ELECTRICAL AND EMI SHIELDING PROPERTIES OF SONICATION AND IRRADIATION MODIFIED GRAPHENE NANOPLATELETS FILLED THERMOPLASTIC POLYMER NATURAL RUBBER NANOCOMPOSITES

This report is submitted in accordance with the requirement of the University Teknikal Malaysia Melaka (UTeM) for Bachelor's Degree in Manufacturing Engineering (Hons.)

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I hereby, declared this report entitled "Electrical and EMI shielding properties of sonication and irradiation modified graphene nanoplatelets filled thermoplastic polymer natural rubber nanocomposites" is the result of my own research except as cited in references.

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APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Hons.). The members of the supervisory committee are as follow:

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ABSTRAK

Kegiatan elektromagnetik telah timbul dari kerumitan peranti elektronik yang semakin meningkat dalam bentuk kepadatan pakej yang lebih tinggi untuk masa reaksi yang lebih pendek. Oleh itu, keperluan untuk melindungi bahan dengan berkesan dari kesan berbahaya telah menjadi perhatian besar. Untuk mengurangkan masalah yang timbul kerana EMI, bahan pelindung yang berkesan diperlukan untuk melindungi pengoperasian sistem elektronik dan elektrikal yang mahir. Secara amnya, polimer seperti polipropilena (PP) adalah penebat, dengan kategori polimer yang sedang berkembang menjadi pengecualian, walaupun sukar, keanjalannya rendah, dan mahal untuk menggunakan polimer pengalir sebagai struktur yang tersendiri untuk tujuan pelindung EMI. Oleh itu, hibridisasi polimer tanpa pengisi dengan graphene dan karbon hitam yang lebih murah dicadangkan sebagai bahan pelindung EMI. Nanokomposit getah semula jadi polimer pengisi hibrid akan disediakan menggunakan pencampuran lebur dalaman. Sifat pelindung termoplastik hibrid diperoleh menggunakan ujian Analisis Rangkaian Vektor. Data dianalisis lebih lanjut melalui ciri morfologi oleh SEM, analisis struktur melalui XRD, sifat elektrik melalui analisis terma, dan ujian ketahanan permukaan. Keberkesanan pelindung nanokomposit elastomer termoplastik hibrid ternyata lebih baik daripada bahan pelindung sedia ada. Penambahan hanya 1phr Nanoplatelet Graphene mencukupi untuk meningkatkan kekonduksian elektrik dengan ketara dan penambahan jumlah yang sedikit Nanotube Karbon juga menyumbang dalam meningkatkan kestabilan terma komposit. Dengan dos penyinaran tertentu yang terdedah pada Nanoplatelet Graphene juga membantu dalam meningkatkan keberkesanan pelindung sampel komposit. Hasil kajian ini sangat penting dalam menyumbang kepada pengembangan industri teknologi elektronik dan juga bermanfaat bagi alam sekitar.

ABSTRACT

The electromagnetic activity has arisen from the rising complexity of electronic devices in the form of higher package density for shorter reaction time. Therefore, the need for efficient protection of materials from their harmful effects has been a great concern. To reduce these issues arising due to EMI, effective shielding materials are required to protect the proficient operation of electronics and electrical systems. In general, polymers such as polypropylene (PP) are insulators, with a developing category of polymer conducting being an exemption, although it is difficult, low elasticity, and expensive to use conducting polymers as stand-alone structures for EMI shielding purposes. Therefore, the hybridization of non-filler polymer with graphene and cheaper carbon black is suggested as an EMI shielding material. The hybrid filler filled polymer natural rubber nanocomposites are prepared using internal melt mixing. The shielding properties of the hybrid thermoplastic are obtained using Vector Network Analysis test. The data are further analyzed via morphological characteristics by SEM, structural analysis through XRD, electrical properties through thermal analysis, and surface resistivity test. It is expected that the effectiveness of shielding of the hybrid thermoplastic elastomer nanocomposites turns out to be better than existing shielding materials. Addition of only 1phr of Graphene Nanoplatelets are sufficient to significantly increase the electrical conductivity and addition minimal amount of Carbon Nanotubes also contributes to improve the thermal stability of the composites. With certain doses of irradiation exposed on the Graphene Nanoplatelets also helps in increasing the shielding effectiveness of the composites sample. This study’s results are critical in contributing to the development of the electronic technology industry as well as beneficial to the environment.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Over the years of technological advancement and evolution, digital electronic and telecommunication devices create undesired electromagnetic pollution (interference) and is a growing concern in the industry. Electromagnetic interference (EMI), also known as radio frequency interference (RFI) in the radio frequency spectrum, is a disturbance induced by an external source that influences the electrical circuit by electromagnetic induction, electrostatic coupling, or conduction. This intervention can impact the output of the electronic system or even stop it from functioning. Any materials acquiring the characteristics needed for shielding have been used to avoid this problem. Electrical and magnetic dissipation influences that attenuate the electrical and magnetic elements of EM waves are mainly these characteristics. Electrical conductivity is one of the main considerations for electromagnetic interference (EMI) shielding; to be able to lessen the EM waves, the material should have a particular degree of electrical conductivity. In addition to the fact that a system does not produce radiation that interferes with another, electronic systems must be capable of working from other sources under EMI; that is to say, they must be electromagnetically compatible. (EMC) (Lowell, n.d.).

Efficient shielding materials are needed to protect the effective operation of electro/electrical systems in order to mitigate these problems resulting from EMI. Optimized use of lossy dielectric materials and magnetic materials is one of the known solutions in the removal of EMI as they protect the electronic devices by reflection and absorption from unnecessary EM radiation. Absorption dominant shielding materials are particularly desirable for devices rather than reflection, as reflection can again lead to more interfering results for devices nearby. Thin, lightweight, less density, wide-range frequency bandwidth, and strong absorption potential are some of the good qualities of strong absorbing material. In the chosen matrix, a feasible mixture of magnetic and dielectric fillers will create a strong absorbent EMI shield (Garg et al., 2020).

Sheet metal, metal screens, and metal foam are the most common materials used for electromagnetic shielding. For insulation, these traditional sheet metals include copper, brass, nickel, silver, steel, and tin. The metal's physical characteristics affect shielding effectiveness, which is how much electromagnetic radiation is mirrored or absorbed/suppressed by a shield. Conductivity, solderability, porosity, thickness, and weight may be included here. In material selection, the properties of a metal are an important factor. For example, electrically dominant waves are reflected by highly conductive metals such as silver, copper, and brass, whereas magnetically dominant waves are absorbed/suppressed by less conductive metals such as steel and stainless steel.

Plastic shielding has many benefits over concrete, as Quantum Devices and several other producers have learned. It is lighter, less costly, and more corrosion resistant. It also gives greater freedom of design for complicated shapes, consolidation of components, and assembly choices (Shielding With Thermoplastic Compounds, 2000). Nanocomposites are ideal as high-performance composite materials for applications where good filler dispersion can be obtained and the properties of the nanometer size filler are dramatically different or better than those of the matrix. Graphene with exceptionally high mechanical, thermal and electrical properties is very appropriate as a nanofiller in polymer matrixes for the manufacture of high-performance nanocomposites. Since polymeric nanocomposites were found (Okada et al., 1990), diverse types of fillers have been tried for developing nanocomposites with improved properties. Different fillers for the processing of nanocomposites with improved properties have been sought. These comprise inorganic fillers, such as layered silicate compounds or synthetic clay of the natural montmorillonite type, metal nanofillers, a variety of nanoparticles, and carbon-based fillers such as carbon black, extended graphite (EG), carbon nanotubes (CNT), and carbon nanofiber.

Polymers such as polypropylene (PP) are insulators with an evolving category of polymer conducting being an exemption. Conducting polymers makes a straightforward alternative while selecting polymeric materials for EMI shielding application (Jia et al., 2018). The use of conducting polymers as stand-alone structures for the purpose of EMI shielding is complicated. Hence, the way forward could be to mix conducting polymers with the most stable and durable thermoplastics. By combining two related polymers for EMI shielding, several researchers have used the idea of mixtures. Obviously, blending would express the individual characteristics of the result. One of the key criteria, if not the only one for EMI shielding blends, is to perform network development. A conducting network composition is one of the main requirements if not the only one for EMI shielding blends (Shakir et al., 2019).

1.2 Problem Statement

In this modernized age, where every person would at least have an electronic device such as a smartphone. Unfortunately, some electronic devices despite having the newest technology in the industry would be fit only with conventional thermoplastic in its structural component in order to cut cost. This conventional thermoplastic is easily penetrated by EMI. Since electromagnetic interference (EMI) usually occurs on a daily basis, such as microphone noise from a mobile phone handshake with a communication tower for call handling, television transmission-reception distortion, and radio frequency interference, most electronic devices must be shielded against electromagnetic interference (EMI) or electrostatic discharge (ESD), especially in military discharge.

Lately, polymer composites have earned recognition because of their lightweight, corrosion resistivity, structural flexibility, excellent processability which can be further modified based on user requirements compared with conventional metal-based structures (Pang et al., 2014). Due to their electrically-isolating and non-magnetic nature, polymeric fabrics are invisible to electromagnetic radiation. the best approach to resolve this EMI problem is by electrically dispersed conductive fillers or inherently conducting polymers inside polymer matrices. Polymer blends are a group of products that have better properties than their individual components and are both ecologically and economically scalable (Smitthipong et al., 2009). Polymer blends have common usage and can for certain practical uses supplement conventional materials, such as metals. However, the final properties of the blends depend on the morphology produced during processing and the interfacial bond between the matrix and the reinforcement. The theory of nanoparticles to stabilize the blend morphology and selective position of nanoparticles in a particular stage has gained considerable enthusiasm in recent times, as it also contributes to the simultaneous enhancement of functional properties (magnetic/electrical/optical).

Over the years, different types of fillers, such as talc, glass fibers, carbon black, layered silicates, and calcium carbonate, have been used to improve the properties of polymers and reduce the cost of polymer products. Among the numerous fillers, due to their high mechanical strength and high aspect ratio, carbonate nanofillers such as carbon nanotubes (CNTs) and graphene nanosheets (G) have made a major contribution to the regulation of the mechanical, thermal, and electrical properties of polymers (Roy et al., 2012). The outstanding characteristics of graphene and its ability to spread in different polymeric matrices have allowed the creating of new polymeric nanocomposite classes.

1.3 Objectives

The overall objective of this project is to analyse the electrical and EMI shielding properties of irradiation modified graphene nanoplatelets filled thermoplastic polymer natural rubber nanocomposites. There are several objectives listed below that need to achieve in this project:

- To evaluate the impact of filler hybridization on the electrical and shielding properties of PP/NR thermoplastic elastomers.
- To investigate the effect of electron beam irradiation on the nanofiller electrical and shielding properties of nanofiller filled PP/NR composites.

1.4 Scope of Study

This project is feasibility study to test the amount of graphene nanoplatelets added to thermoplastic polymer natural rubber nanocomposites to increase the electrical properties. The electron beam irradiation on composites will be applied to improve the filler distribution, hence increase the performance of the nanocomposites.

1.5 Rationale of Research

The following is the rational of research:

a) The increasing amount of electronic devices lead to electromagnetic radiation pollution.
b) The flexibility of EMI shielding material to be used in small size electronic devices.
c) Conduct research in shielding effectiveness test to improve the materials used for EMI shielding.
d) Conduct analysis on the produced TPE added filler to collect data as the results of this study.

1.6 Summary of Methodology

Below is the proposed research methodology in stages:
Stage 1: Preparation of raw material.
Stage 2: Preparation of electron beam irradiation on the TPE added filler.
Stage 3: Characterise the TPE added filler for viscosity, swelling, and surface fracture.
Stage 4: Further analyse the TPE added filler for morphological, shielding effectiveness, and thermal characteristic.

1.7 Thesis Arrangement

The arrangement of the thesis consists of 5 chapters and each chapter gives information related to the research interest of electrical and EMI shielding properties of irradiation modified graphene nanoplatelets filled with thermoplastic polymer natural rubber nanocomposites.

- **Chapter 1** is about the introduction of the research. This introduction includes the background of the study, problem statement, objectives of the research, scope of the research, rationale of research, a summary of the methodology, and thesis arrangement. It is to inform the reader regarding the background and objectives of the research as well as how the thesis will be presented.

- **Chapter 2** is a literature review of the project. Its consists of an explanation regarding the EMI interference and shielding, materials for EMI shielding, fillers, thermoplastic polymer natural rubber, and the blending effects.
- **Chapter 3** is about the methodology of the research. It contains the information on materials, parameters, equipment, materials preparation, and procedure of this research.
- **Chapter 4** consists of the result and discussion of the research. The results are obtained from the testing and analysis in Chapter 3 will be recorded and tabulated in this chapter. The results will be analyzed and discussed relative to the problem statement.
- **Chapter 5** is about the conclusion of the research. The whole research was concluded, and future suggestions will be discussed in this chapter.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

This section revises the scope of earlier research work related to Polypropylene(PP) and Natural Rubber (NR) filled with different types of fillers from a few years back. In recent years, there is also some research work reported on electrical properties of PP/NR filled with fillers. However, until today there is a limited source of information especially on PP/NR filled with Graphene Nanoplatelets (GNP).

2.1 Electromagnetic Interference (EMI) Shielding

EMI is the interference created by the electromagnetic fields formed by its activity between one electrical or electronic unit and another. Electromagnetic waves are produced from accelerated electrically charged particles and these waves will then contact with other charged particles, exerting influence on them. EM waves are taken away from their source particle by energy, momentum, and angular momentum and can impart those quantities to the matter in which they interact. Electromagnetic interference (EMI) also can be explained as a condition that may occur during an electromagnetic (EM) field exposure to an electronic system. EMI can be vulnerable to any system which has electronic circuitry. EMI problems are gaining concern with the growing use of the electromagnetic spectrum and the increasingly advanced and specialized electronic devices.

EMI Shielding describes as the protection of radio wave or microwave radiation such that the radiation, which acts as a radiation blocker, can effectively not penetrate the shield. The EMI shielding functions by blocking interference from any incoming or outgoing equipment, because EMI comes from high-frequency electromagnetic waves generated from the electronic system to the surrounding field. EMI shielding involves isolating or diminishing electromagnetic waves beyond the shielded region by shielding the body to minimize or remove the harmful impacts of electromagnetic waves inside the shielded area on sensitive structures, electronics, or human bodies.

The EMI shield also referred to as the Faraday cage, is a tiny metal box covering a PCB circuit or segment. These are five-sided boxes in certain situations or made of a two-piece cover and frame connected to the board with clips, pins, and holes, or by soldering. The box walls may be made of solid metal (i.e. without holes), metal mesh, or metal with holes of a prearranged dimension, called apertures. The structure of the wall depends on whether the frequency is released or blocked. The lower frequencies produce bigger waves that can be blocked with holes by material, and higher frequencies mean smaller waves that involve a thick mesh or solid material (CepTech, 2020).

The resonance of the cavity is a challenge related to the box's form and dimensions. For such frequencies, the gap or cavity within the box becomes significant and may lead to emission leakage. Emissions may cross through apertures that are too wide (common advice is a hole that smaller than 1/20 of the wavelength and as tiny as 1/50 of the size), seams, and slots, particularly with shorter wavelengths affecting from high-frequency circuits. Although removing the holes can sound rational, they also allow the flow of air and thermal build-up control. Furthermore, a solid enclosure can be more complicated, difficult, and costly to produce, depending on the configuration.

2.1.1 Theory of EMI shielding

The ratio of affecting energy to the remaining energy is the shielding efficacy. Absorption and reflection occur as an electric pulse travel through a plate. The remaining energy is a portion of the residual energy that the shield does not express or consume, but escapes from the shield. As seen in Figure 2.1, all electromagnetic waves consist of two basic elements, a magnetic field (H) and an electric field (E) (Geetha et al., 2009).

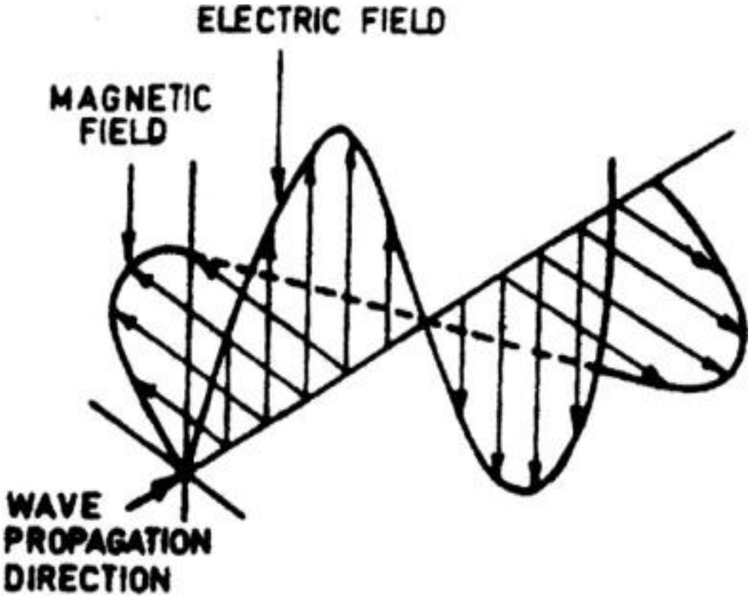

Figure 2. 1: The Electromagnetic Radiation Vector.

These two fields are vertical to each other, and at correct angles to the plane comprising the two elements, the direction of wave propagation is. The relative magnitude depends on the waveform and its source. Wave impedance is considered the ratio of E to H. 377 Ω[7]. EMI shielding consists of two zones, the near field shielding area and the far-field shielding area, which is the inherent impedance of free space. When the distance between the source of radiation and the shield is greater than $\lambda/2\pi$ (where λ is the source wavelength), it is in the area of far-field shielding. For EMI shielding in this area, the electromagnetic plane wave concept is commonly applied. It is in near field shielding where the gap is less than $\lambda/2\pi$, and the principle is used for EMI shielding depending on the role of electric and magnetic dipoles (Geetha et al., 2009).

Shielding effectiveness (SE) is the ratio of the field before and after mitigation of electric and magnetic field and can be expressed as

$$SE = 20 \log (E_t = E_i)$$

$$SE = 20 \log (H_t = H_i)$$

where E and H are electric and magnetic fields and the subscripts t and i refer to the transmitted and incident waves. E is measured in volts/m and H in amps/m. SE is the function of frequency (Geetha et al., 2009).