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Effects Of Doping With Iron Ill Chloride On The Electrical And Thermal Conductivities Of The Polymer Polystyrene

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ABSTRACT : *This work on effects of doping with $FeCl_3$ on the electrical and thermal conductivities of the polymer polystyrene was conducted. The idea behind this experiment is to find a means of reducing the cost of making conductive polymers since it is evident that tailor-made conductive polymers such as poly aniline, poly acetylene etc. do not actually have readily available starting materials and are quite expensive.*
Five grams of poly styrene was mixed with eight different concentrations of the $FeCl_3$ (0.00%,0.05%,0.1%,0.5%,0.75%,1.00%,1.25%,1.5%) after melting with heat application and compressed in a wooden mould into tablets of doped polystyrene materials.
On testing for the electrical and thermal conductivity of the doped polymer, it was observed that its electrical and thermal conductivities were actually enhanced by the potentiating capacities of the dopant.

KEYWORDS: *polystyrene, thermal conductivity, dopant, $FeCl_3$, electrical conductivity*

I. INTRODUCTION

Most commercially produced organic polymers are electrical insulators. Conductive organic polymers often have extruded delocalized bonds (often composed of aromatic units).When charge carriers (from the addition or removal of electrons) are introduced into the conduction or valence bands, the electrical conductivity increases dramatically. Technically almost all known conductive polymers are semi-conductors due to the band structure and low electronic mobility. However, so called zero band gap conductive polymers may behave like metals. The most notable difference between conductive polymers and inorganic semi-conductors is the mobility, which until very recently was dramatically lower in conductive polymers than their inorganic counterparts though recent advancements in molecular self- assembly are closing that gap [1].

The world electronic market has shifted its interest and concern to the use and application of conductive polymers in its production developments because of their simplicity and compactness. All hands therefore must be on deck to evolve highly conductive yet cheap polymers from readily available, easily sourced materials in our environment. This work was gingered by the above premise and its concerned was based on how the readily available polymer, polystyrene could be electrically enhanced by doping with Iron III chloride to help its conductivity, such that it can be employed for this essential function since it is evidently clear that already made conductive polymers are not readily available and are of low cost efficiency. Conductive polymers are generally not thermoplastics i.e. they are not thermo formable although like insulating polymers they are organic materials. They have an advantage over other polymers because of their processability which is mainly by dispersion [2]. The electrical properties of conductive polymers can be fine-tuned using the methods of organic synthesis [3] and by advanced dispersion techniques [4]. The conductivity of polymers is the result of several processes. In the traditional polymers such as polyethylene, the valence electrons are bound in sp^3 hybridized covalent bonds such sigma-bonding electrons have low mobility and do not contribute to the electrical conductivity of the material.

However in conjugated materials the situation is completely different .Conducting polymers have backbone of contiguous sp^2 hybridized carbon centers [5]. Conductive polymers are organic polymers that possess electrical, electronic, magnetic, and optical properties of a metal while retaining mechanical properties processibility commonly associated with a conventional polymer [6]. It can also be defined as any system that contains an additive to lower resistivity. The resistivity of unmodified polymers or plastics is 1016 Ωm while conductive additives can lower resistivity level in steps down to 104 Ωm resistivity range [7]. This work is focused primarily on the enhancement of their crucial properties: electrical and thermal conductivities that are required of a polymer for it to be accepted for all good uses especially as a semiconductor.

Commonly discarded polymer and material from the environment were used as a means of waste control. Cost management was considered since this has served as a strong limitation for their use. These desired polymers were achieved by doping with $FeCl_3$ to help lower the resistivity of the polymers thus increasing their conductivities. Hence the doping process is the introduction of very small amounts of impurities example $FeCl_3$ to generate charge carriers since concentrations of dopants cause certain electrons to become unpaired. Doping also lead to the formation of polarons and bipolarons have extended p-orbital system that have more (n-type) or fewer (p-type) valence electrons to increase the conductivity of a semiconductor [8]

II. MATERIALS AND METHODS

All the materials and equipment used for this research were sourced from the chemistry and physics research laboratories of Nnamdi Azikiwe University Awka, Cutix Nigeria Plc Nnewi and Electronic shops in Onitsha Nigeria.

2.1 Procedure

Polymer polystyrene was prepared by doping it with $fecl_3$ to enhance the electrical and thermal conductivity, considering the fact that it has some intrinsic properties. The changes and differences in the rate of increase in electrical and thermal conductivities of the polymer was also reported. White brittle pack used for protecting electronic gadgets which is pure polystyrene. Electrical weighing balance from Mettler Toledo 2007 mode serial no 021-64852350 ENGLAND, Stirring rods, Beakers (PYREX). Electro-thermal Heater of about 250^oc from Barnstaed 2006 model, serial no 10714483 England, Thermometer - 360^oC thermometer, Iron III chloride from BDH Prole, England, Wooden mold, ELMER 2AK Karthrometer, 500 mega ohms MASTECH multimeter No. 005-1349 5g of the polymer were weighed into a 250 ml beaker and heated at a regulated temperature of 130 ^{o} C - 250 ^{o} C to melt it using a thermometer and on continuous stirring to maintain a uniform temperature. During the process care was taken not to allow degradation. The dopant of known different percentage concentrations 0.00, 0.05, 0.10, 0.50, 0.75, 1.00, 1.25, 1.50 was added into the beaker containing the polymer and the two mixed thoroughly while heating respectively. The mixture was then poured immediately into the mold and compressed to form a doped tablet of polystyrene. Their electrical conductivities were measured using 500 mega ohms MASTECH multimeter No. 005-1349 .Electrical conductivity is the reciprocal of resitivity ,K =1/R
Where K –Electrical conductivity, R- Resitivity
The thermal conductivity was measured with ELMER 2AK Kathrometer

TABLE 1:Formulation of doped polystyrene

Polystyrene (g)	% concentration of $Fecl_3$
5.00	0.00
5.00	0.05
5.00	0.10
5.00	0.50
5.00	0.75
5.00	1.00
5.00	1.25
5.00	1.50

III. RESULTS & DISCUSSION

The results of electrical and thermal conductivities of the polystyrene doped with $FeCl_3$ are shown in tables 2&3

TABLE 2:Electrical conductivity of polystyrene doped with $fecl_3$

% concentration of dopant	Polystyrene doped with $fecl_3$ (x 10^{-6} S/cm)
0	0
0.05	0.08
0.10	0.56
0.50	0.67
0.75	0.83
1.00	0.90
1.25	1.00
1.50	1.11

Iron III chloride is a transition element with a half filled d- orbital thus it is highly reactive. $FeCl_3$ is a deliquescent salt that on exposure at laboratory ambient conditions absorbs water from the atmosphere thus has its nature turned to be wet and will encourage ionization of the salt and thus leaving the dopant with a lot of free electrons. One can also deduce that the movement of electron from the valence band of the polymer into the partially filled conductive band of Fe^{3+} would also be efficient in explaining the excellent performance of the polymer doped with $fecl_3$. The nature of $FeCl_3$ explained above results in formation of 'metallic island' concept in which case the islands of $FeCl_3$ would have conducted electricity through its own intrinsic property as a metallic conductor. It is important to note that in doping with $fecl_3$ there is a spiking from 0.05wt % - 0.10wt %, from which one can deduce that the rate of increase in electrical conductivity of polystyrene at lower concentration tend to be doubled and the rate decreases as the dopants concentration increases. It therefore appears like the electron conductive band gets saturated at a given concentration thus further addition of dopants results in marginal electron transfer activity which results in a reduction. On the other hand polystyrene has a dielectric constant determined by the additive effects of electronic and dipolar polarizabilities the latter is due to the presence of permanent electric dipoles. Polystyrene is essentially non polar with an effective dipole moment of 6.7- 10 x 10^{-31}cm per repeating unit [9] .these effects of the electronic and dipolar polarizabilities is increased by the presence of the dopant thereby creating dipole moments that improve electrical conductivities through polaron assisted tunneling.

TABLE 3 :Thermal conductivity of polystyrene doped with $FeCl_3$

% concentration of dopant	Polystyrene doped with $FeCl_3$ (x 10^{-2} Cal/cm/s)
0.00	0.00
0.05	0.10
0.10	0.20
0.50	2.72
0.75	3.07
1.00	3.85
1.25	4.23
1.50	5.3

The thermal conductivities of the doped polystyrene were increased with increase in the concentration of the dopants. The increase may be due to compactness provided by increase in concentration of the dopants which increase heat transfer through phonon. The intrinsic dipolarity property and amorphous nature of polystyrene made a negligible contribution to the thermal conductivity of its parent form but could be said to have made significant contribution to the thermal conductivity of the doped polystyrene due to its interaction with the delocalized electron in the $FeCl_3$. The density contributes to the thermal property of polystyrene. The free electrons in the $FeCl_3$ could have improved the dipolarity thereby increasing significantly the contribution of electron mobility in conduction through the $FeCl_3$ doped polystyrene. The half – filled orbital structure of $FeCl_3$ would have contributed to the improvement of the polystyrene density which will improve thermal conductivity by wave movement (phonon) or inter atomic heat transfer.

IV. CONCLUSION

The electrical and thermal conductivity of the polymer polystyrene were enhanced and this enhancement is dependent on the nature and properties of the polymer and the dopant. It is also evident that since this is possible, discarded polymers can be employed for some industrial use when improved to the required standard.

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