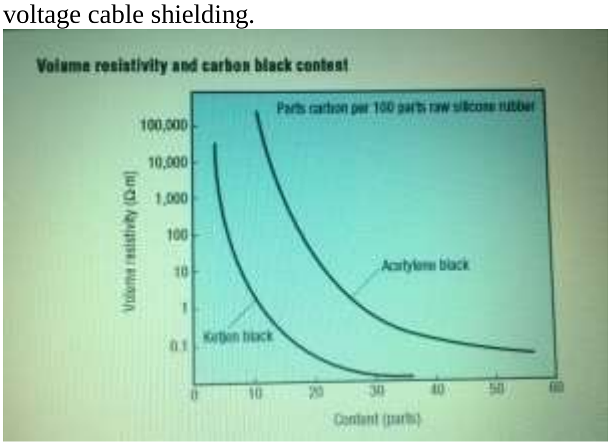

Fig.2. Volume resistivity and carbon black content

So by this we come to know that by increase in the addition of different grades of carbon black we can increase the volume resistivity or the electrical conductivity of silicone rubbers.

5. ELECTRIAL CONDUCTIVITY ENHANCED BY FILLERS [6]:-

Indeed most polymers are mostly electrically insulators but need to be conductive in some applications, especially for dissipating electrical charges. Incorporating conductive filler articles into polymer medium is an interesting way to prepare an electrically conductive polymer.

At a given amount of filler amount, that is called the percolation threshold, a continuous network of filler is formed across the matrix and material undergoes a sudden transition from insulator (>10^{10} Wcm) to conductor (<10^{5}Wcm) state due to the formation of filler network as the filler content increases.

By comparing different values of volume resistivities of fillers we see that of barium titanate, proves good. It has volume resistivity 2.5 X 10^{-10} Ω.m and electrical conductivity 0.4 X 10^{10} S/m).

Also according to the values we can study that the filler silicon carbide has volume resistivity intermediate between the extreme high electrical conductors and that of extreme low electrical conductors. So we can use silicon carbide filler as a semiconductor for many applications of silicone rubber.

Barium titanate is considered to be a filler which imparts good amount of electrical conductivity to the silicone rubber.

6. FOR PRACTICAL EXPERIMENTS:

Materials to be used:

- Silicone rubber (Hardness: 40 Shore A, Density: 1.12 g/cc)
- Barium Titanate ($BaTiO_3$) as a conductive filler of different mesh sizes : 200, 400 and 600, M.P = 1630°C, Density: 6.03 g/cc and having a tetragonal structure.
- Dicumyl Peroxide-98 as a curing agent (Perkadox BC-FF), white crystalline sample, density= 1.11 g/cc, M.P= 39.5°C

7. PREPARATION OF POLYMER COMPOSITES:

- Steps to be followed to prepare our polymer composite samples for testing:
- Mixing of BaTiO3 and other ingredients into Silicone rubber polymer matrix were done in a two roll mill for 15 minutes and a sheet is taken out of each batch.
- Samples are prepared by taking the concentration of the curing agent same and only varying the mesh size of the filler. (200, 400 and 600) in the polymer matrix.
- Filler concentration is kept same in all the batches.
- Monsanto rheometer R 100 will be used to determine the optimum cure time.
- Moulding to be done in an electrically heated press at a specified time (obtained through Monsanto rheometer) at 180°C.

8. TESTING:

- Sheets of 2-3 mm thickness are taken of uncured and cured samples for testing.

- A multimeter is used to measure the resistance of the samples.
- The electrodes of the multimeter are kept at various places of the samples and resistance values are noted; up to 10 readings are taken.
- The distance between the electrodes must be equal at all the time. Standard distance between the electrodes are kept as 2.5 cm.
- An average value of resistance is calculated.
- The value of resistivity is then calculated by the given formula:

$$\rho = R.A/l$$

where ρ = resistivity of the material
R = resistance obtained by the multimeter
A = cross sectional area of the sample
l = distance between the two electrodes = 2.5 cm

- Obtain the conductivity value for the same by doing the reciprocal of resistivity value.

$$C = 1/\rho$$

9. RESULT TABLE:

- **Comparison between resistance, resistivity and conductivity values according to particle size for uncured sample.**

Values	200 mesh	400 mesh	600 mesh
Resistance	16.995×10^{-3} Ω	8.34×10^{-3} Ω	3.959×10^{-3} Ω
Resistivity	0.000153 Ω.m	0.00007089 Ω.m	0.00003959 Ω.m
Conductivity	6.535×10^{3} $\Omega^{-1}m^{-1}$	1.410×10^{4} $\Omega^{-1}m^{-1}$	2.526×10^{4} $\Omega^{-1}m^{-1}$

- **Comparison between resistance, resistivity and conductivity values according to particle size for cured sample.**

Values	200 mesh	400 mesh	600 mesh
Resistance	15.276×10^{-3} Ω	4.706×10^{-3} Ω	2.275×10^{-3} Ω
Resistivity	7.332×10^{-5} Ω.m	2.258×10^{-5} Ω.m	1.092×10^{-5} Ω.m
Conductivity	1.364×10^{4} Ω^{-1} m^{-1}	4.445×10^{4} Ω^{-1} m^{-1}	9.157×10^{4} Ω^{-1} m^{-1}

10. CONCLUSION:

Metallic powder fillers like silver, platinum, copper, nickel, aluminium etc tend to give higher values of electrical conductivities in which silver and platinum give the highest values. But taking their cost into consideration the outcome product will be very expensive.

So, a filler Barium titanate can be used in this case where higher amount of electrical conductivity can be achieved in silicone rubber with reasonable cost.

Other than that silicon carbide is a filer which has volume resistivity intermediate between conductive fillers and insulating fillers. So it can be used as a semi conductor.

By taking Barium titanate as a conducting filler, tests were carried out. As per both the comparison tables, we can see that the values of resistance and resistivity decreases as the mesh size of the particles increases, in case of either cured or uncured state, that is the smaller the particle size, the lower will be the resistance and resistivity values.

The conductivity value of silicone is the lowest with 200 mesh size filler and the highest with 600 mesh size filler. Therefore, we can conclude that the conductivity increases as the mesh size increases or the particle size decreases.

11. FUTURE SCOPE

If we study about the conductivity of the super conductor materials such as metals, this filler does not give as much conductivity value as per the metals. It gives conductivity value just above that of the semiconductors. This can be improved if filler of even lower particles are to be used.

Nano/ Micro sized fillers if taken for this purpose then more amount of conductivity can be achieved.

REFERENCES:

1. Y Rao, S Ogitani, P Kohl, C. P. Wong, (2000) High Dielectric Constant Polymer-ceramic Composite for Embedded Capacitor Application. International Symposium on Advanced Packaging Materials.
2. Y Rao, C. P. Wong, J Qu, (2000) Effective Dielectric Constant Prediction of Polymerceramic Composite Based on Self-consistent Theory. Electronic Components and Technology Conference.
3. Survey of micro/nano fillers used to improve silicone rubbers for outdoor insulators
4. Book- Development of manufacturing of pressure sensitive products, Author- Istevan Benedek
5. Electrically conductive silicone / organic polymer composites, Volume:6 by Aparna M. Joshi and Anjali A. Athawale
6. Shin Etsu Micro Si, Inc Electrically Conductive Series/ Thermal Interface Silicone Rubber, Features and properties of silicone rubber
7. D. Khastgir, K. Adachi, J. Polymer Sci., Part B: Polymer Physics, 37, 3065–3070, (1999).