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Synthesizing Electro - conductive grease using graphite

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Abstract- Graphite as we all know is well renowned for its ability to conduct electricity as well as its lubricant nature. Graphite has a honey comb structured planes where carbon atoms are bound together by strong covalent bonds. And each of these layers of carbon is bound together by weak van der Waals bonds. Grease is a semi solid lubricant widely used in the industrial world to reduce ware and tare. Grease is made of three principal components known as a base oil, thickener and additives. Thus combining graphite with grease would preferably transfer the electro-conductive nature of graphite to grease forming an electro-conductive grease. Usage of such a product would be, Grounding static discharges, provides electrical continuity between irregular or pitted surfaces, ensures electrical contact between loose or vibrating parts and small gaps, apply to ball bearings in computer equipment where it allows static discharge to pass through the bearing instead of building up, arcing, extending the Life of Rotating Switches, preventing Corrosion on Knife Switches, grounding Ball and Socket Connections on Power Insulators.

Natural vein graphite was used to make graphite powder under 75 microns. Basic grade grease was used as the substrate. Different weight ratios of both graphite and grease were mixed by blending to generate the sample series. The samples were tested for electrical conductivity using the impedance analyzer. A standard cell was made to hold the sample. The conducting length was kept to a minimum assuming that in real world applications (12 millimeters). Three measurements were taken with each generating a graph of imaginary part of impedance versus the real part of it. And the resistance of the sample was determined by the point where the curve seemed to make contact with the x axis of the graph. The samples show a near linear variation of both characteristics of conductivity and capacity. But the final sample containing 35% graphite with 65% grease shows a significant elevation in both conductivity and capacity. With a conductivity value of 4.2008×10^{-5} S cm^{-1} this particular sample is in the region of semiconductors with respect to conductivity.

Index Terms- Electro-conductive grease, Graphite, Impedance, Capacity, semi-conductor

I. Introduction

Carbon is found free in nature in three allotropic forms: amorphous carbon, graphite and diamond. More recently a fourth form of carbon buckminsterfullerene, C_{60} , has been discovered [1]. Graphite being one of the allotropes of carbon despite diamond is quite different from diamond referring to its strength and exceptional electro-conductivity owing to its significant structural configuration. The carbon atoms in graphite are sp^2 hybridized. Each carbon atom bonds with three other carbon atoms to form a sheet of carbon atoms lying in a hexagonal pattern or a honey comb structure. Only three electrons out of the four valence electrons of carbon form regular covalent bonds (σ- bonds) with adjacent carbon atoms. The fourth or π electron resonates between the valence bond structures. These electrons get together to form a delocalized electron cloud which induces the electro- conductive nature to graphite. And the lubricating nature too is generated by the very structure of graphite. Layers of carbon are held together by weak bonds which has a strength (1.3-40 kcal/[gram atom]) only about two percent of that(150-170 kcal/[gram atom]) of the bonds which hold the carbon atoms in the layer [1]. Thus the slightest ex-centric force would cause the layers to slip upon each other.

The weak bonds among the layers are explained by van der waals bonding. Consequently, weak forces between the carbon layers account for the tendency of graphite materials to fracture along planes, the formation of interstitial compounds and the lubricating, compressive and many other properties of graphite. However, Spain identifies the π orbital, which has a p_x configuration, and not van der waals forces as the correct source of bonding between the adjacent layers. In general, the π bands are found to overlap by ~40 meV to form the three- dimensional graphite network where the layer planes are stacked in a ABAB sequence.

II. Grease

By definition it is a solid to semi-fluid product of dispersion of a thickening agent in a liquid lubricant [4]. Made out of three components which include a base oil, thickener and some additives that modify the character of the end product. Mineral oils (paraffinic, naphthenic), synthetic hydrocarbons (PAO, alkylates) and other synthetic compounds (esters, polyglycols) are used as base oils. Base oil comprises the largest component of grease, representing 80 - 97% by weight. And this portion of base oil is responsible for the lubricating nature of the final product [4]. Various additives such as oxidation inhibitors, corrosion and rust preventives, metal deactivators, tackifiers, solid lubricants (MoS_2, graphite) and friction modifiers are used depending on the performance of the end product while simple soap, (lithium, sodium, calcium), complex soap (Lithium, calcium, aluminium, sodium) and non-soap (polyuria, bentonite, sulphonates, polymers) are used as thickeners [4]. The thickener is responsible for inducing the semisolid nature to grease.

III. Electro-conductive grease

The electro conductive nature of graphite which it inherits could be induced to semisolid lubricating grease so that the end product would be electro conductive. This product has been there in the market but traditionally metallic particles have been used in generating the conductive character. But the trend towards using carbon based material instead of metallic powder has become a key feature in the industry.

A low carbon blend is used to enhance the channeling ability of conductors. Basically electro conductive greases are used to bleed static charges preventing build up and protecting whatever important parts of a certain machine while some provide enhanced conductivity over a wide temperature range. Most common objectives of using such greases are to,

- Improve electrical connections between irregular or pitted surfaces,
- Extend life of contacts,
- Ensure electrical contact between loose or vibrating parts and small gaps,
- Prevent hotspots, welding, arcing and pitting of switch contact surfaces,
- Prevents normally closed switches from corroding in place,
- Shield EMI s [5].

IV. Methodology

Natural vein graphite was used to make graphite powder under 75 microns. And this powder was used to prepare the sample series that was to be tested. Basic grade grease was used as the substrate. Different weight ratios of both graphite and grease were mixed by blending to generate the sample series shown in table 01. The blending was done in periods of 5 seconds and three to five times depending on how it appeared to achieve homogeneity. The blender compartment was washed thoroughly after every sample that was blended to ensure that the contamination was kept minimal.

Table 1: Sample series

Sample number	Graphite weight %	Grease weight %
01	2	98
02	4	96
03	6	94
04	8	92
05	10	90
06	15	85
07	20	80
08	25	75
09	30	70
10	35	65

The samples were tested for electrical conductivity using the impedance analyzer. A standard cell was made to hold the sample while they were being tested for their electrical conductivity. The cell electrodes were designed in such a manner that two over rings were placed to ensure that the effective conducting length was kept constant throughout the sample series tested. The sample holder was thoroughly washed, cleaned and dried before advancing on to measure the sample next in line. Three measurements were taken with each generating a graph of imaginary part of impedance versus the real part of it. And the resistance of the sample was determined by the point where the curve seemed to make contact with the x axis of the graph. The conductivity of the samples was determined by the following formulas.

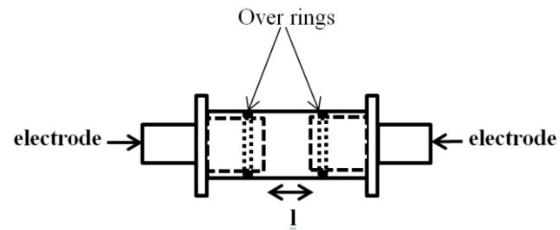


Figure 1: Standard cell

R= ρl /A………………………….. (1)

Where,

R = bulk resistance , **ρ** = resistivity, **l** = conducting length, **A** = cross sectional area

ρ= 1/c …………………………….. (2)

Where,

ρ = resistivity, **c** = conductivity

The impedance analyzer is used to measure the impedance of semi-solid substances such as electrolytes and is an alternating current method. Impedance can be simply described as the generalization of the concept of resistance from DC to AC. It can be described as a way to represent how much current would flow across a specified AC voltage across the impedance. If one volt AC voltage lets one ampere of AC current flow through the impedance the impedance value would be one.

Complex impedance is a standard method to determine the bulk conductivity of ion conducting materials. Usually the complex impedance Z (ω) is defined by the ratio of the complex voltage and current,

$$Z(\omega) = \frac{V(\omega)}{I(\omega)}$$

Where,

ω – Angular frequency of the applied signal (ω = 2πf)

And, Z (ω) can be expressed in terms of the real and the imaginary parts $Z^{/}$ and $Z^{//}$,

$Z = Z^{/} + j\,Z^{//}$

Where,

$Z^{/}$ - resistance, $Z^{//}$ - reactance

An equivalent circuit containing these resistive and reactive components has the ability to theoretically explain the characteristic behavior of the complex impedance of an ionic conductor. In practice the sample is kept in between two electrodes in a sample cell. The equivalent circuit can be give as,

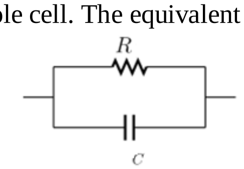
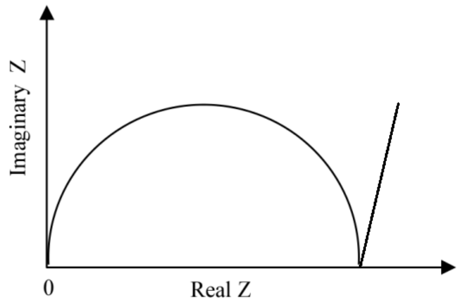


Figure 2: Equivalent circuit

The bulk resistance of the conducting material depends inversely upon the number of charge carriers and their mobility while the geometrical capacitance of the simulated parallel plated capacitor depends on cell geometry and is independent from the number of charge carriers and their mobility.



Bulk resistance

Figure 3: Graph of imaginary impedance vs real impedance

Once the bulk resistance is obtained from the graph, following equations lead to the conductivity of the particular sample.

R= ρl /A………………………….. (1)

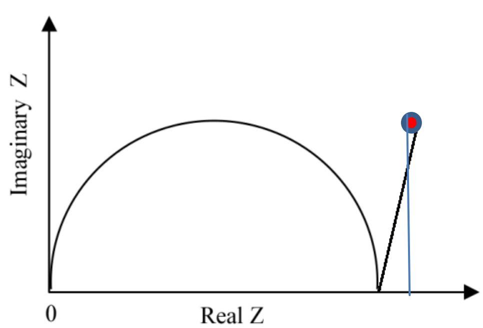
Where,

R = bulk resistance, **ρ** = resistivity, **l** = conducting length, **A** = cross sectional area

ρ= 1/c …………………………….. (2)

Where,
ρ = resistivity, **c** = conductivity

And the capacity of the particular sample can be determined by finding out the frequency of the peak point of the semicircle.



$2\pi f = \omega$ ……………(3)

R

$\omega = \frac{1}{Rc}$ ……………(4)

Thus,

$2\pi f = \frac{1}{Rc}$, ………… (3) & (4).

$$c = \frac{1}{2\pi f R}$$

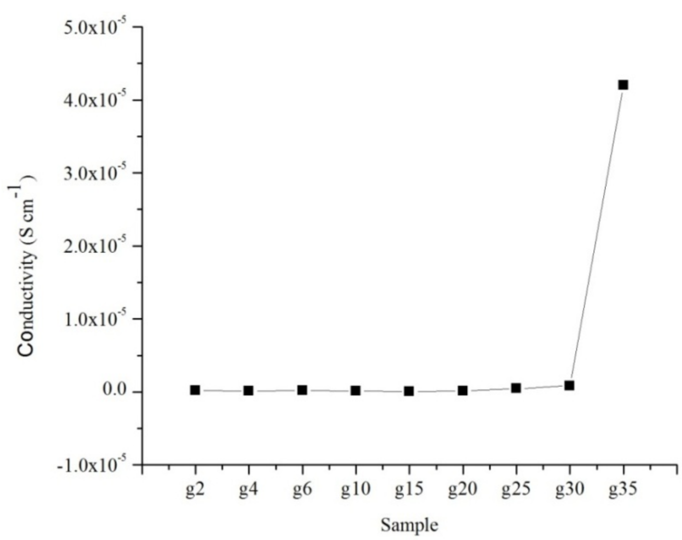
Where,
c- Capacity,
f- Frequency of the peak point of semicircle,
R- Resistance of the peak point of semicircle.

V. Results and Discussion

The samples were made by blending the two ingredients according to weight percentages. The range of graphite weight percentage was decided to be from 2% to 30%. The maximum weight percentage for graphite powder had to be kept below 30% since higher percentages caused the samples to form particles and excess graphite was left even after intensive blending. And furthermore higher percentages would cause the product to lose its semisolid nature therefore would fail in applications that it is expected to comply with.

The impedance analyzer was used to measure the conductivity of the samples. This equipment was recommended to be use in conductivity measurements of semisolid materials like most electrolytes. A separate electrode was designed equipped with a sample holder since conventional sample holders were vulnerable for contamination. The conducting length was 2 millimeters while the diameter of the surface perpendicular to the conducting length was measured to be 12 millimeters. The conducting length was kept to a minimum assuming that in real world applications, the grease coating would be around 2 millimeters. And to ensure that no surface other than the one we expect to conduct current through make contact with the sample, two over rings were placed at the end of each electrode.

The samples show a near linear variation of both characteristics of conductivity and capacity. But the final sample containing 35% graphite with 65% grease shows a significant elevation in both conductivity and capacity. With a conductivity value of 4.2008 x 10^{-5} S cm^{-1} this particular sample is in the region of semiconductors with respect to conductivity.

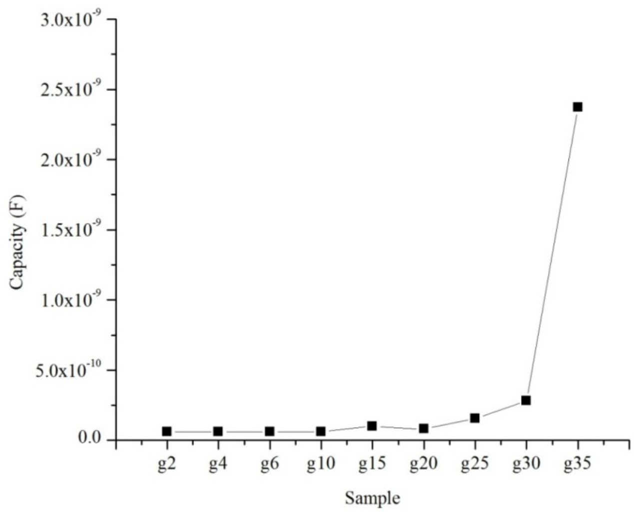


Graph 01: Conductivity variation of the sample series at room temperature

The graph indicates a clear and significant elevation of conductivity for the sample containing 35% graphite with 65%

grease while the preceding samples are scattered very closely with respect to their conductivity values.

And the capacity of the samples vary almost linearly with the amount of graphite in them and shows a rapid increase when it come to the sample with 35% graphite according to graph 2 below. The capacity values change from Pico farads to Nano farads.



Graph 02: Capacity variation of the samples in room temperature

VI. Conclusions

The samples show a near linear variation of both characteristics of conductivity and capacity. But the final sample containing 35% graphite with 65% grease shows a significant elevation in both conductivity and capacity. There for with in the specifications of the graphite powder used and upper boundary of the amount of graphite that could be added pertaining to that particle size (75 micrometers), the sample that best performed was the sample with 35% graphite, with a conductivity value of 4.2008 x 10^{-5} S cm^{-1} [7] which puts it in the region of semiconductors with respect to conductivity. And all the samples resembled a parallel plate capacitor connected to a resistance parallel, implying that they had a capacity to store static charges. And all these characteristics are in favor of the product with respect to its uses.

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