ISSN: 0974-5823 Vol. 7 No. 10 October, 2022

International Journal of Mechanical Engineering

Thermal Conductivity, Mechanical Properties, and Thermal Properties of Polycarbonate Composite Materials Reinforced With Talc and Some Ceramic Fillers

Lanh T. Pham

Faculty of Biotechnology, Chemistry and Environmental Engineering,

Phenikaa University, Yen Nghia, Ha Dong, Ha Noi, Viet Nam.

Cuong V. Tran

Faculty of Biotechnology, Chemistry and Environmental Engineering,

Phenikaa University, Yen Nghia, Ha Dong, Ha Noi, Viet Nam.

Duc M. Vu

Faculty of Biotechnology, Chemistry and Environmental Engineering,

Phenikaa University, Yen Nghia, Ha Dong, Ha Noi, Viet Nam.

Dung V. Nguyen

Laboratory of Polymer and Composite Materials, Institute of Materials Science,

Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Cau Giay, Ha Noi, Vietnam.

Trang T. Tran

Laboratory of Polymer and Composite Materials, Institute of Materials Science,

Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Cau Giay, Ha Noi, Vietnam.

The K. Ngo

Laboratory of Polymer and Composite Materials, Institute of Materials Science,

Vietnam Academy of Science and Technology, 18 Hoang Quoc Viet, Cau Giay, Ha Noi, Vietnam.

Abstract Polymers are widely used as insulating materials. However, a lot of effort has been made to improve their properties, especially their thermal conductivity. The goal is to create materials with high thermal conductivity to dissipate heat efficiently. In this study, the influence of fillers: talc, aluminum nitride, and boron nitride on the thermal conductivity and mechanical properties of polycarbonate (PC) was investigated. The fillers were modified with silane coupling agents and composites were prepared by a twins screw extruder. It has been shown that: in comparison with neat PC, the thermal conductivity of composites with 50% wt. modified talc, BN and AlN increase significantly: 457%, 307% and 294% respectively. Tensile strength, flexible strength and izod impact strength decrease by adding these fillers. In the presence of a coupling agent, mechanical properties show a little improvement compared to the samples without a coupling agent. Using silane coupling agents has improved the interaction between the fillers and PC matrix in composite materials. The study also showed that: talc is quite a suitable filler to increase the thermal conductivity of polymer composite materials from PC.

Index Terms - Polycarbonate, boron nitride, aluminum nitride, talc, thermal conductivity

1. INTRODUCTION

Currently, in the market, the heat sink of LED bulbs is usually made from aluminum. Using metal heat sinks brings high heat dissipation efficiency, but it also has some disadvantages such as high volume, complicated machining, high cost of materials, etc. This is particularly disadvantageous with high-powered LEDs when large and heavy heat sinks are used. The solution of using heat sinks made of polymeric material is to overcome the limitations above. However, the low thermal conductivity of the polymer leads to some application limitations of this material. Therefore, the research on the fabrication of heat-conducting polymer materials from polycarbonate with mechanical strength meeting the requirements and application orientation in LED lighting technology has been conducted to improve the thermal conductivity of polycarbonates and expand their applicability in electrical-electronic equipment in general and LED light fabrication in particular.

In general, polycarbonate is heat-insulation material, reinforced with ceramic or other heat-conducting fillers to increase the thermal conductivity and its application in electricity and electronics. The choice of fillers is based on the desirable properties of the material. The thermal conductivity of the polymer can be achieved by using ceramic fillers. Current studies are all about making electric-insulating but efficient heat-conducting materials. The study by Julia A. King et al. [1] focused on creating a material with thermal conductivity based on nylon 66 and polycarbonate used for heat dissipation applications. Three carbon fillers are used: carbon black, granular synthetic graphite, and fibrous carbon. The objective of this study was to determine the influences and interaction of each filler on the thermal conductivity characteristics of the resin. The result showed that the surface thermal conductivity of both nylon 6.6 and granular synthetic graphite-reinforced polycarbonate resin increased the most, followed by carbon fiber. Khatua et al. [2] investigated the fabrication and thermal conductivity of polycarbonate (PC)/aluminum oxide (Al_2O_3) composite materials. First, nano Al_2O_3 powder was synthesized and dispersed into methylmethacrylate (MMA), followed by bulk polymerization. Nanocomposite PC/PMMA-Al_2O_3 with different Al_2O_3 content was prepared by mixing PMMA- Al_2O_3 melt mixture with PC. Incorporating Al_2O_3 into PMMA by bulk polymerization has a good efficiency in dispersing Al_2O_3 particles in the PC matrix. The influence of Al_2O_3 particle size on thermal conductivity and mechanical and optical properties of composite materials has been studied.

Introducing fillers with high thermal conductivity such as aluminum nitride or boron nitride into electric-insulating polymers is also a common way of improving materials' electrical, mechanical, and thermal properties [3]. It is also possible to use talc as a reinforcing filler to increase the thermal conductivity of some composite polymer materials [4]. Improving the thermal conductivity of polymers will open up many applications for this material. Composite materials with thermal conductivity of about 1-30 W/m.K can be used to build heat sinks in electrical, electronic systems,...[5].

2. EXPERIMENT

2.1. Raw materials

Polycarbonate (PC)

Granular Polycarbonate (Redwood Plastics Corporation), the density of 1.2 g/cm^3, and the soft melting temperature of 428 – 446^{o}F (220 – 230^{o}C).

Mineral talc

Talc minerals originate from Thanh Son, Thanh Thuy, Phu Tho Province, with the main composition of oxides, of which SiO_2 accounts for 61.8% and MgO for 28.5%.

Aluminum nitride

Aluminum nitride (AlN) powder originates from China, and the average particle size is 5-10 µm.

Boron nitride

Boron nitride (BN) originates from China, and the average particle size is 5-10 µm.

Surface modifier

The surface modifier is a silane coupling agent from Dow Corning (USA):

- γ-Aminopropyltrimethoxysilane
- Vinyltriethoxysilane

PP-g-MA: the product from Polymer Center, Hanoi University of Science and Technology.

2.2 Prototype research and fabrication methods

2.2.1. Prototype fabrication process

a. Surface modification of talc, AlN, and BN fillers

The modification of the mineral filler surface by the solution method was carried out as follows: the silane compound was diluted at a concentration of 4% in a 96% ethanol solution pH adjusted to 4-5 with acetic acid. The filler is then introduced into the silanizing solution. The silanized solution was stirred for 30 minutes. The mixture was stirred for 4 hours at 30°C, then filtered and dried at 50°C for 8 hours under atmospheric pressure.

b. Process for fabricating a composite prototype from PC resin

The granulation mixing method was carried out on a twin-screw extruder - Leistritz at the Polymer Center, Hanoi University of Science and Technology.

The process is carried out as follows: the PC mixture and the filler in certain proportions and components are mixed together and then fed to a preheated device feed hopper. The feed speed and the rotation speed of the shaft are adjusted accordingly. The material mixture after exiting the barrel is passed through a water-cooled system, then through a cutter to granulate.

The temperature of the heaters during the mixing process is shown in Table 1.

c. Forming press method

The mixture of materials after being homogeneously mixed and granulated, is pressed in blocks according to the required size of the methods of measuring material properties on a Gotech 30T hot press machine at the Polymer Center, Hanoi University of Science and Technology.

Take the mold and cool the prototype. The material was fed into the pre-filled size mold and fed into a pre-heated press at 270 °C. Maintain the temperature and press pressure of 100 kgf/cm2 for 10 minutes then release the pressure and increase the pressure to 100 kgf/cm2 again, maintaining for 5 minutes. The prototype was allowed to stabilize at least 24 hours prior to the property measurements.

Table 1.

Temperature (°C) of the extruder heaters during prototype fabrication

Heaters **Material sample**	**1**	**2**	**3**	**4**	**5**		**6**	**7**	**8**	**9**	**10**
PC/Talc	260	265	265	265	265		265	260	260	260	255
PC/BN	255	260	265	265	265		265	260	260	255	255
PC/AlN	255	260	265	265	265		265	260	260	255	255

2.2.2. Research Methods

a. Thermogravimetric analysis

The thermal strength of the material was evaluated by differential thermal analysis. Measurements were performed on Netzsch STA 409 thermogravimetric analyzer (DTA, TG).

The analysis was performed under the following conditions:

+ Heat lifting speed: 10^0C/min.

+ Research temperature range: 25 - 800 ^{0}C.

+ Environment: air

b. Scanning Electron Microscopy (SEM)

The fracture surface morphology of the material was studied by high-resolution scanning electron microscopy (FE-SEM) on a Hitachi S-4800 instrument.

c. Method of determining thermal conductivity

The thermal conductivity of the composite material samples was measured on a C-therm TCI^{TM} thermal conductivity measuring instrument in accordance with ASTM D784.

The fabricated material prototype has a size of ≥ 17mm and a thickness of ≥ 0.5mm.

d. Group of methods for determining mechanical properties of materials

The elongated mechanical properties of the PC and composite material samples were determined on the GOTECH AI-7000-M instrument. The technical parameters of the meter are as follows:

Force sensor: 20 kN

Load resolution: 1/200 000

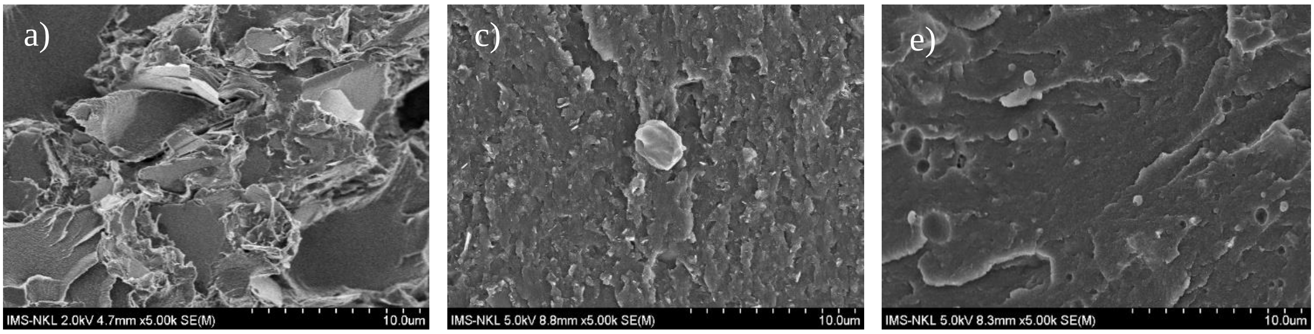
Load accuracy: ± 0.5%

Test speed: 0.0001- 1000 mm/min

3. RESULTS AND ARGUMENTS

3.1. Material surface morphology

SEM imaging of the destructive surfaces of different material samples was performed: PC resin samples containing 30% unmodified and aminosilanes modified talc, AlN and BN. The result is shown in figure 1.



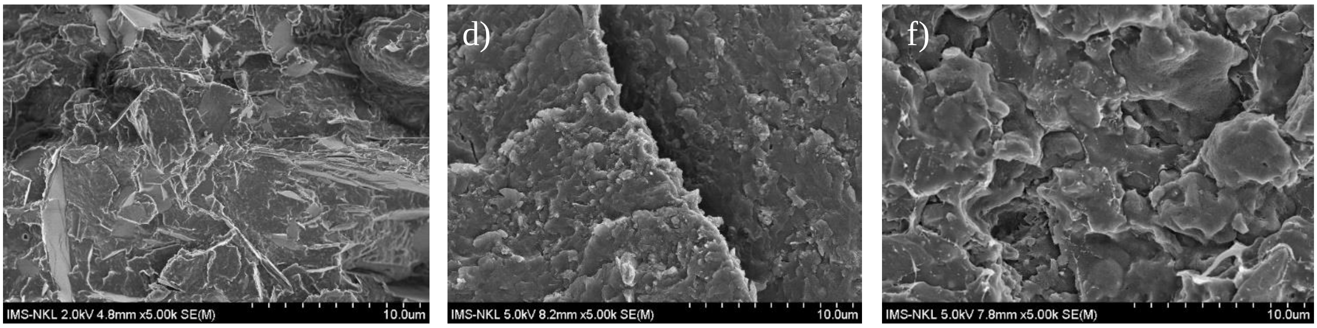


Figure. 1.

SEM images of the destructive surface of PC sample containing 30% unmodified talc (a); 30% amino silane modified talc (b); 30% unmodified BN (c); 30% amino silane modified BN (d), 30% unmodified AlN (e) and 30% amino silane modified AlN (f)

From the SEM images of PC samples containing unmodified and aminosilanes modified talc, BN and AlN (Figure 1), it was found that the silane binding agent has a significant influence on uniformly dispersing talc, BN and AlN into PC-based resin. In addition, the filler particle size is also reduced in the presence of the silane coupling agent.

With unmodified PC/BN and PC/AlN composite samples (Figures 1c,e), on the destructive surface of the sample, there were some filler particles with a size of more than 1 µm distributed scattered in the PC resin matrix. The phase interaction between the matrix resin and the filler is very poor in that the filler particles after peeling off leave a flat, smooth surface and the gap between the filler particles and the polymer matrix is quite large. The above phenomena have been thoroughly overcome with the addition of silian amino binder: improved phase interaction, reduced filler particle size and no longer large micrometer-sized particles appearing in the PC matrix (Figures 1d,f).

The silane binder also has the same effect as the PC/talc composite material. The more uniform degree of dispersion and the reduced filler particle size (Figures 1 a, b) are the most specific demonstrations of the role and effect of aminosilanes in improving the degree of phase interaction between polymer and filler particle.

3.2. Mechanical properties of materials

In order to investigate the mechanical properties of PC-based resin with 3 types of filler including talc, BN and AlN, materials from PC and the above fillers at the contents from 0 to 50% by the method of mixing the molten mixture on a twin-screw extruder have been fabricated. The sample after mixing is hot pressed in the mold to form a pattern. The mechanical properties of the PC-based composite material were determined after allowing to stabilize for at least 24 hours. The survey results are shown in Figures 2 and 3.

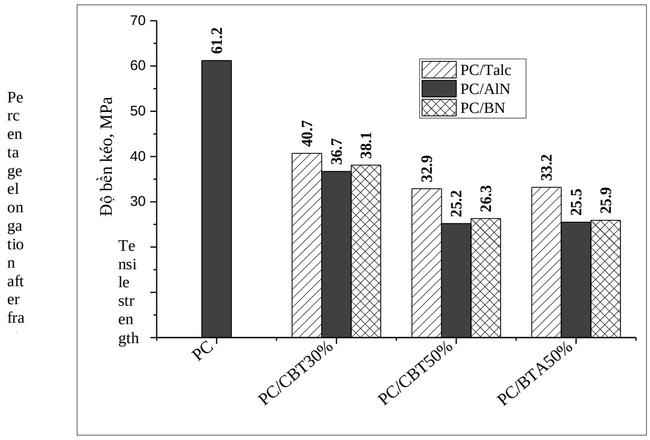


Figure 2.

Effect of filler on tensile properties of composites

(PC: polycarbonate; CBT: unmodified, BTA: aminosilane modified, BTV: vinylsilane modified)

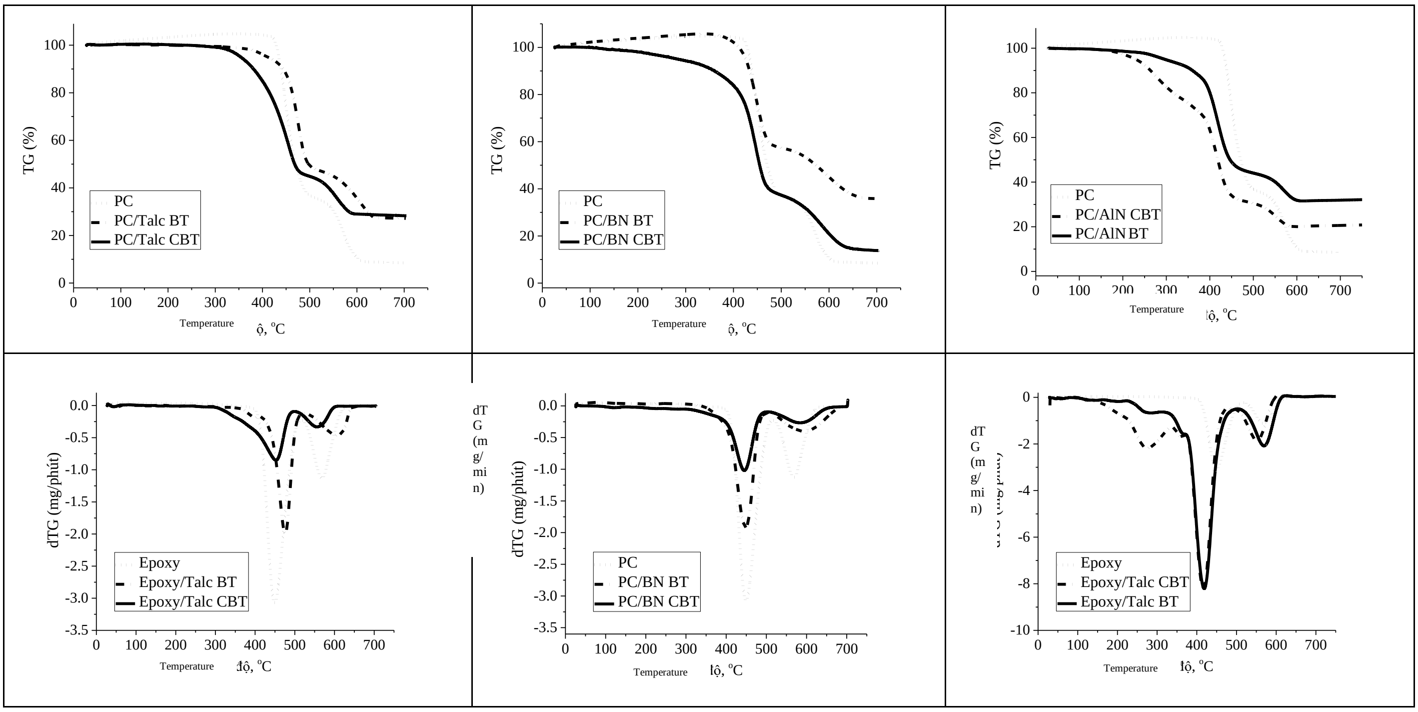


Figure 4.

TGA/dTG schema of PC-based composite samples:

(a,b) PC/talc 30% unmodified (PC/talc CBT) and amino silane modified (PC/talc BT),

(c,d) PC/BN 30% unmodified (PC/BN CBT) and amino silane modified (PC/BN BT)

(e,f) PC/AlN 30% unmodified (PC/AlN CBT) and amino silane modified (PC/AlN BT)

From the TGA/dTG survey tests of PC-based composites with 30% talc, AlN and BN found that the filler did not significantly affect the thermal strength of the composites. From the above schemas, we have the table of thermal parameters of materials (Table 2) below:

Table 2.

TGA and DSC data of the composite sample from PC

No.	**Sample name**	**$T_{50\%}$**	**T_{max}**
1	PC	485.4	449.2
2	PC/BN CBT30%	454.8	445.4
3	PC /BN BTA30%	468.2	452.3
4	PC /talc CBT30%	472.8	448.3
5	PC /talc BTA30%	497.1	475.7
6	PC/AlN CBT30%	417.1	417.2
7	PC/AlN BTA30%	443.6	418.7

(T_{50}: the temperature at which the sample is decomposed by 50%, T_{max}: the temperature at which the sample is decomposed at the greatest rate)

.4. Thermal conductivity and resistivity of PC-based composite materials

Ceramic fillers (BN, AlN, SiC, etc.) are commonly used to fabricate heat-conducting polymer materials due to their high thermal conductivity. The thermal conductivity of polymer materials depends greatly on the type and content of filler. Characteristics of filler particle size, compatibility with base resin, degree of purity, etc. have a great influence on the thermal conductivity properties of the material. Therefore, the influence of filler type on thermal conductivity of composite was investigated. The result is shown in figure 5.

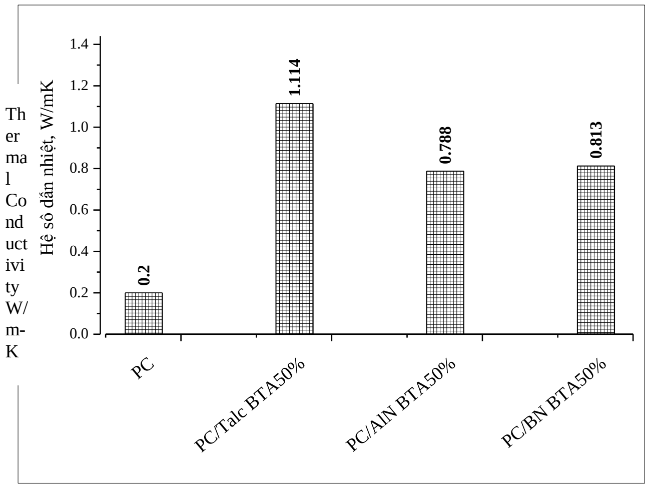


Figure 5.

Influence of fillers on the thermal conductivity of polycarbonate-based composites

From the results of measuring the thermal conductivity of PC-based composite materials Figure 5 shows that all 3 types of fillers selected for the stud

From the results of measuring the thermal conductivity of PC-based composite materials Figure 5 shows that all 3 types of fillers selected for the study are talc, BN, and AlN capable of enhancing the thermal conductivity of PC. The thermal conductivity increases when the filler is surface-modified with aminosilanes and the filler content increases.

When using an AlN filler, the highest thermal conductivity of the PC composite sample is 0.788 W/mK (294% increase compared to the sample without filler). However, compared to the other two fillers BN and talc, AlN has a lower level of thermal conductivity increase because AlN molecules are very susceptible to hydrolysis when exposed to moist air which reduces the material's thermal conductivity.

Considering the effect of talc on the thermal conductivity of the material, it was found that for composite material from PC resin and 50% aminosilane modified talc, the thermal conductivity increased by 457% (reaching 1.114 W/mK) compared to PC without filler.

With the sample of composite from PC resin, when introducing 50% of modified BN powder, the thermal conductivity increased by about 307% compared to the PC without filler (reaching 0.813 W/mK).

Thus, the combination of micro-nano fillers with high thermal conductivity: AlN (thermal conductivity of about 200 W/mK); BN (thermal conductivity of 250 – 300 W/mK); and talc (thermal conductivity of only about 10.6 W/mK) (modified) strongly increased the thermal conductivity of the composite material from PC. Changing filler particles has broken some particle sets, reducing the filler particle size, thus increasing the total number of filler particles in the base resin (at the same content). Smaller-sized particles can fill in voids in the material bed or voids between large filler particles, increasing the likelihood of forming efficient thermal pathways in the material mass. Therefore, the presence of modified talc, BN and AlN fillers increases the thermal conductivity network in the material. On the other hand, when agitated at high speed, along with good compatibility, the matrix resin can be pushed into the gap in the agglomerates resulting in more efficient heat transfer between the filler and the matrix resin.

Talc has a much lower thermal conductivity in all three fillers than AlN and BN. However, the efficiency of enhancing the thermal conductivity for composites is much better. This proves that the thermal conductivity of the composite material depends not only on the thermal conductivity of the components but also on several other factors.

4. LITERATURE REVIEW

Conductivity is the major aspect of conducting polymers. Conducting polymers are accompanied by the amorphous structure, unlike the crystalline structures, which consist of conduction and valence bands, while the carriers are mobile in energy bands. Charge carriers are positioned in conducting polymers' local doping energy level [1]. The Conductivity of conducting polymers is a temperature dependence that is the same in semiconductors; hence it obeys the Mott Variable Range Hopping (VRH) model. The conductivity property of the conducting polymers is nearly associated with the polymer main chain's ordering degree. The Conductivity of conjugated macromolecules increases with respect to the increase in the doping degree of the conjugated polymers.

Conductive polymers do not dissolve in water due to their inflexible conjugated main chain, which reduces their uses. Some companies have tried to look for a solution to insolubility by manufacturing a soluble conducting polymer by counter anion-induced solubility.

4.1. Conductive polymers

The conductive polymer is the most crucial research subject in recent times and is characterized by various applications. These macromolecular polymeric have material-specified properties like electrical transportation, as indicated by their name. The conductive polymer may be characterized as a conductor due to metallic conductivity [7]. Initially, the polymer was considered the insulating material that was used to insulate the conducting wire. Four major classes of a polymer have been developed with respect to their ability to conduct. These include conjugated conducting polymer, charge transfer polymer, ionically conducting polymer, and conductively filled polymer.

Since 1970, scientists have been struggling hard to synthesize more conducting polymers and find their more innovative applications in the different fields like polymeric light-emitting diodes, corrosion resistance substances, sensor technology, supercapacitor, electromagnetic devices, electromagnetic shielding, etc. Different properties like corrosion resistance, ecological integrity, and matrix incongruity have made it more worthy and demanding in recent decades. The Nobel Prize in chemistry in 2000 was awarded to MacDiarmid, indicating the importance of conducting polymer in this era [2].

4.2. Band Theory

The electrical Conductivity of conjugated polymer can be explained in a better way in terms of band theory for the insulator, semiconductor, and conductors. In any solid, two energy levels exist: the highest energy level designated as the valence band and the lowest energy level called the conduction band [2]. The difference in energy between these two bands is known as the energy band gap. In metal, valence and conduction band overlap, allowing the free electron to occupy the conduction band and show good electrical conduction.

Insulator has a band gap energy larger than 3eV that inhibits the free movement of the electron from the valence band to the conduction band, even an increase in temperature does not favor the jumping of the electron from the valence band to the conduction band

Conducting polymer has a large band gap ranging from 1eV to 3eV. The valence band is nominated as a highly occupied molecular orbital (HOMO), and the high energy band is nominated as the lowest occupied molecular orbital (LOMO) [4]. Conduction polymer normally behaves as a semiconductor but, under the reduced or oxidized states, shows high Conductivity due to the decreased band gap.

4.4. Doping process in conductive polymer

Conductive polymers are different from a semiconductor with respect to the doping process [9]. In a semiconductor, the impurities occupy a specific position in the lattice, used to increase the charge carriers leading to the increase in the Conductivity. But in the conductive polymer, there is a transfer of charges due to the oxidation and reduction process During the duration oxidation process, an electron is removed from the polymer leading to the formation of a free electron and spineless positive charge. These charges are coupled together in the resonance process [3]. The charging site and radical electron are commonly known as polaron, which carries ½ charge and +e. It leads to the creation of a new electronic state which has low energy and is occupied by a single electron. Removal of the second electron produces two positive charges [26]. The polymeric chain having two charges is called bipolaron. The Conductivity in conducting polymer increases due to the charge movement along the polymer backbone, creating an electrical current known as intrachain mobility.

4.5. Hoping process in conductive polymer

The mechanism of Conductivity in the conductive polymer can be explained by understanding the impact of temperature on the Conductivity of the polymer. Under ordinary conditions, the conducting polymer behaves as a semiconductor. Arrhenius model and variable range hopping model are used to expose the Conductivity of the conducting polymer [2]. According to the Arrhenius model, in the disordered material, transportation of the charge carrier takes place by photon-assisted hopping between occupied and unoccupied localized states.

Overall, polymers are generally used as electrical insulators due to the high resistivity they possess [8]. With increasing technology, designers have decided to blend conduction characteristics to these polymers by using conductive materials such as conducting polymers, carbon fillers, carbon blacks, and metal particles. The filler particles are arranged in such a way that the Conductivity of the material is realized, and this process can be described by medium theories or by percolation. The microstructure of the filler particles is taken into consideration, whereby it is observed that the polymer matrix directly influences electrical Conductivity to a larger degree because of its property of elasticity [9]. By applying heat to these conducting polymer composites, electrical Conductivity can either be increased or reduced depending on the desired outcome

4.6. Application of Conductive Polymer

4.6.1. Supercapacitors

Supercapacitors have been engrossed in the production of modern electrode materials, which have increased efficiency. The Supercapacitors are categorized into the following classes conducting polymers, high-surface carbons, and transition metal oxides. Supercapacitors are also known as ultra-capacitors or electrochemical capacitors. The manufacturing of the modern electric vehicle leads to an increase in demand for high-power energy resources that are non-pollutant to the environment [18]. These high-power energy resources are not charged using batteries, but rather they use the capacitors in order for them to store power. Supercapacitors are marketable due to the upgrade of large braking and acceleration, which makes electric vehicles to be more effective and efficient.

The capacitances are given in Mf and μF quantities. Supercapacitors are made to give thousands of farads [18]. However, these devices develop their performance from the double-layer capacitance known as electrochemical double-layer capacitors. The pseudo capacitor, which is one of the Supercapacitors, derives its performance from the storage of charge in the bulk of a redox material in response to an oxidation and reduction reaction. The fact that the pseudo capacitors rely on redox reaction makes its store greater capacitance as compared to EDLC.

Light Emitting Diodes (Led)

Polymer light-emitting diodes have become an upcoming and one of the best products in the market for commercial purposes. The main advantages of the polymer electroluminescence devices are as follows:

Have good processing ability

Response with respect to time is good

Use low voltage in its operation

The most commonly used LEDs are green and orange LEDs, which are largely found in the market [8]. The performance of the PLEDS can be improved by adjusting the chemical structure of the polymer with bulky phenyl side groups or by the use of the PPV-based alternative copolymers technique.

4.6.2. Solar Cell

The use of polymeric materials has been considered most in the manufacturing and designing of cheap electronic appliances, photovoltaic devices, and plastic electronics. The organic technology and the siliconbased photovoltaic complement one another [9]. Some factors that affect the efficiency of the OPVs are the morphology of the film, the choice of electron acceptor, and the structure of the polymer.

4.6.3. Carbon Nanotubes

Nanotechnology has brought evolutionary changes in present-day life. It is a technology that provides important information about the material like its properties, structure, etc. [19]. Carbon nanotubes (CNTs) are an allotropic form of carbon that is cylindrically arranged. They have a bundle of applications in different fields like material science, optics, and Nano-electronics. CNTs have a wide range of applications, imparted due to their extraordinary strength and thermal, mechanical, and electrical properties. Actually, the CNTs are the other name for buck tubes. They belong to the fullerene family, discovered by Kroto in years of 1985.

It is considered tubular fullerene, comprising two steps for its synthesis. Graphene is a flat sheet of carbon that is sp2 hybridized. This sheet is rolled in a cylindrical shape in order to form the different isotopes of carbon like fullerene, Graphite, and CNTs. [18] Exposed that the diameter of CNTs is about 10 thousand times smaller than that of natural hair. CNTs were the first time noticed in soot synthesized by the CO decomposition in the presence of the iron catalyst at 600 C. long; filamentary carbon crystals were noticed, which were mainly characterized by a Transmission electron microscope. It was also noticed that these cylindrical shape crystals of carbon are 50nm in diameter. However, the discovery remained unnoticed due to the low concentration of researchers on nanotechnology. Nowadays, CNTs have turned from dream material to real-world material [21]. Its application fields are growing day by day, enclosing different fields like energy devices, composites, medical and electronic applications, etc. The number of layers, chirality, control of diameter, and purity are some critical parameters for making CNTs novel in their application. To make the CNTs more effective in their applications, it is needed to take control over these parameters so that all the potential of CNTs can be utilized.

5. CONCLUSION

There is extensive utilization of polymers in the contemporary world with the essentiality for materials that can offer various characteristics that are hard to obtain from individual materials. It is essential the incorporation of other materials that have the ability to yield better properties in comparison to their individual materials. This paper will analyze polycarbonate to help us gain a better understanding of its responses and reactions to nanomaterials that specifically focus on Graphene. This study also carries out the identification of the Graphene effect on the polycarbonate composites' effects of transparency on strength and additional mechanical properties such as impact performance and abrasion. This paper focuses on the methods used in the preparation of polycarbonate composites (PC) and Phosphorus-containing polyhedral Oligomeric silsesquioxane (POSS). As such, SEM observations of Graphene in polycarbonate and POSS dispersion are identified in this study. In composite formulation, it is very fundamental to gain a deep understanding of the various techniques that are employed in the reduction of the separation of the phase in a measure aimed at increasing interfacial adhesion between an arrays of components used in the formulation of the composite. Polymer compatibility poses a significant challenge when it comes to composite development. As such, the various techniques used in the incorporation of POSS and Graphene in polycarbonate and the steps and the ways in which they affect the overall outcomes are discussed in this paper.

Graphite has gained a significant amount of attention when it comes to composite formulation since it is used as a relevant material in this process. As such, Graphene enables property modification of materials on a Nano scale. As such, the price of Graphite is relatively cheaper and readily available and, therefore, can be economically used in composite property improvement. Graphene possesses a resistivity of 50 micro-ohms centimeters and an in-plane stiffness of 1060 Gpa. The study into Graphene's thermal Conductivity shows that 3000W is the approximate thermal Conductivity and also possesses a 98.7% transmission normal to the beam of incidence as obtained from the first layer of the Raman intensity. Additionally, Graphene also has a 2.4% transmission reduction for a vacuum's subsequent layers (Abbasi et al. 2010).

Graphene also has mechanical peeling properties. As such, the polymer Nanocomposites of Graphene have a significant number of applications, such as field emission displays, emissive displays, micro chemical uses, and transparent conductors, among many others. In updated technologies, Graphene has attracted a significant amount of interest towards polycarbonate polymers modification; studies show the capabilities of Graphene to affect the mechanical stability and improve mechanical properties as it mainly focuses on the overall viscosities of composites, affects polycarbonate composites' transparency, and improve resistance to significant forces such as punching. Graphene has a number of properties that enhance its suitability as a nanomaterial that can improve the interface properties and the surface of polycarbonate composites. Graphene possesses good capabilities for transferring electrons resulting in improvement of electrical properties in its applications. Graphene is also very strong when it comes to compressive stress (Al-lafi et al., 2016). This is attributed to its strong covalent bonds, therefore, improving stress or load transfer in polycarbonate composites. Graphene introduction results in the improvement of compatibility and dispersion of a polymer matrix to various Nanocomposite materials. Graphene's van der wall relationship with aromatic structures is very fundamental in the transportation of electrons. The polycarbonates of Graphene have good process ability, which is evident from the extended pair model of approximation. This study will also talk about Graphene that has been subjected to chemical modification and imparts a number of properties for increased inclusion in the composite matrices. Additionally, the electrical properties, optical properties, fracture toughness, and mechanical properties of Graphene are studied (Balandin et al. 2008).

The filler is more uniformly dispersed in the base resin. The level of interaction between the base resin and the filler powder phase in the composite material is markedly improved when using the amino silane binding agent.

All three fillers including talc, BN, and AlN have a great influence on the mechanical properties of PC-based composite materials. In the presence of a binding agent, the strength is slightly improved compared to a sample with the same filler content without using a binding agent. In general, when the filler content increases from 0 to 50%, the mechanical strength of the material decreases.

When introducing talc, BN and AlN into the material, it has a significant effect on increasing the thermal conductivity of the material, in which talc proved most effective: With 50% aminosilane-modified talc, the thermal conductivity increased 457% compared to PC without filler (reaching 1.114W/mK).

Acknowledgments. *The authors would like to thank the Key Laboratory of Polymer and Composite Materials – Institute of Materials Sciences – Vietnam Academy of Science and Technology for its support in facilities and funding to carry out this study.*

REFERENCES

[1] Erik H. Weber, Matthew L. Clingerman, Julia A. King. Thermally conductive nylon 6,6 and polycarbonate-based resins. I. Synergistic effects of carbon fillers. Inc. J Appl Polym Sci 88: 112–122, 2003.

[2] Tvarit Patel, Supratim Suin, D. Bhattacharya & B. B. Khatua. Transparent and Thermally Conductive Polycarbonate (PC)/Alumina (Al_2O_3) Nanocomposites: Preparation and Characterizations. Polymer-Plastics Technology and Engineering, Volume 52, Issue 15, 2013.

[3] Hu M.; Yu D. & Wei J. Thermal conductivity determination of small polymer samples by differential scanning calorimetry. Polymer Testing, vol.26, pp.333-337, 2007.

[4] Nguyen Viet Dung, Ngo Ke The, Nguyen Van Thuy, Pham Thi Lanh, Nguyen Ngoc Tu, Tran Thu Trang - Effect of talc mineral content and phase interaction on mechanical properties and thermal conductivity of polypropylene-based composites. VNU, Hanoi Journal of Science: Natural Sciences and Technology, Vol. 32(4), 77-82, 2016.

[5] Wypych G. Handbook of fillers: physical properties of fillers and filled materials, ChemTec Publishing, Toronto, 2000.

[6] Z. Han and A. Fina, “Thermal conductivity of carbon nanotubes and their polymer nanocomposites: a review,” Progr. Polym. Sci., vol. 36, no. 7, pp. 914-944, 2011.

[7] R. Kochetov, Thermal and electrical properties of nanocomposites, including material processing, PhD dissertation, Delft University of Technology, 2012.

[8] M. Choudhury, S. Mohanty, S. K. Nayak, and R. Aphale, “Preparation and characterization of electrically and thermally conductive polymeric nanocomposites,” J. Minerals Mater. Charact. Eng., vol 11, pp. 744-756, 2012.

[9] Han Z. & Fina A. Thermal conductivity of carbon nanotubes and their polymer nanocomposites: A review, Progress in Polymer Science, vol.36, Issue 7, pp.914-944, 2011.

[10] Julia A. King. Characterization of exfoliated graphite nanoplatelets/polycarbonate composites: electrical and thermal conductivity, and tensile, flexural, and rheological properties. Journal of Composite Materials August 15, 2011.

[11] Huang, X., Fan, Y., Zhang, J., & Jiang, P. (2017). Polypropylene based thermoplastic polymers for potential recyclable HVDC cable insulation applications. IEEE Transactions on Dielectrics and Electrical Insulation, 24(3), 1446-1456.

[12] Easter, M. R. (2009). U.S. Patent No. 7,473,742. Washington, DC: U.S. Patent and Trademark Office.

[13] Kodur, V. K. R., Bhatt, P. P., & Naser, M. Z. (2019). High temperature properties of fiber reinforced polymers and fire insulation for fire resistance modeling of strengthened concrete structures. Composites Part B: Engineering, 175, 107104.

[14] Yang, Y., He, J., Li, Q., Gao, L., Hu, J., Zeng, R., ... & Wang, Q. (2019). Self-healing of electrical damage in polymers using superparamagnetic nanoparticles. Nature nanotechnology, 14(2), 151-155.

[15] Wang, G., Zhao, J., Mark, L. H., Wang, G., Yu, K., Wang, C., ... & Zhao, G. (2017). Ultratough and super thermal-insulation nanocellular PMMA/TPU. Chemical Engineering Journal, 325, 632-646.

[16] Rogers, L., Clark, R. A., Jones, B. J. P., McDonald, A. D., Nygren, D. R., Psihas, F., ... & Bailey, K. (2018). High voltage insulation and gas absorption of polymers in high pressure argon and xenon gases. Journal of Instrumentation, 13(10), P10002.

[17] Tu, Y., Chen, J., Wang, S., & Wang, W. (2016). Moisture migration in oil-impregnated film insulation under thermal ageing. IEEE transactions on Dielectrics and Electrical Insulation, 23(2), 1135-1141.