PREPARATION AND CHARACTERIZATION OF NATURAL RUBBER LATEX FILLED WITH STANNIC OXIDE NANOCOMPOSITES

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

by

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DECLARATION

I hereby, declared this report entitled "Preparation And Characterization Of Natural Rubber Latex Filled With Stannic Oxide 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 a partial fulfilment of the requirement for Bachelor Degree of Manufacturing Engineering (Hons). The member of the supervisory committee is as follow:

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ABSTRACT

Nano sized filler reinforced to the natural rubber latex was to generate high performance of the natural rubber based composites. The purpose of preparing this study is to determine the effects of stannic oxide (SnO_2) nanofiller loadings and ultrasonication period to the tensile strength of NRL/SnO_2 nanocomposites. This study also had aimed to correlate between the mechanical tensile strength, physical properties and the electrical surface resistivity properties of NRL/SnO_2 nanocomposites based on the fracture surface morphology. The study was designed followed by the standard operation procedure which utilizing the solution casting method by using the response surface methodology. From this study, the good dispersion of stannic oxide into the natural rubber latex based nanocomposites was expected based on the good result of tensile strength for the fracture surface morphological. This study was to understand the interaction involved between the process variable of the solution mixing for the preparation of NRL/SnO_2 nanocomposites via two-level full factorial approach. There are two (2) independent variables which are the filler loadings (wt. %) and stirring period (minutes), involved in this work. A set of by 2^2 two-level full factorial design with three (3) replications at a center point and no block was applied to yield a total set of 7 set of experiments. The DesignExpert 6.0.8 statistical software had optimized the resulted tensile strength (TS) response as dependent variable of prepared NRL/SnO_2 nanocomposites. Fracture surface morphological observation via SEM has been performed to correlate further the interaction between the processing variables toward the resulted TS response. In overall of this study, it has significance to facilitate manual processing of the composites started at the early integration between the stannic oxide as reinforcement phase and natural rubber latex as the matrix phase using horn sonication method and magnetic stirrer.

ABSTRAK

Pengisi bersaiz nano yang diperkukuh kepada lateks getah asli adalah untuk menjana prestasi tinggi komposit berasaskan getah asli. Tujuan penyediaan kajian ini adalah untuk menentukan kesan muatan stannik oksida (SnO_2) bersaiz nano dan tempoh ultrasonik terhadap kekuatan tegangan nanokomposit NRL/SnO_2. Kajian ini juga bertujuan untuk menghubungkaitkan antara kekuatan mekanikal, sifat fizikal dan sifat kerintangan permukaan elektrik bagi komposit NRL/SnO_2 berdasarkan morfologi permukaan patah. Kajian ini direka bentuk diikuti dengan prosedur operasi piawai yang menggunakan kaedah tuangan larutan dengan menggunakan metodologi permukaan tindak balas. Daripada kajian ini, serakan stannik oksida yang baik ke dalam nanokomposit berasaskan lateks getah asli dijangka berdasarkan keputusan kekuatan tegangan yang baik untuk morfologi permukaan patah. Kajian ini adalah untuk memahami interaksi yang terlibat antara pembolehubah proses pencampuran larutan untuk penyediaan nanokomposit NRL/SnO_2 melalui pendekatan faktorial penuh dua peringkat. Terdapat dua (2) pembolehubah tidak bersandar iaitu beban pengisi (wt. %) dan tempoh kacau (minit), yang terlibat dalam kerja ini. Satu set dengan 2^2 reka bentuk faktorial penuh dua peringkat dengan tiga (3) ulangan pada titik tengah dan tiada blok digunakan untuk menghasilkan jumlah set 7 set eksperimen. Perisian statistik DesignExpert 6.0.8 telah mengoptimumkan tindak balas kekuatan tegangan (TS) yang terhasil sebagai pembolehubah bersandar bagi nanokomposit NRL/SnO_2 yang disediakan. Pemerhatian morfologi permukaan patah melalui SEM telah dilakukan untuk mengaitkan lagi interaksi antara pembolehubah pemprosesan terhadap tindak balas TS yang terhasil. Secara keseluruhan kajian ini, ia mempunyai kepentingan untuk memudahkan pemprosesan manual komposit bermula pada penyepaduan awal antara stannik oksida sebagai fasa tetulang dan lateks getah asli sebagai fasa matriks menggunakan kaedah tanduk sonikasi dan pengacau magnet.

DEDICATION

My beloved mother, Rohaiza Asmari

My beloved father, Ameruddin Yusof

My adored sisters and brother, Natasha, Sabrina and Daniel

for giving me moral support, money, cooperation, encouragement and also understandings

Thank You So Much & Love You All Forever

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By The Name of Allah The Most Merciful and Gracious

In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project successfully without difficulty.

First of all, I wanted to thank my parents Encik Ameruddin Yusof and Puan Rohaiza Asmari for their moral support since starting till the end. Next, thank to my supervisor, Associate Professor Ts. Dr. Jeefferie Bin Abd Razak who has given me guide and sufficient informations, etc. upon completion of my PSM report writing as well as experimentation. I would also like to thank UTeM's technician who had given a lot of help. I would also like to thank other lecturers who have been so cooperatively effort. Finally, thank you to all my friends. For those who read this technical report, thank you for spending your precious time.

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LIST OF ABBREVIATIONS

IC	-	Integrated chip
SEM	-	Scanning electron microscope
NRL	-	Natural rubber latex
NR	-	Natural rubber
SnO_2	-	Stannic oxide
TAB	-	Tape automated bonding
DOE	-	Design of experiment

CHAPTER 1
INTRODUCTION

This chapter provides full explanation about the background of study, problem statement, research objectives, scope of study, rationale of research and thesis organization. The relevancy of conducting this research is comprehensively justified and accomplished. Furthermore, in this chapter, depth and limitation of investigation are covered in the research scopes.

1.1 Background of Study

Electronic packaging is the design of housing or enclosure for electronic devices up into one complete system. Packaging of an electronic devices are crucial to provide robust protection from mechanical damage, electrostatic discharge, moisture and many other external factors which reducing the reliability of electronic products. There are lots of problem might occur due to disruption of electrical system such as components that burn-out and explosion when the temperature rise-up. This happens when the electronics packaging material is unable to accommodate the amount of voltage or current that passes through. Therefore, the breakdown voltage or current for electronics packaging material should play an important role in this research. This study aim to formulate new advanced material for such purpose using natural rubber latex based nanocomposite in considering the flexibility of rubber and functionalities of nanocomposite system.

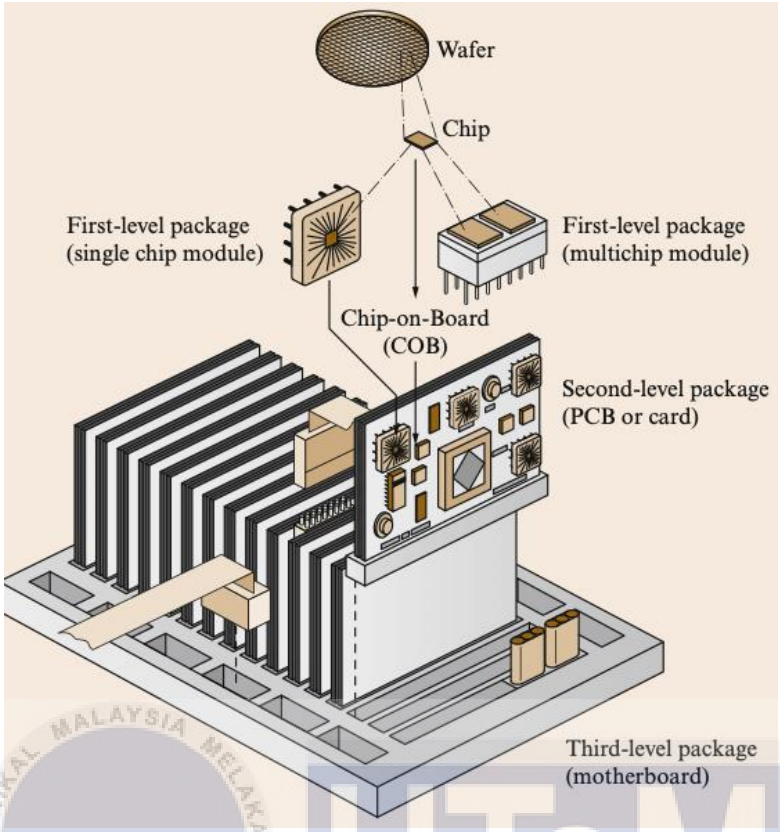

Figure 1.1: Electronic packaging application (Suhling, 2008)

The following Figure 1.1, depicts the common structure of integrated circuit (IC) electronic packaging. In one complete electronic packaging system or assembly, it might consist of component devices, circuit card assemblies, connectors, cables and components such as transformer, power supplies relays and switches. Electronic package is considered material intensive system. The families of materials included in one package are consists of but not limited to semiconductor, ceramics, glasses and metal. Insulation part is the most crucial component in any electrical and electronic packaging system. The insulator parts are included to cope with high speed electronics of integrated circuit. The insulation material for electronic packaging must have several characteristics of high resistivity, high moisture resistance or hydrophobic, able to bear vibration. Insulation material in electronic packaging are found in transformers, electric switches and circuit breakers. Most common insulator material for electronic packaging are made from polymer material such as polyethylene (PE), polytetrafluoroethylene (TEFLON) (Amin, 2016). The real motivation in developing reliable insulator for electronic packaging are able increasing due to demands on high speed switching in electronic and IC. Recently, the application of nanocomposites are overwhelmingly increase due to enhance insulation properties by increasing the material

resistance towards the dielectric breakdown, partial discharge resistance, tracking resistance, higher thermal conductivity and higher glass transition temperature, as major failure of high power electronic devices are normally due to the failure of dielectric insulation or can be called it as breakdown voltage. The following Figure 1.2 depict and architecture of electronic packaging , that forming insulation part or substrate (Houzet and Gregory et al. 2021).

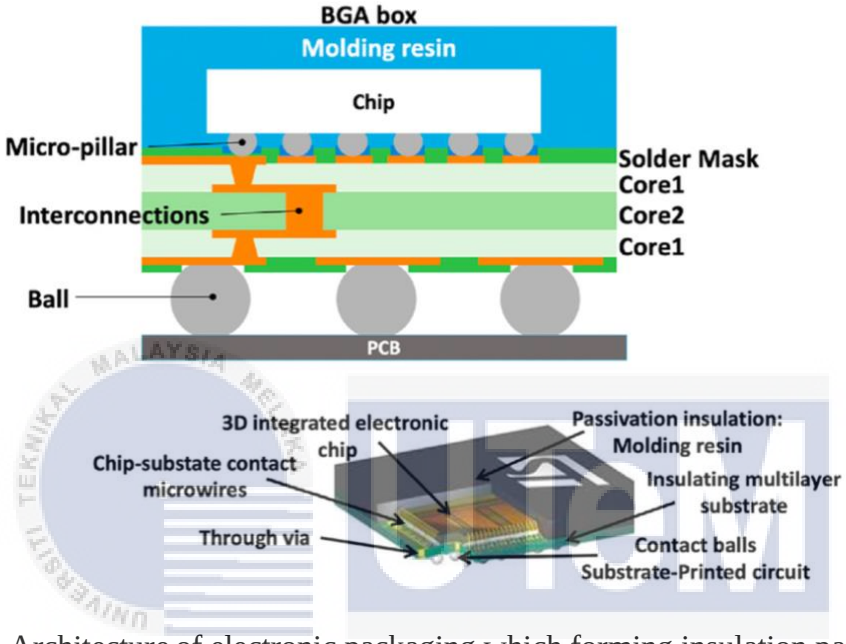

Figure 1.2: Architecture of electronic packaging which forming insulation part/insulating substrate (Houzet and Gregory et al. 2021)

Breakdown voltage can be defined as potential difference in voltage which applies across an electrically insulating layer that is just enough to cause a disruptive discharge. It is a local phenomenon in an insulating media subjected to a large voltage difference. All materials will eventually conduct the electrical current if the application of the potential energy (voltage) is high enough (Anon, 2018). The application of voltage is required to cause the breakdown in a given insulating object known as breakdown voltage object. It is where the failure occurred and the material is no longer electrically insulating. Electrical insulator is when the dielectric material does not allow current to pass through even when the voltage across them are under normal circumstances. Although breakdown voltage will be larger for thicker materials and smaller for thinner materials, the dielectric strength are remains unchanged, theoretically. To summarize, the arcing between electrical contacts is when the electrical potential between difference charged contacts reaches the breakdown voltage. This

will results the electrons have sufficient energy to escape the cathode to travel towards anode. The electrons will collide with an ionize gas molecules between the exchanged contacts and will producing more freely electrons attracted to the anode. Oppositely, the positive ions attracted to cathode then will move towards cathode. Furthermore, the contact between ion and electrons produce heat and emitted more ions and electrons as they collide to each other. However, electrons will flow through the arc until current and voltage falls below critical threshold and the arc extinguishes. The following Figure 1.3 shows the details description of how electrical arcs form under sufficient voltage to initiate electrical breakdown of gap and subsequent arc.

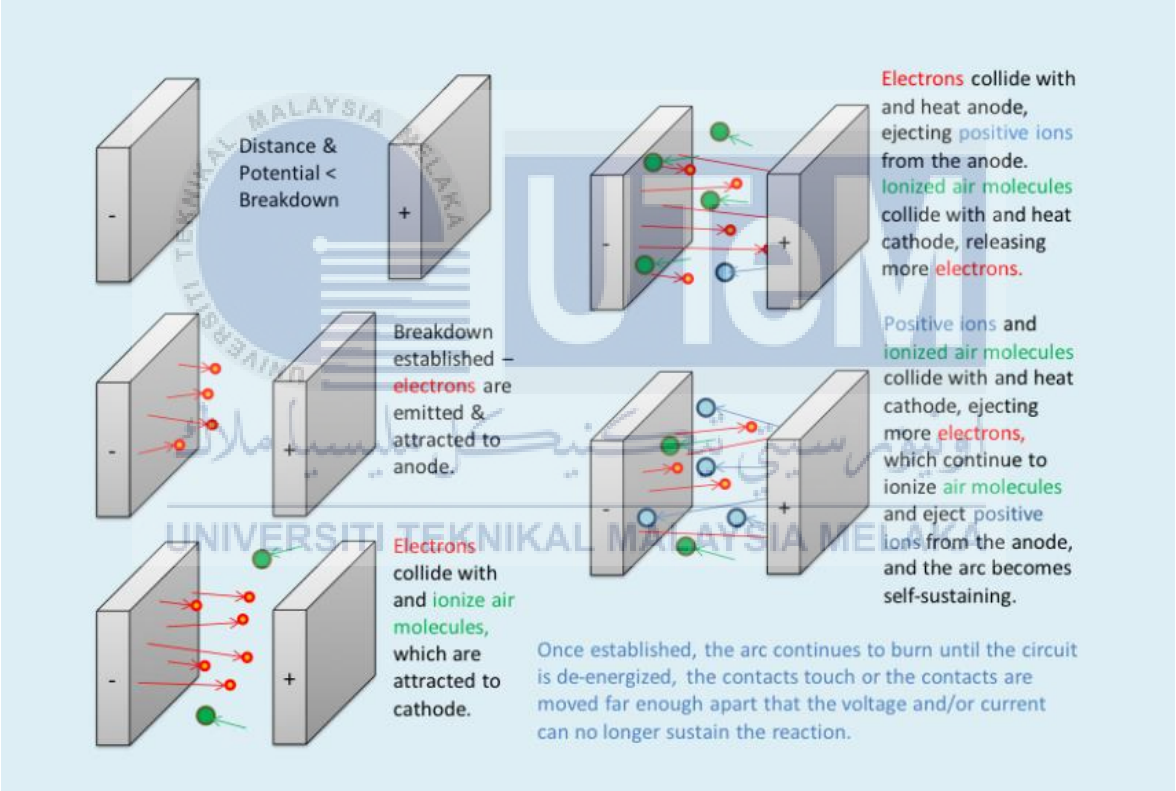

Figure 1.3: Details description of electrical arcs form under sufficient voltage to initiate electrical breakdown of gap and subsequent arc (Anon, 2018)

Dielectrics materials responsible for not allowing the current to flow through it. They are commonly known as insulators because its function is an opposite of conductor materials. All the insulators dielectrics have the special property which is known as polarizability. However, the good dielectric is one which is easily polarized. Due to that, the amount of polarization that occur when the voltage is applied to an object will affect the amount of electrical energy that been stored in the electrical field. In addition, a good dielectric material should have good dielectric constant, dielectric strength, low loss factor, higher temperature stability, high storage ability and also good frequency response. In this study, dielectrics play an important role in high frequency integrated circuits. It is because the dielectric materials are important to provide protection for an electronic devices packaging system.

Meanwhile, dielectric breakdown is a process that occurs when an electrical insulating material is subjected to high level voltage and abruptly becomes an electrical conductor, which allowing the electrical current to flow through it. All the insulating materials will undergo breakdown when the electrical field caused by an applied voltage exceeds their dielectric strength. Currently, electronic industry had emphasized on utilizing sustainable materials in their electronic packaging design. This to allow them, applying green economy in their production. Considering Malaysia as one major producer for natural rubber latex and tin, utilization of local resources might give extra benefits and profits to this industry. Development of robust insulator for IC design using these materials might be compelling, as the source are abundant in our country and easily available for industrial usage. Thus, in this study, natural rubber latex was utilized as polymer matrix or substrate, while stannic or tin oxides are added as nanofiller in dielectric NRL/SnO_2 nanocomposites preparation for electronic packaging purposes.

Natural rubber latex (NRL) is produced from Hevea Brasiliensis trees. Major commercial source of natural rubber is the Amazonian rubber tree, the family of Euphorbiaceae. Natural rubber is classified as polymer that is in a form of milky white fluid known as latex obtained from the rubber tree. Polymer is a chemical compound which made by many small molecules known as monomers of the same kind to produce large macromolecules. Natural rubber is obtained from latex that is referred to any polymer in water-based liquid or viscous state. Natural rubber latex is composed of about 55% of water and around 40% of rubber material.

In this era, natural rubber latex is attractive for several applications due to its lower temperature flexibility, higher elasticity, fatigue resistance and low heat build-up. Its low temperature flexibility will not cause harm but higher temperature can pose an issue, especially for electronic packaging application. Thus, the strategy of adding filler will be beneficial. The most ideal temperature range to use latex is between -55°C until 82°C. Natural rubber latex will begin to degrade with the temperature of above 82°C. However, by adding treatment chemicals is one of the solution that can protect latex from degradation due to heat, ultraviolet light and also oxygenation.

In another way, natural rubber latex can be reinforced by adding fillers. This is because, fillers and reinforcements are used to alter and also to improve the physical and mechanical properties of the natural rubber latex. It usually increasing the hardness and the durability of the natural rubber. However, fillers can also be used as a method to improvise the properties such as thermal conductivity, electrical resistivity, friction, flame resistance and wear resistance. In addition, this process is used to reduce the cost of rubber compounding. Fillers can be found in two basic type which are conductive fillers and extender fillers. Conductive fillers are used to increase the electrical and the thermal conductivity. Meanwhile, the extender fillers are used to reduce the material costs or as cheapener. Some of the filler available in the market are likes inorganic minerals, metal particles or natural filler. In this study, tin or stannic oxides was used as filler for natural rubber latex based nanocomposites.

Tin (Sn) is an element under the group 14 of the periodic table. Tin is soft and silvery-white metal. This element is not easily oxidized and it was also resists corrosion because protected by an oxide film. It can be attacked by strong acids, alkali and acid salts, since this element does not eroded if exposed to distilled sea and soft tap water. Tin exist in two different forms which are beta-tin (β) and alpha-tin (α). Beta-tin (β) is form in metallic or white tin. It is stable at room temperature and malleable above the room temperature. While, alpha-tin (α) is non-metallic form or known as gray tin. This form of tin stable at below than 13.2°C and it will turn into white at above of 13.2°C, rapidly changes at temperature above 100°C. Alpha-tin is brittle with no metallic properties. Tin (Sn) can be used for coating such as tin-plated steel containers that are widely used for food preservation.

In this study, alpha-tin or known as stannic oxide will be utilized as particles type filler for nanocomposites production.

Stannic oxide is also known as Tin (IV) Oxide which is an inorganic compound consist of oxygen and tin. This compound is a transparent conducting oxide and also possessed wide band gap n-type semiconductor, where it can allow electric current to flow through it. According to Dodoo-Arhin et al. (2018), tin (IV) oxide has been used in many applications such as gas sensor, electrodes in solid-state ionic devices and solar cells due to its unique properties such as being chemically inert, good electrical performance, mechanically hard and thermally stable. Tin (IV) oxide occurs naturally as mineral cassiterite and it is the only one stable phase for cassiterite structure. Synthetic tin (IV) oxide is produced by variety techniques such as sol-gel, hydrothermal method, precipitation, spray pyrolysis and chemical vapor deposition. However, techniques as precipitation will result of agglomeration due to particles sizes of less surface area and smaller pore size. Therefore, precipitation method is not suitable for applications such as gas sensors and electrode materials for supercapacitors and etc compared to other techniques. In this study, the nanoparticles of stannic oxides were synthesized by using sol-gel method and was used as purchased.

Theoretically, extrinsic semiconductors are stannic oxide (SnO_2) nanoparticles, which are materials that rely on chemical heterogeneities or lattice defects which provide charge carriers. Therefore, these nanoparticles had electronically neutral molecules with excess of negative electron to the crystal lattice of stannic oxide nanoparticles due to the oxygen acts as electron donor atoms to produce tin dioxide. Tin (IV) oxide is highly thermally insoluble compound. These elements are a colourless inorganic compound of tin and oxygen. Tin (IV) oxide have two forms which is a stable blue-black form and a metastable red form. The following Figure 1.4 depicts the semi-conductivity of SnO_2 nanoparticles (Şerban and Enesca, 2020).

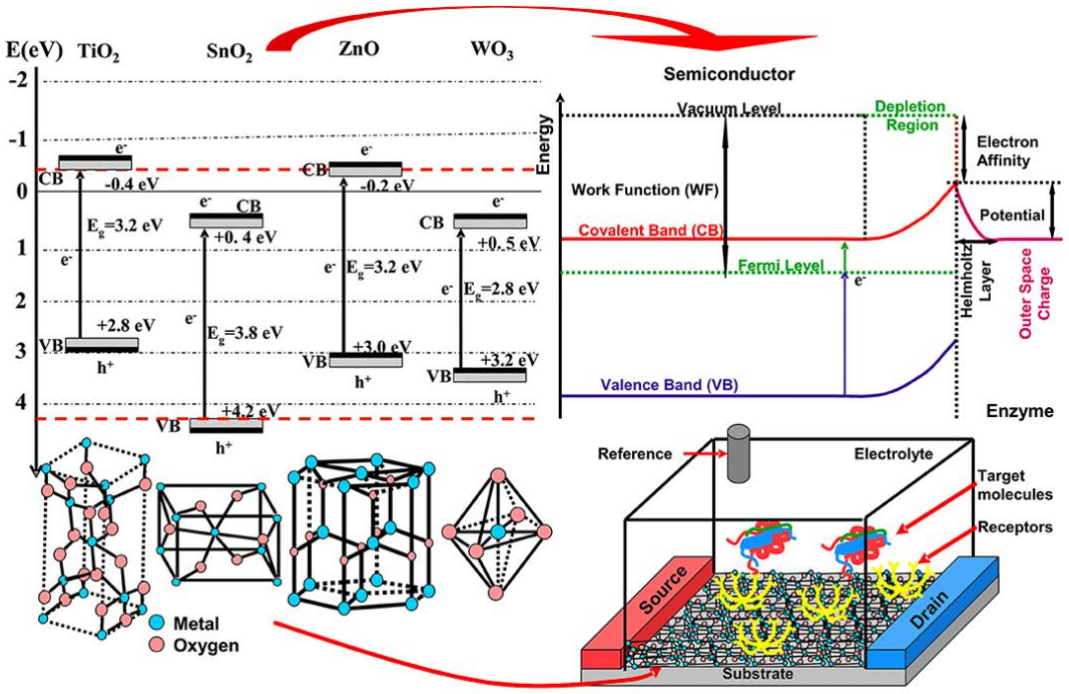

Figure 1.4: Activity of stannic oxide (Şerban and Enesca, 2020)

In fact, oxide compounds are not conductive to electricity. However, there are certain perovskite structured oxides are acted as electronically conductive application in the electrostatic discharge insulator. They are compounds that consist of at least one oxygen anion and one metallic cation. Usually, they are typically an insoluble in aqueous solution (liquid state) and extremely stable useful in ceramic structures of advanced electronics packaging and in light weight structural components.

This study has been motivated by the overwhelming courage in developing new advance material candidate for dielectric insulator to be utilized in electronic packaging. Selection of natural rubber latex and stannic oxide has been instigated by their availability as common commodities in Malaysia. This able to provide cheaper alternative of raw material for engineering application. In addition, considering the advantage of natural rubber which able to provide flexibility in an insulator design for IC, it will gives extra benefits for electronics industry in utilizing such material. Furthermore, the usage of stannic oxide as functional filler for insulator in IC design would be able to provide strengthening effect into natural rubber latex substrate, while enhancing the dielectric strength of produce natural rubber latex based nanocomposites with ability of efficient electrostatic discharge. Hence,

the development of natural rubber latex filled stannic oxide nanocomposites was significant to be conducted for emerging flexible electronic packaging application.

1.2 Problem Statement

There are many studies about the natural rubber latex. Up till now, the study of natural rubber latex is still actively carried out by the researchers throughout the world. The advances of electronic packaging in miniature size has made thermal management are increasingly important. This size has been shrunk from the original size in the last twenty years and cause the power generating heat in this smaller compartment has been increased. Due to that, this research will be redesigning the new material for electronic packaging to take advantage of their thermal, elasticity and tear resistance.

In this study, materials that have been chosen as filler to develop as new material is stannic oxide (SnO_2). The first issue arising here is no availability of using stannic oxide (SnO_2) reinforced natural rubber latex (NRL) for the electronic packaging purposes. Since there is no research about the combination of these two materials, this will be the biggest challenges in producing a multiscale nanocomposites. Another issues is on the dispersion of nanoparticles within the natural rubber latex (NRL) as matrix. These may lead to the dispersion problem which is the particles are agglomerated after stannic oxide (SnO_2) was added to the natural rubber latex (NRL) or vice versa. Despite that, agglomeration should be avoided because the particles that having the dead ends does not conducting any path for the electric current. Therefore, the situation in which the particles on the matrix can conducting path by connecting each other.

In this research, stannic oxide (SnO_2) was embedded into natural rubber latex (NRL) to produce nanocomposites. By adding the filler to natural rubber latex (NRL), the properties and performance would be enhanced. Therefore, there are still on-going in searching the definite conclusion on the effects of tin nanoparticles reinforced natural rubber latex. Hence, the effects of stannic oxide (SnO_2) nanocomposites addition at various loading percentages were evaluated. By performing this evaluation, it can be decided which loading of stannic

oxide is required to enhance the properties of natural rubber latex without making it damage and useless.

Failure of an electrical components can be cause by the thermal and also excess current or voltage. If the materials cannot achieve high resilience, the voltage breakdown will occur in a short time and will cause the material no longer electrically insulating. In this research, stannic oxide nanocomposite reinforced natural rubber latex need to be tested in which level the materials can last longer until it achieved the breakdown phase. Therefore, this study is importance in proposing a suitable advance material for flexible electronic packaging purposes.

1.3 Objectives

The objectives of this study are as follows :

i) To determine the effects of stannic oxide (SnO_2) nanofiller loadings to the mechanical properties of NRL/SnO_2 nanocomposites.

ii) To determine the effects of stannic oxide (SnO_2) nanofiller loadings to the physical properties of NRL/SnO_2 nanocomposites.

iii) To correlate the mechanical and physical properties with the fracture surface of NRL/ SnO_2 nanocomposites via the Scanning Electron Microscope (SEM).

1.4 Scopes of the Research

The research scopes are as follows :

(a) Develop the natural rubber latex (NRL) filled with stannic oxide nanocomposites using a simple set-up of high-speed stirring and ultrasonication method.

(b) Characterize the mechanical properties, dielectric properties and morphological properties of the NRL/SnO_2 nanocomposites.

(c) Determine the breakdown voltage for NRL/SnO_2 nanocomposites using high voltage testing apparatus.

(d) Analyze the morphological characteristics of NRL/SnO_2 using the Scanning Electron Microscope (SEM) observation.

(e) The SnO_2 loading are in between 0-10 wt.% and the NRL used are local source available in Melaka state, Malaysia.

1.5 Rational of Research

The rationales of research are detailed as follows:

(a) To establish new knowledge about SnO_2/NRL based nanocomposites as potential advanced materials for high elasticity and stretchable electronics packaging system by carrying out some related testing and characterization.

(b) Higher thermal and higher strength of nanocomposites product would be developed from this research. Therefore, by embedding stannic oxide nanofiller to the natural rubber latex, such properties of the nanocomposite might be enhanced. This research is to study on how the stannic oxide nanocomposite would improving the properties when it being combined with the natural rubber latex.

(c) Establish more information about the breakdown voltage of the NRL based nanocomposite a guideline for electrical components system design by using high voltage apparatus.

1.6 Summary

The overall research flow can be seen as in Figure 1.5. At the beginning of the flow, the research has started with the mixing of stannic oxide nanocomposites with natural rubber latex. After that, the natural rubber latex filled with stannic oxide nanocomposites samples were fabricated by using the sonication casting method. Next, the composite will undergo several standard laboratories testing to investigate their properties. Those testing that will be carried out are the mechanical testing, voltage testing, dielectric testing and morphological testing. The entire collected data will be analyzed and discussed afterward. Then, the conclusion is made based on the data analysis. At the end of this flow chart, the higher performance of stannic oxide filled natural rubber latex nanocomposites was produced and characterized at the end of this research. Therefore, the good outcome would enable us to propose the natural rubber latex reinforced with stannic oxide nanocomposites for specific potential applications.

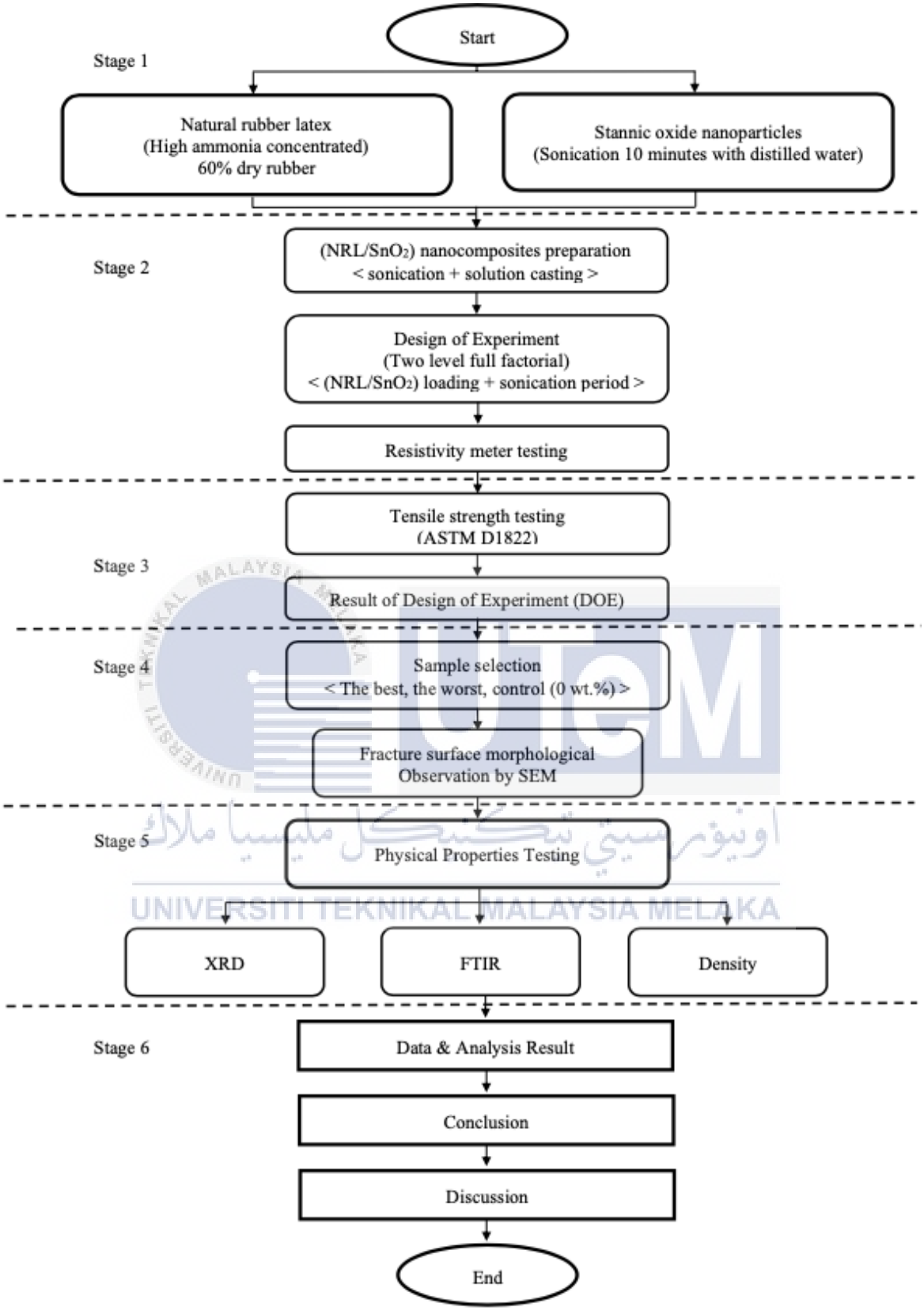

Figure 1.5: Schematic Summary of Methodology Flow Chart

1.7 Thesis Organization

In this study, it was all began with Chapter 1. The first chapter has started with the research background, problem statement, objectives and scope of the study. Followed by Chapter 2 which consists of literature review exploring related previous study on natural rubber latex, stannic oxides, nanocomposites, voltage breakdown and dielectric properties. All of the criteria mentioned are important to develop the natural rubber latex reinforced stannic oxide (NRL/SnO_2) nanocomposites system. Next, the Chapter 3 is the methodology that describes the entire raw materials that were used in this study and also related experimental work to produce the NRL/SnO_2 nanocomposites. In addition, the standard testing procedure was included in this chapter as well as several importance parameters of study. Then, the result and discussion were included in the Chapter 4. Chapter 4 is about data analysis that gained and collected from various testing which were elaborated and discussed in this part. These include the mechanical properties, dielectric properties as well as morphological observation. Finally, Chapter 5 has summarizing an overall conducted study and several recommendations for future improvement. Several statement on sustainability, life-long learning also has been included in this chapter.

CHAPTER 2
LITERATURE REVIEW

This chapter is mainly describe the theory and research which have been defined and done by various researcher years ago. Related information of previous studies are extracted as references and discussion based on their research about the advanced materials used for electronic packaging and their packaging hierarchy. In this chapter, it also mentioned about the breakdown voltage and the dielectric properties for the reinforcement of the nanoparticles.

2.1 Electronic Packaging

According to Hubing (2007), an electronic packaging is known as parts of an electronic structure that protects an electrical element from outside environment. This technology interconnects the ICs and the other components into a system-level board to form a complete electronic product. Integrated circuit (IC) is an assembly of many circuits or components which fabricated as a single unit. The following Figure 2.1 depicts an example of an integrated circuit (IC).

Figure 2.1: Picture of integrated circuit (IC)

The function of an IC package are to protect the microelectronic devices as well as providing an electrical and mechanical connection between the chip and external parts. According to Kwak (2007), the package of an IC must provide a structure to physically support the chip, a physical housing to protect the chip from the environment, an ability to remove heat generated by the system, electrical connections to allow signal and power access to and from the chip. Wiring structure is the most important part to provide an interconnection between the chips of an electronic system.

As reported by Szendiuch (2011), semiconductor chip and integrated circuit (IC) design was completely separated from the design package as IC was designed in the first place then there are a process to choose a suitable package for assembly. This packages was created based on standardized set defined with ISO registered outlines. In that time, these advanced IC and packaging development has mainly driven by military, commercial design rules and also aeronautics and space application. Due to that, it means the type of electronic packaging had only small effects toward the design and performance of an integrated circuit (IC). Figure 2.2 depicts the type of packaging used in the past generation (Szendiuch, 2011).

Figure 2.2: Package type used in the past generation (Szendiuch, 2011)

However, there are three important parameters for fabricating an electronic packaging. The first parameter is the amount of an input and output that determines the field of the IC package as well as the wiring needs at the system level. Next, sizing of the IC also plays an important role that will affects the reliability of IC to package connection.

Meanwhile, the power of an electronic devices also affects the heat dissipation properties of the components inside the system (Alim, 2021).

2.1.1 Packaging Hierarchy

In an electronic system, there are more than one packaging required due to of integrated circuit (IC) technology. In fact, typical electronic system consists of several layers and level of packaging. This is because, some components are not readily integrated into a chip. Usually, this happened because of high-power resistor, mechanical switches, capacitors and any other undefined reason. However, each level of electronic packaging has their own distinctive interconnection devices. The hierarchy of interconnection level can be seen as the following Figure 2.3.

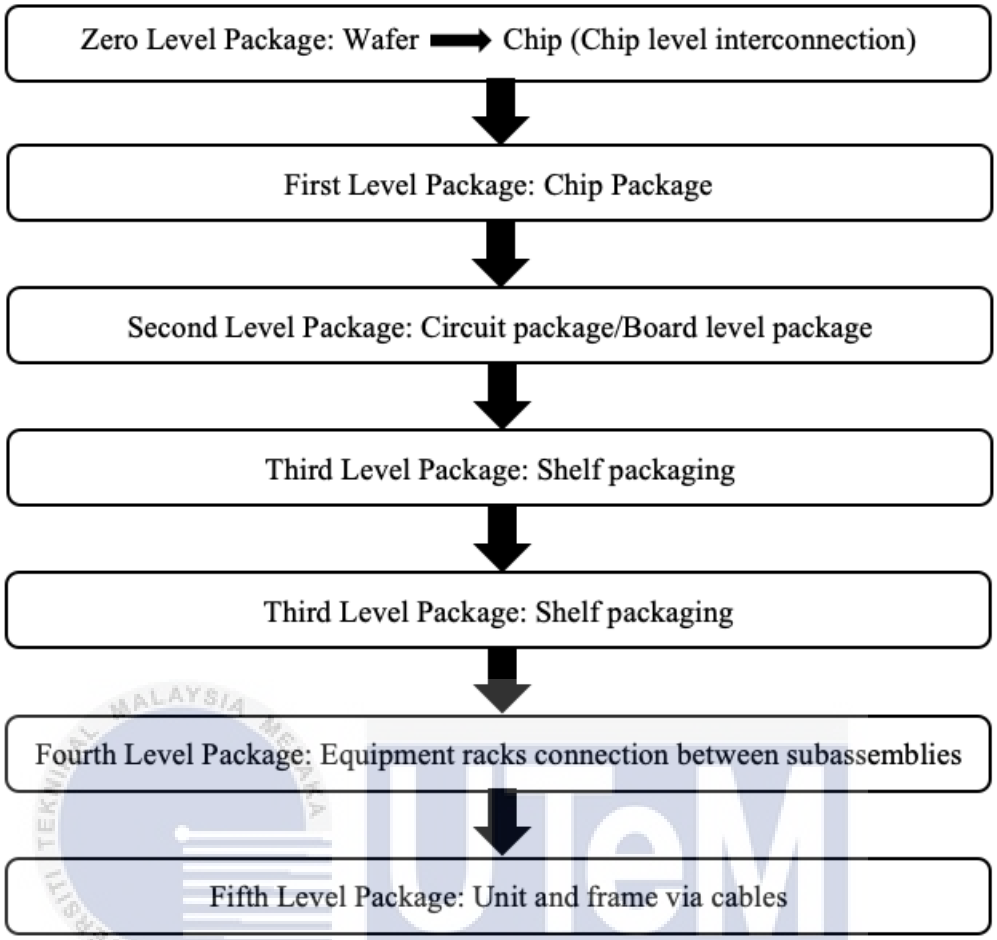

Figure 2.3: Packaging Hierarchy Flowchart

Integrated circuit chips such as small terminal that is relatively fragile. Due to that, there are few level need to go through to make sure that the component are been taken carefully. The first step known as zero level packaging which is gate-to-gate interconnections during integrated chip fabrication. Then, the process continue to the first level of packaging which refers to the technology required of getting the electrical signals into and out of the integrated chip (IC). On this level, the connections are required between the pins of the package and the binding pads on the integrated chip (IC). This can be related to the wire-bonding, flip chip bonding and tape automated bonding (TAB) (Lupinski, 2014).

Second level interconnection refers to the electrical connection of an integrated circuit (IC) to a circuit board which commonly knowns as conventional printed wiring board (PWB). According to Brown (2010), single integrated chips normally undergo encapsulation

in either plastic or ceramic-based packages prior to connect from first level to a printed wiring board (PWB). However, an integrated chip (IC) also can be bonded directly to the printed wiring board (PWB) using wire bonding scheme and using tape automated bonding (TAB). Then, the chip is protected by a “glob-top” encapsulant such as a epoxy or silicone. In this stage, second level packaging interconnection is the packaging which combined the multiple chips (Lim Soo King, 2013).

After that, the process continued to the next level which known as third level interconnection. In this third level, the multiple chips that have been bonded to the printed wiring board (PWB) in the second level was connected between the printed wiring board (PWB) and black planes or known as motherboards. Then, all of the subassemblies will be connected and put together between them in the fourth level connection. Last but not least, all of units and frames level are connected together. The connection in this process usually via cables. In other word, the connection is occur between physically separated system. This fifth level connection completes on overall system (Rahim, 2017).

2.1.2 New Packaging Generation

Due to this new era generation, new packaging for electronic devices are proposed in the industry. The three-dimensional (3D) packaging were introduced as the interconnection provides in increasing the electrical performance and packaging density compared to two-dimensional (2D) packaging that have been used for a very long time ago. The following Figure 2.4, illustrate the development of electronic packaging up to year 2020.

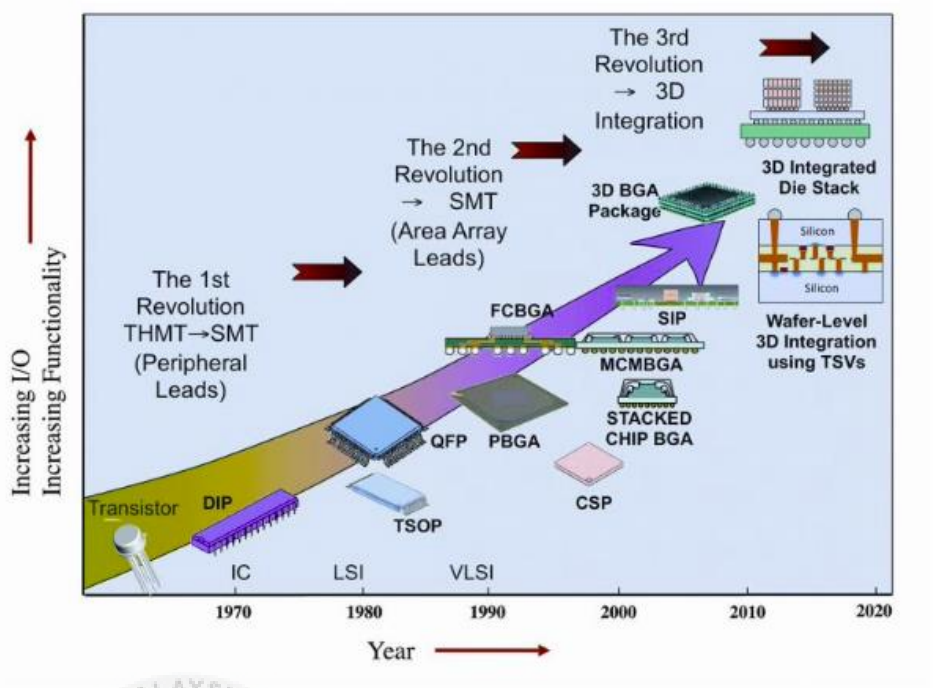

Figure 2.4: Integration development of electronic packaging (Jeffrey Gotro, 2018)

Furthermore, three-dimensional packaging and interconnection could increase the density by stacking integrated circuit (IC). About four generations of integration development stage of electronic packaging which illustrated the single chip packaging consists of 2-D system packaging, 3-D system of packaging and future polymer multi-functional solution.

Electronic packaging development are consists of increasing component input and output densities, substrate or package technology which migrating to higher density interconnection (HDI) and new materials and principles. However, a characteristic feature of current electronic packaging development is by utilizing the third dimension which consists of z-axis to build a complex 3-dimensional electrical circuit and system. According to Szendiuch (2011), there are few solutions for high integration constructions currently available:

- √ Die stacking
- √ 3-Dimensional design
- √ IC and package co-design

- √ Embedding
- √ Direct die/wafer and wafer/wafer bonding
- √ Optical interconnect
- √ System in package (SiP)
- √ Package on package (PoP)
- √ Plastic packages for high-power
- √ Effects of regulation/legislation

2.1.3 Three-Dimensional Packaging (3D)

In three-dimensional electronic packaging, there are some new aspects in the behaviour of components that have to be predicted. The priority is given to the interaction in electronic packaging. However, both single level, horizontal cross-talk between stacked layers can be a problem due to intensification in very high-speed applications. In electronic packaging, heat is spreaded in multiple high power devices to thermal operating specifications as well as thermal and thermo mechanical stress design limits (Szendiuch, 2011).

The format for three dimensional microelectronic devices of manufacturing process are chosen depending to their final product. There are different technologies used in this process including from the challenging semi-conductor to the less expensive non-vacuum product. Besides, the electronic packaging elements of layered dies including the chips themselves, the dielectric material between the die and the interconnection system. The elements of dies include dies on edge, layered dies and vertically stacked module include dies, attachments between electrical components and the interconnects between dies or modules (Szendiuch, 2002).

Furthermore, system on package (SOP) technology has the potential to contribute into a modular design flexibility and higher performance integration of heterogeneous chip technologies. It has also to support robust chip and component to be manufactured with high yield and low cost chips for the wide range of product applications. There are two fundamental drivers for miniaturization in Figure 2.5:

Figure 2.5: Two fundamental drivers for miniaturization

The following Figure 2.6 depicts the three stage of 3-dimensional electronic packaging development.

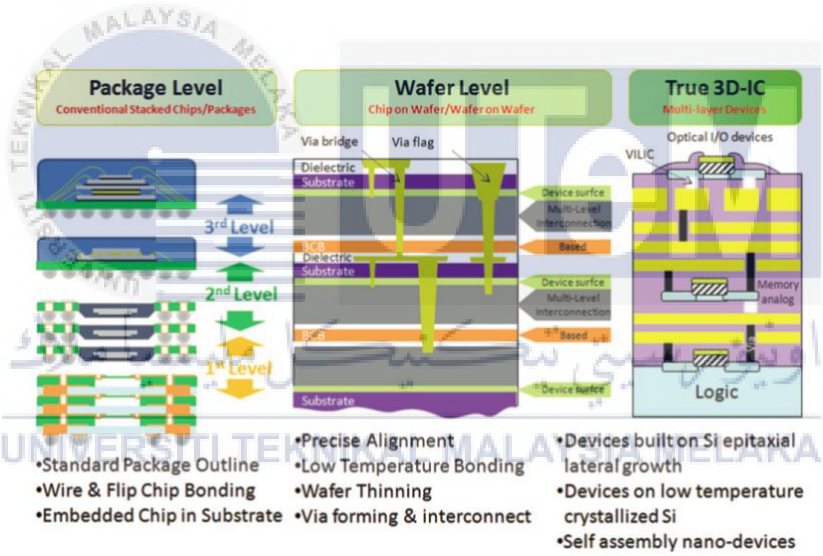

Figure 2.6: Three stage of 3D electronic packaging development (Szendiuch, 2011)

2.1.4 Size and Weight

Electronic packaging systems need to operate in many environmental exposes. Due to that challenges, there are two physical parameters need to be considered to achieve performance goal as protection to the systems. In electronic packaging, weight may be a critical factor to the system if the resulting system is used to be operated in the satellite or to produce a portable computer and handphone devices. Meanwhile, the size may be critical

toward the applications especially in term of volume or some combination of two materials to produce a product. However, size and weight such an important part that gives impact to the design aspects of the electronic packaging especially on material specifications and cooling requirement (Johnson, 2005).

2.1.5 Thermal Design for Electronic Packaging

The basic goal of thermal design is to remove heat from integrated chip (IC) connections to ensure an optimal operation and to avoid heat trapped. Thus, it can help to save the system from activated failure mechanisms. This situation occurs by conducting the heat away from the integrated chip (IC) then released in the form of gas or by creating a coolant against the system. Thermal design cannot be ignored because of an operating frequencies and circuit densities are becoming great enough when packaging the chips (Yeh, 2002).

However, the thermal design for the electronic packaging need the high consideration on the use of a high thermal conductivity material which implies high dielectric constant and also high breakdown voltage. This is because to avoid the occurrence of failure toward any component while producing an effective electronic packaging. The material used to produce good conductive electronic packaging need to be investigated the properties of heat removal from the integrated chips either directly from the back of the chip or through the substrate used (Remsburg, 2017).

2.2 Breakdown Voltage

Minimum voltage that causes a portion of an insulator to experience electrical breakdown is known as breakdown voltage. The insulator material will become an electrically conductive due to breakdown phenomena. Breakdown voltage is an important property of electrical conducting inside the integrated circuit (IC) of electrical system. Meanwhile, the converter transformer has attracted by all the researchers as the direct current transmission system is developing rapidly. The voltage of the complex waveforms

withstands by valve side windings in the converter of the transformer (Bao et. al, 2016). The turn-to-ground insulation of the valve side wingdings withstands pulsating to the DC voltage (Zhou et al., 2015).

2.3 Dielectric Properties

According to the previous research, polymer dielectrics have wide applications in electromechanical systems especially in high charge storage capacitors, electrostriction for artificial muscles and drag reduction where high dielectric constant is required (Ponnamma, 2015). Usually the dielectric constant of composite is enhanced by incorporating it with high dielectric constant or conductive component. According to Chen (2021), silicone rubber is widely used in dielectric applications due to its excellent chemical resistance, electrical insulation and good flexibility.

2.4 Natural Rubber Latex

Natural rubber latex is derived from the tree named Hevea Brasiliensis or better known as rubber tree (Azevedo Borges, 2014). This type of polymer can be seen in the form of milky white fluid which is known as latex from the tree itself. Latex from Hevea Brasilensis tree contains about 30%-40% rubber that dispersed as rubber latex particles in water minor non-rubber constituents such as proteins, lipids, carbohydrates and sugars, metal ions, etc (Cai et. al, 2003).

Natural rubber latex is also can be referred as an elastomer when it is in a raw state. In another hand, this material is an unique material that is elastic and viscous. According to Schaefer (2018), rubber is capable of sustaining a deformation of as much as 1000 percent due to it low modulus of elasticity. It is very quickly and forcibly react to its original dimensions after a deformation. This material can be processed into a variety of shapes and can be reinforced to the metal insert but nanofiller have emerged as promising fillers for improving the properties of natural rubber latex with only low filler loading due to the small size and increased surface area (Sahakaro, 2017). Furthermore, natural rubber latex is resistance to corrosion and it normally does not required any lubrication (Butler 2016).

2.4.1 Properties of Natural Rubber Latex

Natural rubber latex has been attracted in the industry for several applications due to their special properties. Figure 8 depicted the fresh natural rubber latex gathered from the rubber tree. This material having higher elasticity due to its lower temperature flexibility. Natural rubber latex required very low heat to build up the desired shape. Due to that, it can be very flexible to be placed and inserted between narrow and very complex space in the integrated circuit of electronic packaging.

Figure 2.7: Fresh natural rubber latex from the rubber tree (Narix Global Sdn Bhd, 2022)

Due to physical properties of natural rubber latex, it has higher tensile strength which can withstand of being stretched out to the maximum limit. Due to its specialty, it can be used in the miniature size of component to be made as electronic packaging. However, synthetic rubber is more resistant to wear and tear, oxygen exposure and also it can hold out with extreme temperature conditions. This is the reason why most of the natural rubber are being added with other element or compound to change the properties of the rubber to the better level according to the application of an industry (Roslim et. al, 2018).

2.4.2 Deproteinized Natural Rubber Latex

Deproteinized is a method or process in which removing protein from a rubber substance. In this study, deproteinizing process is used to remove protein from the natural rubber latex. This is because, protein that attach inside the latex cause the allergy reactions.

Some people have an allergy reaction toward their skin after repeated contact with the latex. Latex allergy usually occurs to people who are exposed frequently to the rubber products such as latex gloves. This will contribute to the increasing of health problem.

There are three different methods of deproteinizing strategy such as saponification, surfactant washing and enzymatic treatment. This method usually used to determine the effect of deproteinized to the properties of natural rubber latex. In fact, the amount of protein in natural rubber latex can be estimated in terms of nitrogen content of the rubber. According to the report written by (Nawamawat, 2010), the efficiency of protein reduction by deproteinization is shown in Table 2.1.

Table 2.1: Deproteinization result (Nawamawat, 2010)

Sample	Nitrogen content (%w/w)	Ester content (mmol/kg rubber)
Fresh Natural Rubber Latex (FNRL)	0.65	14.0
Enzymatic Deproteinized Natural Rubber Latex (DPNR)	0.14	20.1
Washed Natural Rubber Latex (WSNR)	0.02	25.1
Saponified Natural Rubber Latex (SPNR)	0.12	12.3

2.5 Vulcanized Deproteinized Natural Rubber Latex

Vulcanization is a chemical process which improving the physical properties of natural rubber latex and synthetic rubber. In this process, the natural rubber can be changed their properties by getting higher tensile strength compared to fresh natural rubber latex. It was also can be resistance to swelling and abrasion after going through the vulcanization process. Other than that, the elasticity of the natural rubber is over a greater range of temperature.

Vulcanization is a process which brought about by heating natural rubber with sulfur. Due to that, the material can be toughened by this process and can be modified for special purposes by reinforcing with other fillers. By adding other material, natural rubber latex can build extraordinary strength in line with the demands of the industry (Matador Rubber,

2007). The following Figure 2.8 depicts the network formation of vulcanization process of natural rubber latex with sulfur.

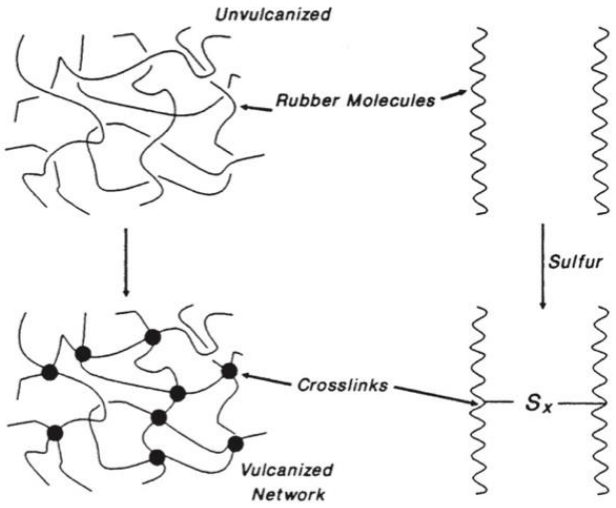

Figure 2.8: Network formation of vulcanization process of natural rubber latex with sulfur (Coran, 2013)

2.6 Nanocomposites

Jordan et al. (2005) reported that traditionally, composite was reinforced with micron size inclusion. However nowadays, processing technique has been developed to nanoscale inclusion. Nanoscale inclusion will tend to increase the elastic modulus of produced composite with increase the volume fraction of inclusion. In addition, interaction between matrix and filler play an important role in the effect of nanoparticles on composite properties. Therefore, preparing a good polymer matrix nanocomposite with a good dispersion must be considered when producing a nanocomposite. Tjong (2006) added that the microstructure parameters such as properties of the matrix, properties and distribution of the filler as well as interfacial bonding and the synthetic or processing methods also will affect the mechanical properties of polymer-nanofiller composites.

2.7 Stannic Oxide

Stannic oxide is also known as tin (IV) oxide which it can be found naturally as the mineral cassiterite. This chemical bonding is a covalent compound bonding which the tin element is bonded with two oxygen. Stannic oxide can be written as SnO_2. It can be found naturally as mineral cassiterite which typically to off-white and sometime grey crystalline solid (National Center Biotechnology Information, 2022)

2.7.1 Properties of Stannic Oxide

Stannic oxide known as tin (IV) oxide. SnO_2 is a metal oxide with characteristics of high thermal stability and semi-conductivity material. It required high temperature which is 1127°C to melt the stannic oxide. Stannic oxide is a light-weight material with 150.71 g/mol molecular weight, respectively. Due to its uniqueness of thermal properties, stannic oxide can be a good conductor for electrical system (Azo Nano,2013). Besides that, SnO_2 is one of the synthesized nanoparticles that can be used to recycled waste polymers. It is an application of the polymers that has both economic and environmental benefits (Naushad, 2016). Stannic oxide nanoparticles may lead to the improvement in the mechanical, thermal properties and the performance of polymers (Zare, 2013).

2.7.2 Stannic Oxides as Reinforcement Fillers

Stannic oxide may be strengthened by the uniform dispersion of several percent volume of fine particles. The dispersion materials usually used oxide material composite. Stannic oxide or known as tin (IV) oxide are going through a process to produce fine particles which called nanoparticles to ease the uniform dispersion of stannic oxide on the deproteinized natural rubber latex. Usually, the dispersion will become the biggest problem to produce homogenous mixtures. Homogenous mixture may be solids, liquids or gases. In this study, there are two component which are stannic oxide and natural rubber latex that will undergo mixture process without changing their chemical properties. However, homogenous are matter of scale. Due to that, there are conditions need to be fulfilled by mixing the components according to their sizing. These compound forms when the elements

and the molecules chemically react with each other to produce a new product. If this compound succeeded react to each other, that means the new product is produce by remains their properties.

2.7.3 Reinforcement of the Filler

Reinforcement of filler need the particles to be small in nanoparticles sizing. Nanoparticle is a small particle that ranges between 1 until 100 nanometers size range which cannot be seen by human eyes. In this study, natural rubber latex must adhere well to the filler that will be reinforced to the elastomer. If this condition cannot be fully complied with, the power of the reinforcement will become less than it should be. However, the size of the particles plays an important role to be able to get the observation of the reinforcement effect. This is because the smaller the size of the particle, the greater the reinforcing effect to be observed especially on the greater surface area.

In the study of reinforcement, the fine particles are able to change the properties of materials to be strengthen and toughen on the elastomer compound. This is because the material properties changed as their sizing approaches the atomic scale. This is related to the possibly associated with the bonding of highly stressed elastomer molecules from the filler particles, reduce the stress on the polymer chains and also delaying catastrophic fracture. This process enables nanoparticles of material to possess unexpected physical and chemical properties because they are small enough to confine their electrons and produce quantum effects.

CHAPTER 3
METHODOLOGY

3.1 Introduction

This chapter describes the proposed methodology of this research which consists the principles of methods that was performed to achieve the research objectives as mentioned in Chapter 1. It will be focused and elaborated on how the flow of experiment and procedural steps that need to be conducted to achieve the stated research objectives. This research was performed based on detail consideration in accordance to the standard reference of procedure and previous researches. The elaboration of raw materials, characterization, experimental procedure for sample preparation, sample testing and analysis would also be conducted in methodology chapter.

Basically, this research had focuses into evaluating the effect of stannic oxide (SnO_2) nanofiller loadings and ultrasonication period to the tensile strength of NRL/SnO_2 nanocomposites. Apart from that, this research has also investigated the mechanical properties, voltage breakdown and morphological behaviour of produced NRL/SnO_2 based nanocomposites through extensive related characterization.

Since the stannic oxide nanofiller loadings is the main parameter in this research, it was important to determine the optimum filler loading for maximum performance of the mechanical and electrical insulation properties. The amount of filler added was basically ranged between 0 wt.% - 10 wt.%. The flow chart related to the whole study was depicted the following Figure 3.1. Since the first objective of this study had focused into the filler loadings effects, it was important to consider the proper preparation of stannic oxide and

natural rubber latex (NRL/SnO_2) by using ultrasonication technique with solution casting and proper preparation procedure.

In here, the combination of the best loading and sonication period is executed by the optimization methods using two level full factorial experimental strategy. Later, after the test validation, the best, the worst and control samples were selected for the subsequent experimental stage.

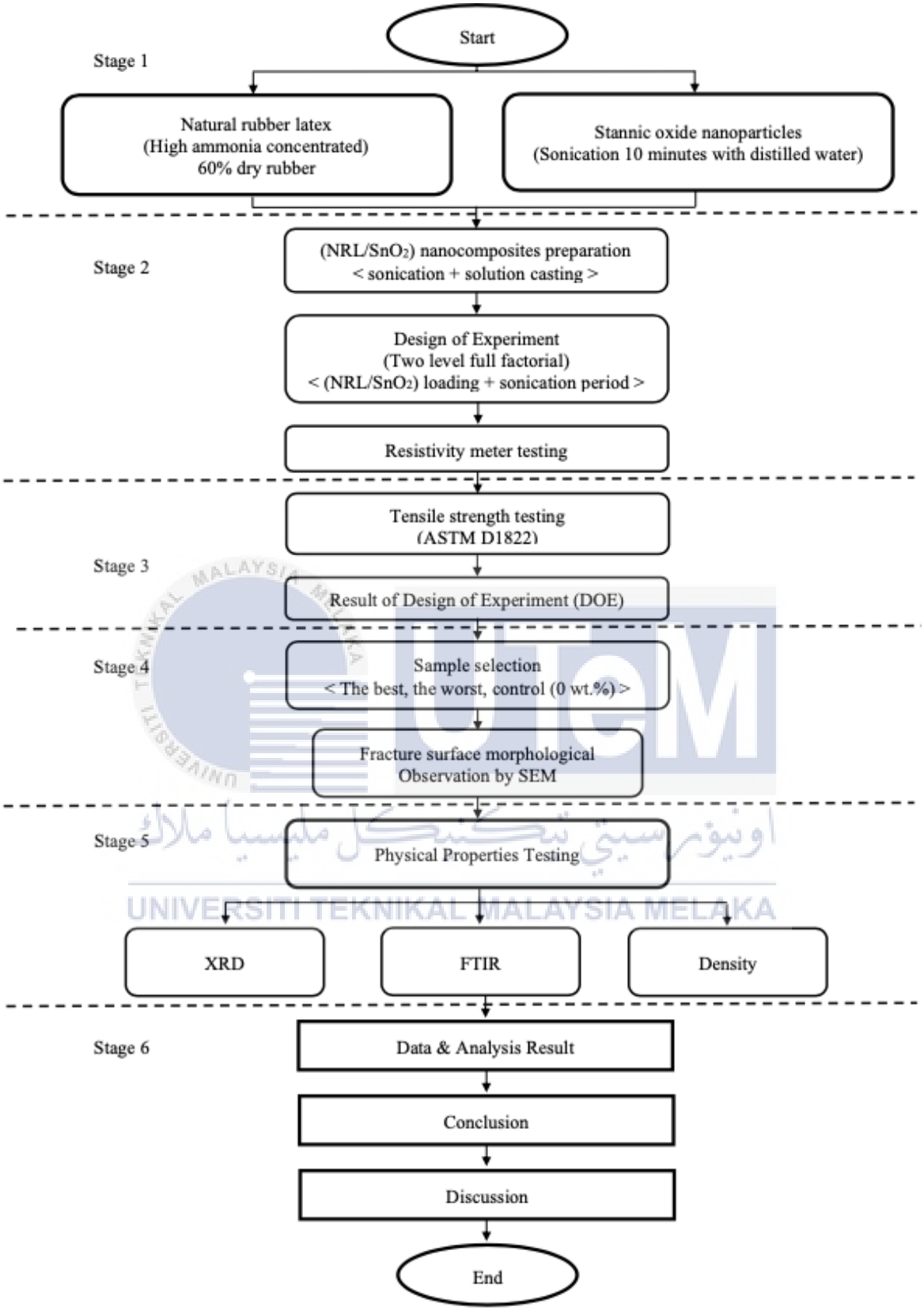

Figure 3.1: Schematic Experimental Flow Chart

3.2 Raw Material Preparation and Characterizations

Composite is a mixture of different materials which combined two or more substances. The materials is composed of the different physical properties to form a new material. In this study, the composite is made of natural rubber latex reinforced with stannic oxide nanoparticles may consist of about 1 μm sizing. Thus, the filler nanoparticles are chemically linked to the natural rubber particles as it expected that the remarkable mechanical properties and high performance application requirement can be achieved by forming chemical linkages between natural rubber particles and filler nanoparticles (Yusof, 2015). Besides, all materials are used as purchased without further purification steps. In this study, the stannic oxide (SnO_2) nanoparticles is used as filler reinforcement, while the natural rubber latex is used as matrix for polymer nanocomposites preparation. The following section, describes the information related to both raw materials.

3.2.1 Stannic Oxide (SnO_2) Nanoparticles

Stannic oxide (SnO_2) appears as white or off-white crystalline solid and powder form. It is also known as dioxotin which consists of 6.95 g/cm^3 for density value and it is soluble in water. Stannic oxide has high melting point of 1127°C. Furthermore, this nanoparticles are soluble in concentrated sulfuric acid and hydrochloric acid. It is also known as tin (IV) oxide which occurs naturally as mineral cassiterite. However, material of stannic oxide was bought from the Xinglu Chemical from China. The material of stannic oxide bought from this company is in the form of high quality nano powder for the research purpose. The following Figure 3.2 depicts the SnO_2 nanoparticles powder.

Figure 3.2: Stannic oxide in form of nano powder

3.2.2 Preparation of Natural Rubber Latex and related raw materials

Natural rubber latex was produce from the extracting a liquid sap from the rubber tree which named Hevea Brasiliensis. Natural rubber latex is gathered from the rubber tree by tapping the bark and collecting the sap flows into the cups. In preparation of this material for this study, the ammonia was added into the latex to prevent the latex from solidified. However, in this process, it does not remove the water from the latex. Besides that, natural rubber latex used for this research was bought from Rubber Leisure Products Sdn Bhd. This company is located in Jasin, Melaka. The latex bought from this company is in the form of 60% of dry rubber with highly concentrated ammonia for the research purpose.

3.3 Preparation of Natural Rubber Latex/Stannic Oxide (NRL/SnO_2) Nanocomposites via Design of Experiment (DOE) Approach

In this stage of NRL/SnO_2 nanocomposites samples preparation, pre-experimental planning was designed by using a statistical software of Design Expert® Software (Statistics Made Easy, version 6.0.8 Portable, Stat-Ease, Minneapolis, US.). It is a software used to design and interpretation of multi-factor experiments. In this study, two level full factorial design was employed for this experiment. A 2^2 full factorial design for two independent variables with three replications at the centre point and no blocks were implemented to yield a total of 7 sets of experiments. This study were respectively applied the independents variables of stannic oxide nanofiller loadings (X_1) and sonication period (X_2), with a range of 1-7 wt.% and 10-50 minutes, respectively. The selected range of each independent are

determined from the trial and error experiment and processing equipment limitation. Table 3.1 shows the levels of independent variables represented. The dependent variables tested in this study was focused particularly on tensile strength properties (Y_1) response. The tensile strength response is selected to repeat the homogeneity of SnO_2 nanoparticles dispersion with the NRL based nanocomposites. The higher the tensile strength, the better the interaction between the filler and matrix.

Table 3.1: Experimental Variables

SnO_2 Nanofiller Loadings (A, wt. %)	**Horn Sonication Period (B, minutes)**
1 wt. % (+1)	10 (+1)
0 wt. % (0)	30 (0)
7 wt. % (-1)	50 (-1)

The following Table 3.2 summarized the experimental strategy as suggested by the DOE software. In total, it has yielded about seven experiment combining the different SnO_2 nanoparticles loading and sonication period.

Table 3.2: Experimental strategy as per suggested by DOE software

Experiment Number	**Factor A: SnO_2 Nanofiller Loadings (wt.%)**	**Factor B: Horn Sonication Period (minutes)**
Control Sample	0	30
1	1	10
2	7	10
3	1	50
4	7	50
5	4	30
6	4	30
7	4	30

Several stannic oxide nanoparticles loading with varied contents of 0-10 wt.% were added into natural rubber latex without any prior surface modification. This process prepared through conventional methods that involving mixing procedure by

using horn sonication approach and solution casting technique. The preparation procedure was systematically planned before hand by using the DOE approach and combination of experimental strategy is summarizing in the Table 3.2. The depiction of SnO_2/NRL nanocomposites preparation is illustrated in the following Figure 3.3.

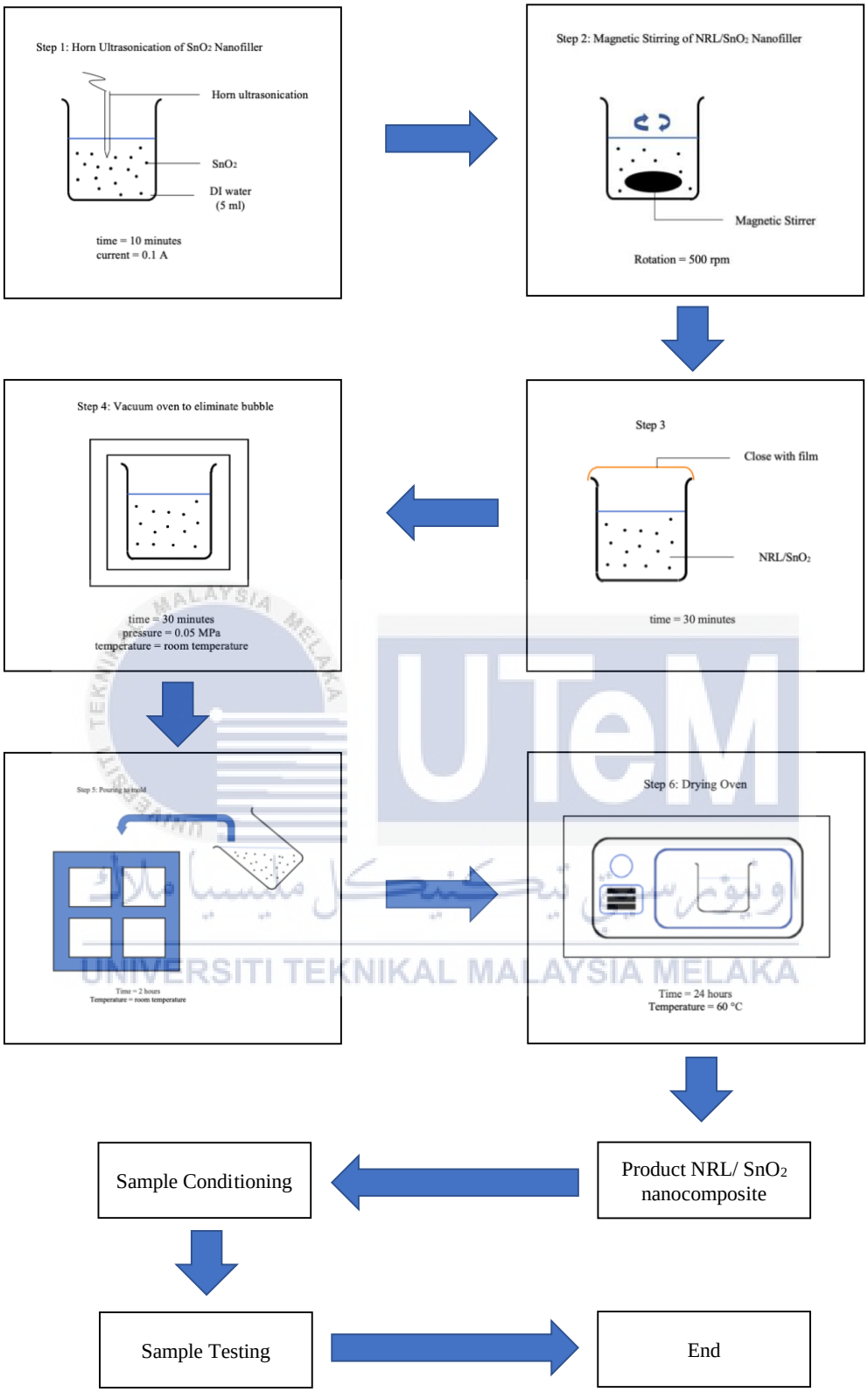

Figure 3.3: Schematic diagram NRL/SnO_2 nanocomposites preparation steps

3.4 Tensile Testing (D 412)

The tensile testing was performed using the equipment in compliance to the ASTM Standard Test Method for rubber. The ASTM D 412 standard for rubber was chosen specifically for the tensile testing of rubber based nanocomposites. This tensile testing are performed using Universal Testing Machine UTM (brand Shimadzu, from Japan) at room temperature. The purpose of conducting tensile testing was to determine the tensile strength, elongation at break and the elastic modulus for NR/SnO_2 based nanocomposites produced at different sonication period and nanofiller loading. The resulted of NRL/SnO_2 nanocomposites were cut by following the respective testing requirement in specific dimensions for tensile testing for mechanical properties evaluation according to the standard. According to D 412 standard testing, the specimen should be cut into dog-bone shape with dimension of 115 mm x 6mm x 3mm. The gauge length used was 25 mm. The maximum load was 20 kN with the crosshead speed rate of 300 mm/min. In this study, the average value was taken by repeating for five (5) samples for each composites formulation. The following Figure 3.4 depicts the setting of UTM machine which available in the Faculty of Manufacturing Engineering, UTeM. The following Figure 3.5 depicts the testing set-up for tensile strength determination.

Figure 3.4: Universal testing machine (UTM) model Shimadzu 20 kN

3.5 Surface Resistivity Testing

Surface resistivity is obtained by measuring the resistance of insulating material against current leakage along the surface of the material. The measurement of surface resistivity is done along the surface of materials and is denoted by the unit of Ohm/sq. By having higher surface resistivity, it could enable the insulator based product to have better protection against the leakage current due to high electrical voltage exposure. Besides, surface resistivity testing is non-destructive testing method which will not destroy the tested samples. In this study, the equipment used was Monroe Portable Resistance Meter (Model 272A). The test was performed in accordance to ASTM D257 standard testing method. The image of resistivity meter equipment was depicted in figure below. The equipment comes along with the ring probe that allows the measurement of surface resistivity directly onto the sample. The resistivity meter was equipped with two option of selected testing voltage either at 10 kV or 100 kV. According to the standard, the chosen testing voltage used in this study was 100 kV.

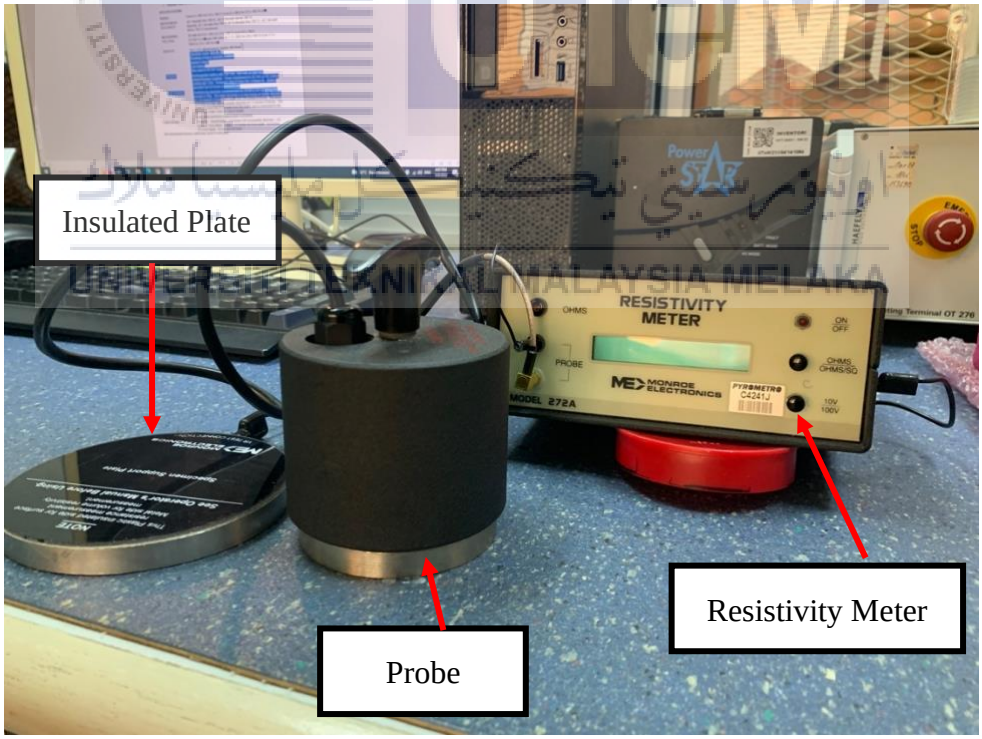

Figure 3.5 : Surface resistivity equipment

3.6 X-ray Diffraction

X-ray diffraction is now a common technique for the study of crystal structure and atomic spacing which is based on constructive interference of monochromatic X-rays and a crystalline sample. These X-ray diffraction are generated by cathode ray tube, filtered to produce monochromatic radiation, collimated to concentrate and directed toward the sample. In this study, XRD has been used to characterized the raw materials in form of powder as shown in Figure below. The analysis can be made through the software connected to XRD machine and types of elements were displayed in form of spectral graph.

Figure 3.6: Powder of raw materials (SnO_2 nanofiller)

Figure 3.7: X-ray diffraction (XRD) machine

3.7 Fracture Surface Morphological Observation Using Scanning Electron Microscope (SEM)

The purpose of performing the Scanning Electron Microscope (SEM) observation as represented in the following Figure 3.8, was investigate the morphological behaviour of the fracture surface of NRL/SnO_2 based nanocomposites samples due to mechanical failure. The fractured surface was cut and mounted onto the stub before being coated with gold palladium coating. This procedure was performed to avoid the electrostatic charging during the observation period. In this study, the fracture morphological structure will be obtained by scanning the sample with strong electron beam at an average acceleration voltage of around 40 kV. The magnification used for the observation was specified into 50x, 100x, 300x, 500x, 1000x of magnification. Three spots have been taken for each magnification scale.

Figure 3.8 depicts the setting of scanning electron microscope (SEM) for fracture surface morphological observation. In this observation, the selected tensile fractured sample were placed on an aluminium stub with carbon tape. Then, the samples were sputter coated with a thin layer of gold using Polaron E-1500 to prevent electrostatic charge and reduce poor images during observation. It is observed with a variable pressure scanning electron microscope (VPSEM) model Zeiss Evo-%0 operated at 15kV of accelerating voltage with secondary electron (SE) mode signal detector.

Figure 3.8: Scanning Electron Microscope (SEM) for fracture surface morphological observation

3.8 Summary

In this chapter, 60% of dry rubber with high concentration ammonia reinforced with stannic oxide based nanofiller based nanocomposites were tested in this study. Meanwhile, the method used for the composite preparation was mainly an ultrasonication method and solution casting. Experimental design DOE focusing to the selected process parameters (A: SnO_2 Nanofiller Loadings, wt. %; B: Horn Sonication Period, minutes) were generated by using a two-level full factorial design for two independent variables utilizing the Design Expert Statistical Software. In this experiment, it was performed 3 times repetition at the centre points to yield a meaningful and represented data. The experimental evaluation for single NR/SnO_2 based nanocomposites were made for tensile strength response, the mechanical properties are comprised of tensile strength which conducted by using a UTM machine. The selected three nanocomposites samples (the best, the worst and control unfilled sample) were taken forward for the next experimental stage which focusing to the dielectric strength and spectroscopy analysis. This was related to the achievement of objective 2. It also have been mentioned about the morphological observation of the fractured surface for the tensile tested NR/SnO_2 based nanocomposites that were analysed by using SEM observation. All the specified steps taken throughout the experimental stage as described in this methodology section was performed in achieving the stated overall objectives of this study.

CHAPTER 4
RESULT AND DISCUSSIONS

This chapter provides summarization of result analysis and related discussions for the entire experimental data findings which gathered from the various testing and observation. The analysis of scientific results discussed and explored comprehensively with addition support from other previous research to reinforce the explanation and relate the findings with related theoretical frameworks. All the tables, graphs and figures as well as micrograph are clearly depicted and presented to assist for better understanding and to enrich the discussions on results.

4.1 Introduction

The main purpose of this research is to investigate the properties of NRL/SnO_2 nanocomposites for electronic packaging purpose. The DOE approach by using the two-level full factorial design was utilized in optimizing the selected response which involving two factors which are SnO_2 nanofiller loadings and horn sonication period. The weight percentage of SnO_2 nanofiller loadings are 0 wt. %, 1 wt. %, 3 wt. % and 7 wt. % while the horn sonication period are 10 minutes, 30 minutes and 50 minutes. Hence, the total number of samples involved were eight samples including the control sample which is natural rubber latex without any SnO_2 nanofiller loadings. The optimized sample as per suggested by DOE system was then been compared with control sample. The worst sample for the other various supporting test. Next, the three selected NRL/SnO_2 nanocomposites samples were further characterized for physical testing which are density, x-ray diffraction (XRD) and fourier transform infrared spectroscopy (FTIR). In addition, the surface resistivity testing was also conducted to evaluate the electrical performances of produced the nanocomposites.

4.2 Raw Materials Characterization

4.2.1 Characterization of X-Ray Diffraction for SnO_2/NRL nanocomposites

Figure 4.1 has depicted the X-Ray Diffraction (XRD) pattern for SnO_2. The searched and matched procedure was performed in accordance to XRD software library which has confirmed the presence of SnO_2 element. The intensities and the positions of broad peak at 15° - 25° was used to identify the phase or underlying structure of SnO_2 material. It was clearly show that the plotted diffraction pattern showing no significant peak which indicate presence of no cassiterite material. The XRD data has proven the existing chemical formula of SnO_2 that was dominated by the phase presence in the composites.

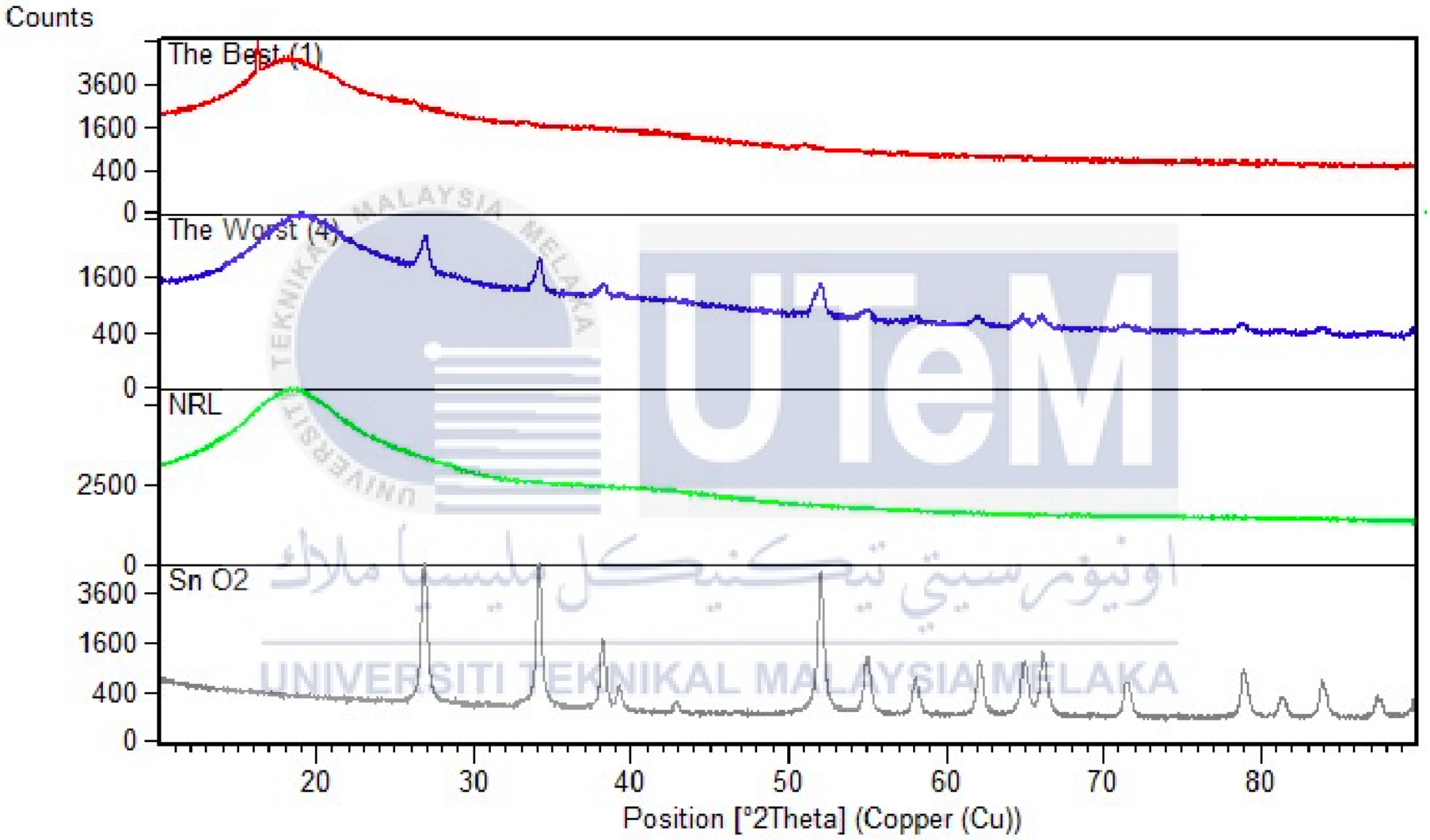

Figure 4.1: Graph of X-ray Diffraction (XRD)

4.2.2 Fourier Transform Infrared Spectroscopy Result (FTIR)

Fourier transform infrared spectroscopy analysis measures the infrared region of electromagnetic radiation spectrum which has a longer wavelength and a lower frequency than visible light to analyse the present of the element of material. The presence of functional group of SnO_2 nanofiller powder was confirmed by FTIR analysis after the granules was proposed to obtain microscopic particles. Figure 4.2 and 4.3 depicted the FTIR spectra of stannic oxide SnO_2 nanofiller powder and the comparison graph of SnO_2 nanoparticles presence. This study was performed at a scanning speed o 2 mm^{-1} with a wavelength range of 400 cm^{-1} to 4000 cm^{-1} and a 7.1 mm aperture. It can be conclude that the SnO_2 nanofiller was successfully attached in this polymer as show in the FTIR analysis.

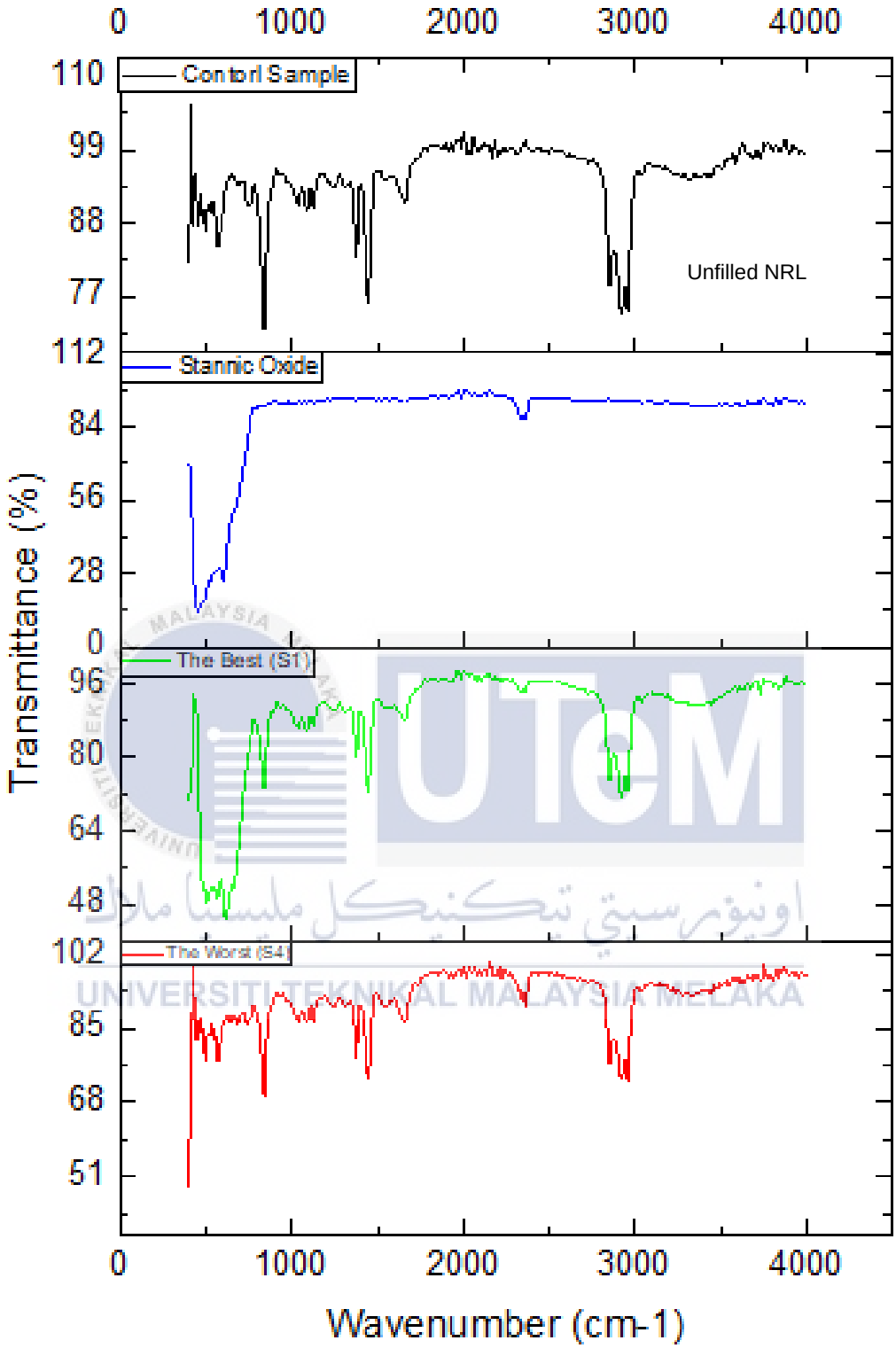

Figure 4.2: Graph of FTIR

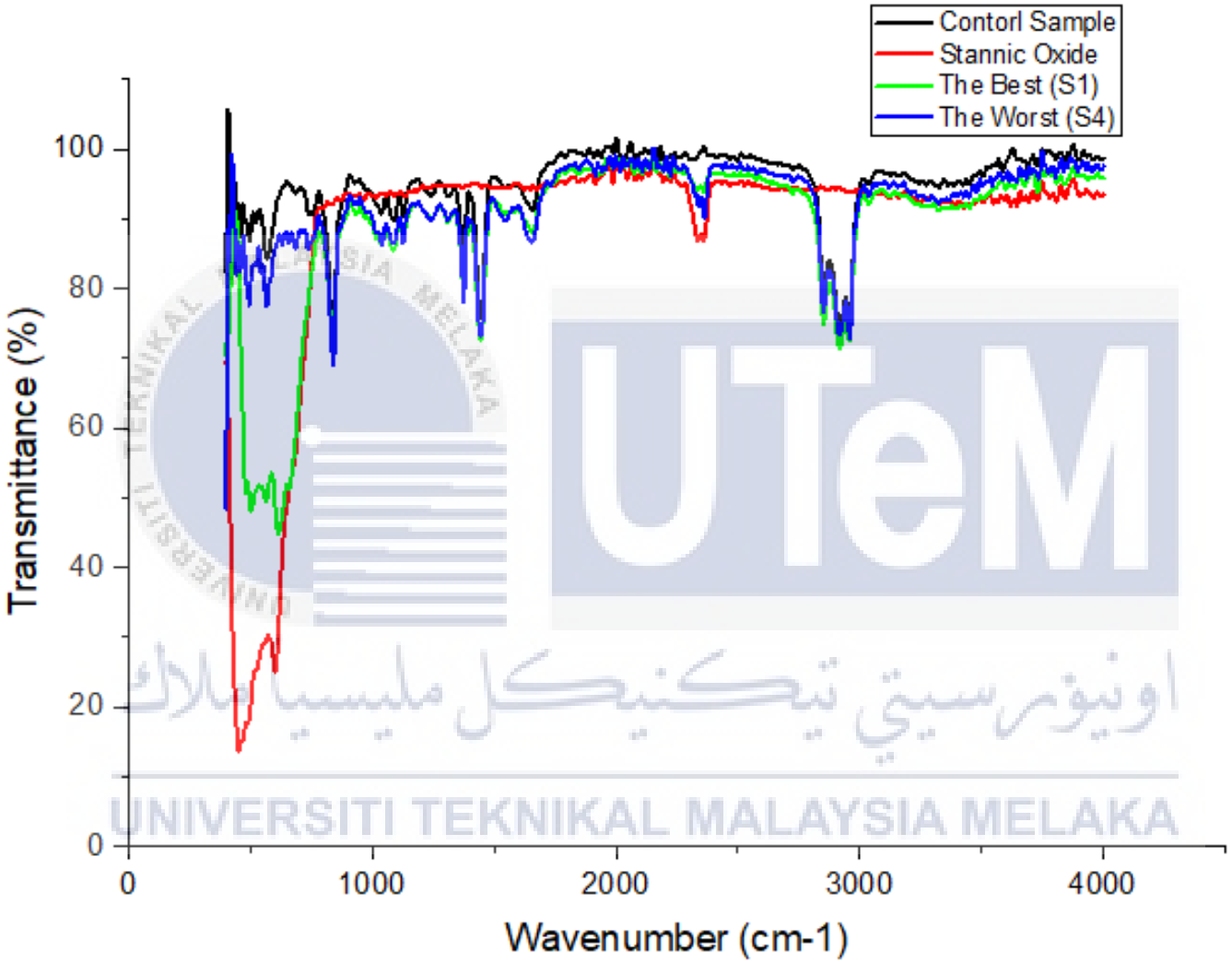

Figure 4.3: Comparison graph of SnO_2 nanoparticles presence

4.3 Design Expert Analysis

Design experiment used in this study was performed using design expert software with screening utilization of two-level full factorial design experiment. There are two independent variables involved which are SnO_2 nanofiller loadings (wt.%) and horn sonication period (minutes). According to this design experiment, there were seven sample of experiments need to be performed including the three replication at the centre point as tabulated in Table 4.2 and the design summary from DOE software are shown in Table 4.1.

Table 4.1: Design summary from DOE software

Factor	Low Actual	Low Coded	High Actual	High Coded
A: Horn Sonication Period (mins)	10	-1	50	1
B: Filler Loadings (wt.%)	0.5	-1	5	1

Table 4.2 : Selected level of variables for NRL/SnO_2 nanocomposites preparation

SnO_2 Nanofiller Loadings (A, wt. %)	**Horn Sonication Period (B, minutes)**
1 wt. % (+1)	10 (+1)
0 wt. % (0)	30 (0)
7 wt. % (-1)	50 (-1)

Table 4.3: Parametric combination for NRL/SnO_2 nanocomposites preparation by 2^2 two-level full factorial design strategies

Experiment Number	Factor A: Horn Sonication Period (minutes)	Factor B: SnO_2 Nanofiller Loadings (wt.%)
Control Sample	30	0
1	10	1
2	10	7
3	50	1
4	50	7
5	30	4
6	30	4
7	30	4

4.3.1 Tensile Strength Analysis of NRL/SnO_2 nanocomposite

The results were averaged from five samples of each respective experimental design at different parametric combination. The results had revealed that, at the highest SnO_2 nanofiller content of 7 wt.%, extended horn sonication period at 50 minutes, the tensile strength respond had decreased. This event has proven by the experiment number 4. Meanwhile, the tensile strength for experiment 3 was about 0.93778 MPa which considerably higher as compared than the highest tensile response from the experiment 1 which was 1.27792 MPa. The result shows in the Table 4.4, at lowest filler loadings requires shorter horn sonication period to produce a better tensile strength performance.

Table 4.4: Parametric combination NRL/SnO_2 nanocomposite preparation and set of experimental value

Std	Run	Block	Factor 1 A: Horn Sonication Period (minutes)	Factor 2 B: Filler Loadings (wt. %)	Response 1 Tensile Strength (MPa)
2	1	Block 1	50	0.50	0.47037
6	2	Block 1	30	2.75	0.20081
1	3	Block 1	10	0.50	1.27792
4	4	Block 1	50	5.00	0.15683
5	5	Block 1	30	2.75	0.23164
3	6	Block 1	10	5.00	0.93778
7	7	Block 1	30	2.75	0.25251

Half normal plot of tensile strength response generated from the two-level full factorial design of experimental approach was depicted in the following Figure 4.4. From the effect of factorial result, it can be seen that the factor A (Horn sonication period) and B (filler loadings) as well as interaction term of AB were positioned near the straight line, indicating the significant terms of this experiment. Next, all model terms were chosen to be analysed through analysis of variance (ANOVA) test.

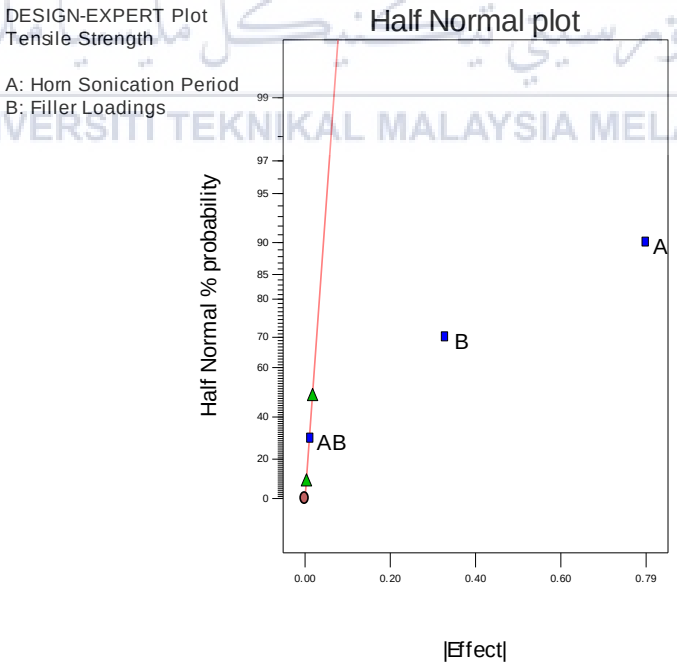

Figure 4.4: Half normal plot of NRL/SnO_2 nanocomposites tensile strength response

The following equation 1 shows the linear equation that has been developed by Design Expert Software, to relate the input variable parameters interaction to the tensile strength response of the tested NRL/SnO_2 nanocomposites. The regression equation for the responses was coded as R1, obtained after analysis variance gives the tensile strength (MPa) as a function of different variables of SnO_2 nanofiller loadings (wt.%) and horn sonication period (B, minutes). The final equation (R1) in terms of coded factor were presented in Equation 1.

Final Equation in Terms of Coded Factors:

Tensile Strength (MPa), $R1 = 0.71 - 0.4*A - 0.16*B + 6.65 \times 10^{-3} *A*B$ —— Eq. (1)

A : Horn Sonication Period (minutes)

B : Filler Loadings (wt.%)

Table 4.5: ANOVA of experimental data for NRL/SnO_2 nanocomposites

Source of variation	**Sum of Squares**	**DF**	**Mean Square**	**F_o**	**P-Value**
Model	0.74	3	0.25	363.56	0.0027
A	0.63	1	0.63	932.51	0.0011
B	0.11	1	0.11	157.91	0.0063
AB	1.77×10^4	1	1.77×10^4	0.26	0.66
Curvature	0.4	1	0.4	589.72	0.0017
Pure Error	1.35×10^3	2	6.77×10^4		
Total	1.14	6			

Table 4.6: Statistical model summary of the tensile strength response for NRL/SnO_2 nanocomposites (Screening experiment)

Statistical Results	**Value**
Standard Deviation	0.026
R-Squared	0.9982
Adjusted R-squared	0.9954
Adequate Precision	51

Analysis of Variance (ANOVA) was conducted to predict the statistical significance of process parameters and it helps to determine the effect of input parameter on the output response. In this case, it was used to determine the significance effect and contribution of each variables factor on the tensile strength response of the tested NRL/SnO_2 nanocomposites. The interacted factors with high importance will show a higher percentage of contribution in relation to other factors in the study. This occurrence has indicated that the parameter gives bigger effect toward the response.

Table 4.5 presented the results of statistical ANOVA for the tensile strength response (R1) of NRL/SnO_2 nanocomposites. Model F-value (F_o) of 363.56 implied that the model was significant. There were only 0.27% of chance that the model F-value could occur due to noise. Curvature F-value of 589.72 has implied that there was significant curvature in design space which measured by difference between average of the center points and average of the factorial points. There was only 0.17% of possibility that the curvature F-value could occur due to noise. However, this result implied that the experiment was conducted perfectly without any error by the DOE software.

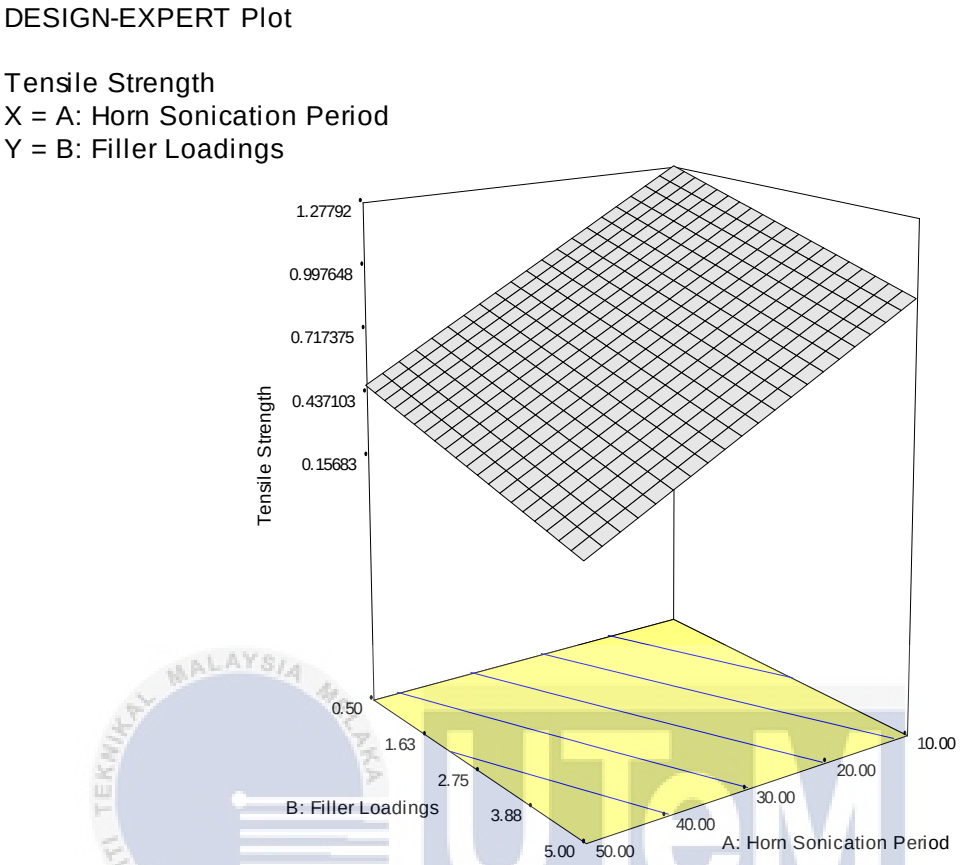

Figure 4.5: Response surface plots of NRL/SnO_2 nanocomposites tensile strength response

Three-dimensional response surface contour plot was utilized to interpret and evaluate the produced statistical model as depicted in Figure 4.5. The surface plot of the tensile strength response was based on the regresses of filler loadings (A, wt.%) and horn sonication (B, minutes). The interaction of two factors through response surface plot has helped to understand and to locate the optimum level between the results. From the response surface plot, the tensile strength response was escalated to the highest of 1.27792 MPa at the lowest SnO_2 nanofiller loadings (factor A). The facts were proven in Figure 4.5, as the tensile response had increased remarkably with less content of SnO_2 nanofiller added into the natural rubber latex. The independent variable corresponded to decrease tensile strength response, substantially with the increase of horn sonication period factors. At the 50 minutes of horn sonication period with the highest nanofiller loadings, the tensile strength has dramatically

decreased. Meanwhile, at the 10 minutes horn sonication period with 7 wt.% of nanofiller loading, the tensile strength increased.

Table 4.7: Optimization results of RSM on NRL/SnO_2 nanocomposites

Parameter	Units	Goal	Level		Optimization
			Lower	Upper	Result
Horn sonication period	minutes	is in range	10	50	10
Filler loadings	wt.%	is in range	0.5	5.0	0.5
Tensile strength	MPa	maximize	0.15683	1.27792	1.27792

Table 4.8: Optimization recommendation of NRL/SnO_2 nanocomposites solution

Sample	Horn sonication period	Filler loadings	Tensile strength	
1	10	0.50	1.27792	Selected
2	10	5.00	0.47037	
3	50	0.50	0.93778	
4	50	5.00	0.15683	
5	30	2.75	0.23164	
6	30	2.75	0.20081	
7	30	2.75	0.25251	

Optimization strategy that are recommended by the DOE software were tabulated in the following Table 4.8, whereas the optimum recommendations were presented in the following Table 4.9. Referring to the Table 4.7, the factors were optimized as follows: horn sonication period (factor A) = 10 minutes and filler loading (factor B) = 0.5 phr / 1 wt.%, with suggested optimized result of 1.27792 MPa. The goal of this optimization was fixed into “is in range” for all independent variable factors and “maximize” for the tensile strength independent response. Meanwhile in Table 4.8, sample 1 is recommended by optimization suggestion with highest desirability of the corresponding tensile strength response. First recommendation with desirability of one (unity) was selected for further validation test, which represents as the most desirable solution for maximum tensile strength response. The selected solution were 0.5 phr/1 wt.% of nanofiller loading and 10 minutes of horn sonication period respectively. The desirability result has approached unity value of one which denoted

that all analysed factors are fully significant and should not be neglected. In this study, the first solution that has been suggested by the software was further used for validation purpose.

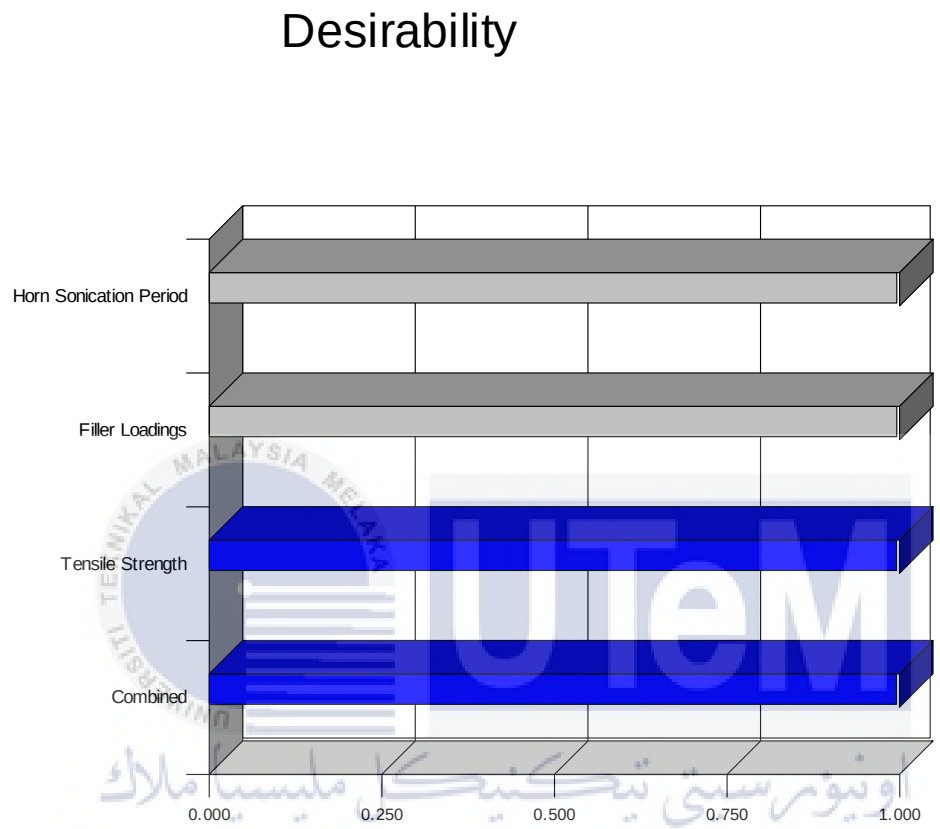

Figure 4.6: Optimization result of NRL/SnO_2 nanocomposites in histogram graphical view

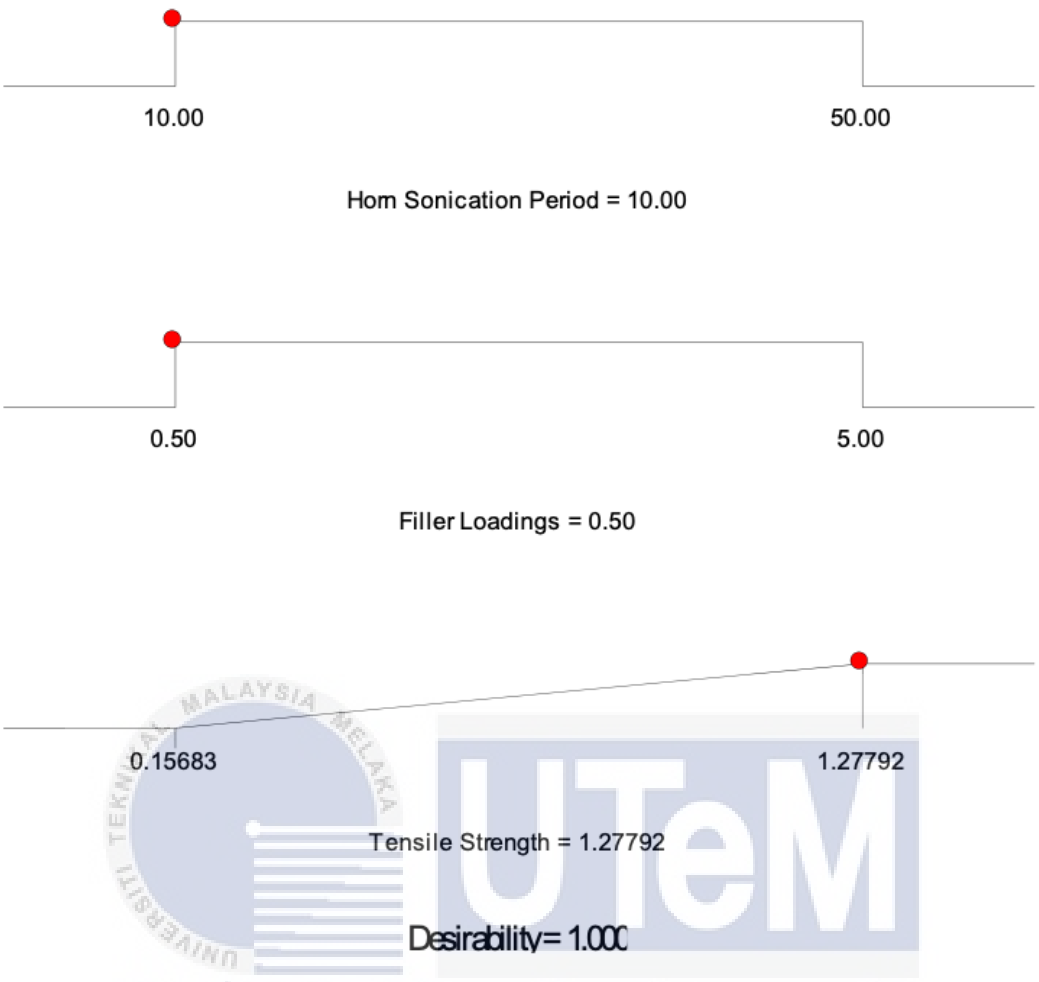

Figure 4.7: Optimization of of NRL/SnO_2 nanocomposites in ramps graphical view

Figure 4.7 depicted the optimization of of NRL/SnO_2 nanocomposites in ramps graphical view meanwhile figure histogram represents the optimization result of NRL/SnO_2 nanocomposites in histogram graphical view. Referring the Figure 4.7, the ramps shows that the optimal factor setting were at the lowest range for filler loading and horn sonication period whereby the tensile strength response at the highest range shown by the red bullet. The histogram graphical view in Figure 4.6 depicted the desirability for each factor and tensile response, individually. The bottom histogram bar shows the combined desirability of all factors for the tensile strength response. The combination of both factors with the recommended solution of 1 wt.% of SnO_2 nanofiller loadings with 10 minutes of horn sonication period, are able to generate the desirability of one or unity value which indicate a perfect interaction between the involved factors.

4.4 Fracture Surface Morphological Result via the Scanning Electron Microscope (SEM)

Scanning electron microscope (SEM) morphological observation were performed to observe the agglomeration state and bonding characteristics between of filler particles with the NRL matrix. The composites sample for SEM imaging was selected based on the best and worst tensile strength performance towards composites due to tensile loading. In this study, NRL with 0 wt.% was used as controlled sample for comparison purpose, while, NRL/1 wt.% SnO_2 nanofiller for the best performer and NRL/7 wt.% SnO_2 nanofiller as the worst strength sample among all.

Figure 4.10 depicts the control sample morphology. Meanwhile, Figure 4.8 and Figure 4.9 shows the filler dispersion of SnO_2 nanofiller at 1 wt.% and 7 wt.% filled NRL matrix, respectively. Filler/matrix interface plays a significant role in determining both mechanical and electrical insulation properties of produced NRL based composite material. In Figure 4.8, it was visually evident that the SnO_2 nanofiller are scattered uniformly over NRL matrix, where good filler dispersion over the entire area of composites bodies are noticed. Good dispersion of SnO_2 nanofiller leads into better strength performance as proven by the tensile properties results and higher insulation behaviour of electrical insulation properties.

In addition, it was also found that the good bonding of NRL/ SnO_2 nanocomposites dominated by matrix detachment through the fracture surface scanning between the matrix and filler. It was achieved by homogenous dispersion of SnO_2 nanofiller. However, this good bonding formed the rough fractured surfaces of NRL/SnO_2 nanocomposites due to matrix detachment caused by stronger matrix-filler interaction that has yield from the SnO_2 nanofiller addition. This morphological observation proves further the well performance of such NRL/SnO_2 nanocomposites for their mechanical and electrical insulation properties.

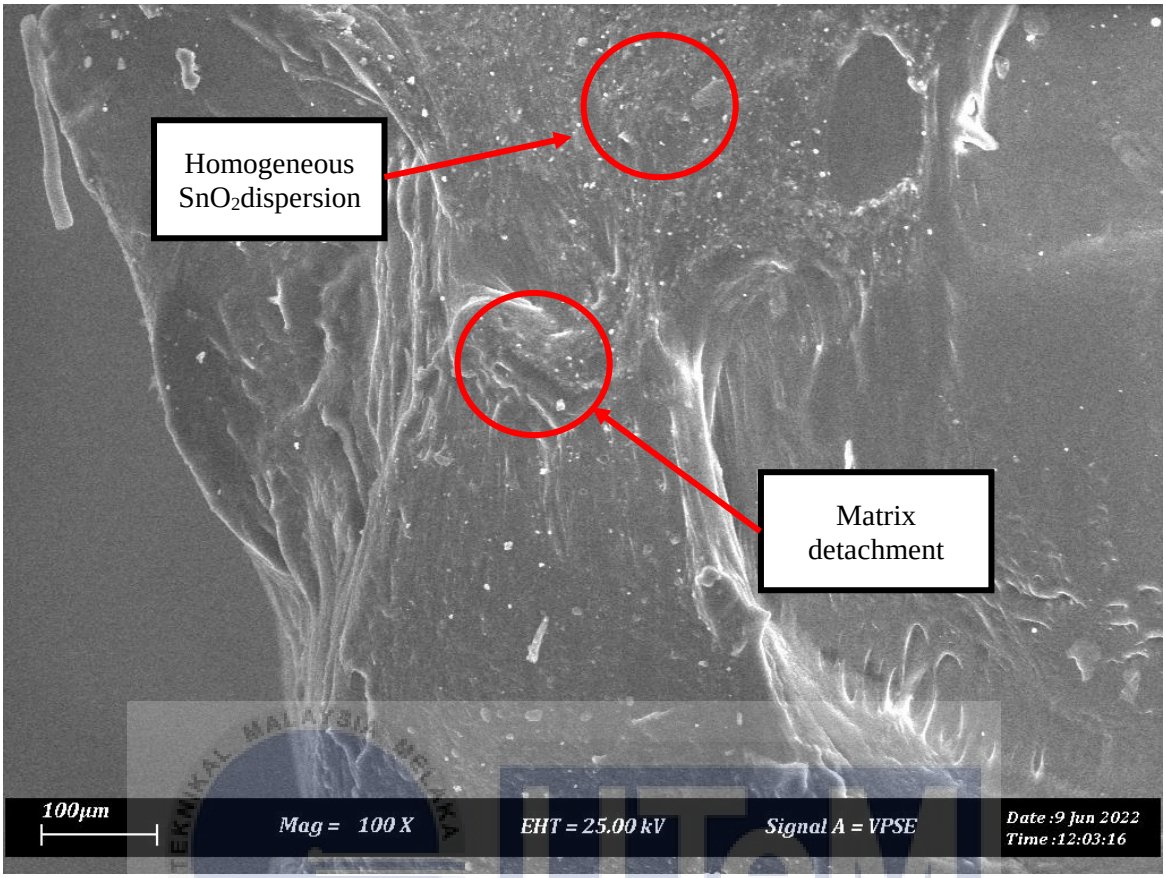

Figure 4.8: Filler dispersion of SnO_2 nanofiller at 1 wt.% as best performance sample

However, this was not evident in composites samples that were added with stannic oxide (SnO_2) nanofiller at 7 wt.% as depicted in Figure 4.9. From the image, it was found that some of the agglomeration has occur at the between the fractured surface of NRL matrix as compared than the controlled sample as shown in Figure 4.9. In this situation, the interfacial bonding between the constituent materials may not be strong enough due to void formation that has resulting from imperfect wetting between nanofiller and matrix. It was clearly seen that the largest width was about 100 µm. This considered big enough to initiate an early premature failure due to tensile loading. The nature of circular shape of SnO_2 nanofiller exposed to cause agglomeration phenomenon between them due to the very small size of the filler in the formed of nano sizing. This agglomeration has been responsible to be acted as stress concentration points, that prone to experience early premature failure during the tensile loadings which proved by mechanical testing results.

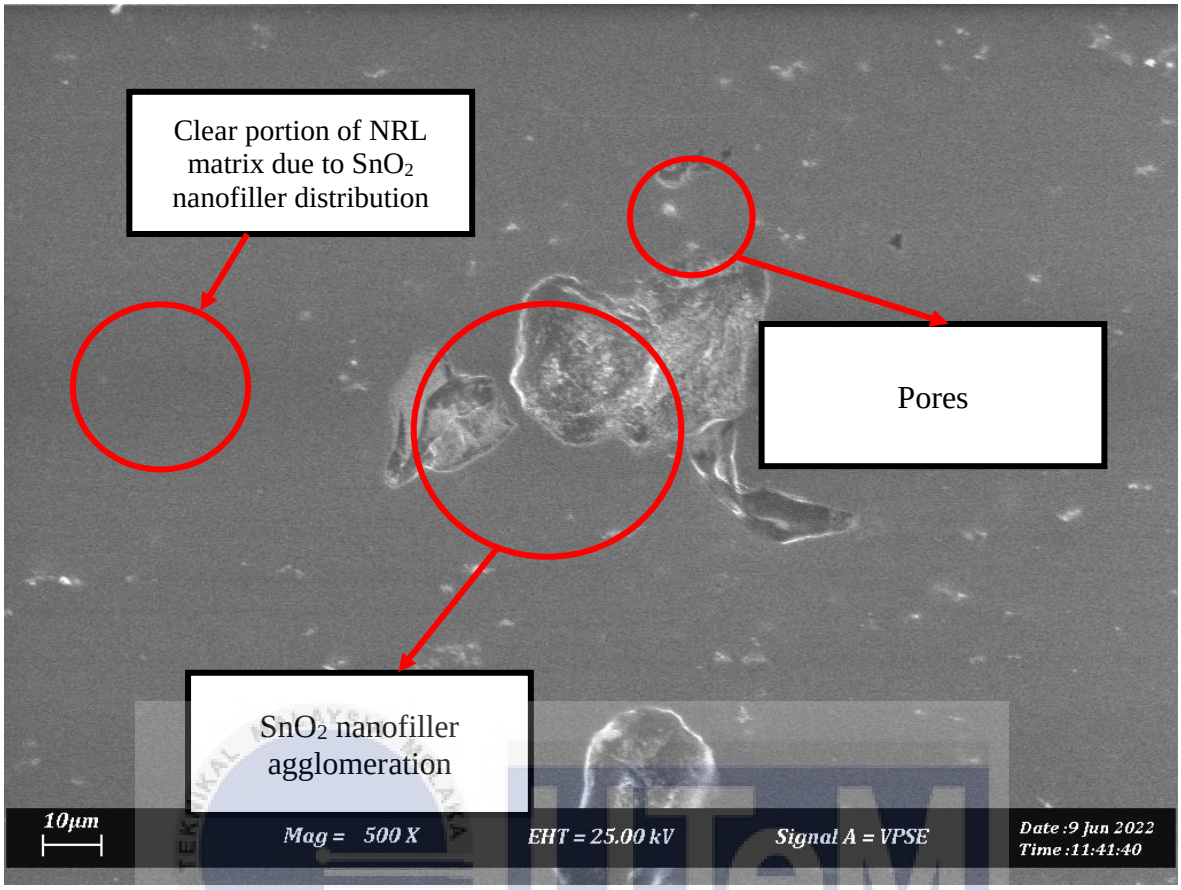

Figure 4.9: filler dispersion of SnO_2 nanofiller at 7 wt.% as worst performance sample

For the sample control which contain 0 wt.% of nanofiller loading, as depicted in the following Figure 4.10, it was clearly shown that the fractured surface due to tensile loading has experienced the matrix detachment. This scenario indicates the superior strength condition of NRL matrix itself without any filler element insert. However, for the case of this research, the presence of SnO_2 nanofiller at the entire loading percentages has proven successfully improved the mechanical, physical and morphological as evidenced from the gathered experimental results.

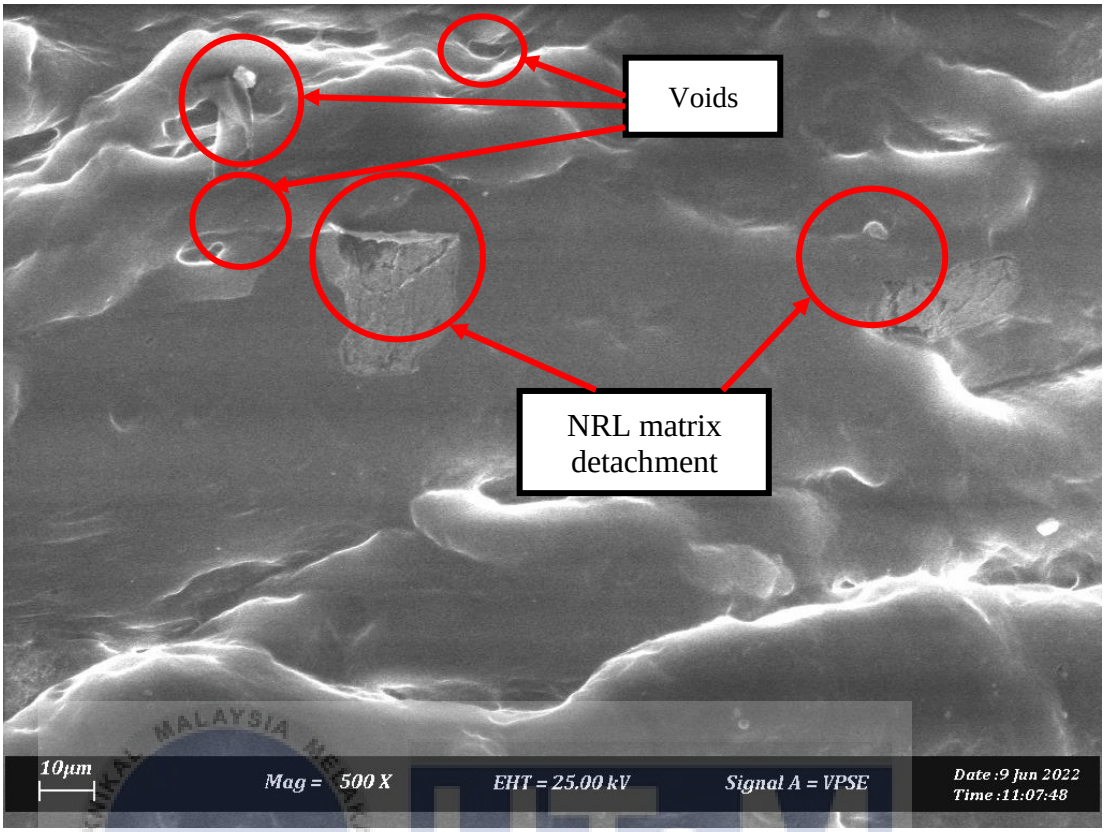

Figure 4.10: The 0 wt.% of SnO_2 nanofiller as controlled sample

4.5 Density of Natural Rubber Latex Reinforced Composites with Different wt.% of Filler Loading

The density results of NRL/SnO_2 nanocomposites is shown in the following Figure 4.11. From Figure 4.11, it was shown that there was an increasing in density as the filler loading is decreasing. It proven by the different wt. % filler loading of SnO_2 nanofiller as shown in Figure 4.11. The controlled sample of experimental gives density measured of 0.998 0.96 g/cm^3. The density of the best sample which is from sample 1 is 1.952 g/cm^3. Meanwhile, the worst sample which is sample 4 is 0.96 g/cm^3. This might be due to a technical fault pertaining to the sensitivity of the weighing balance equipment, which is too sensitive to the vibration from the surroundings which causing the experimental data errors.

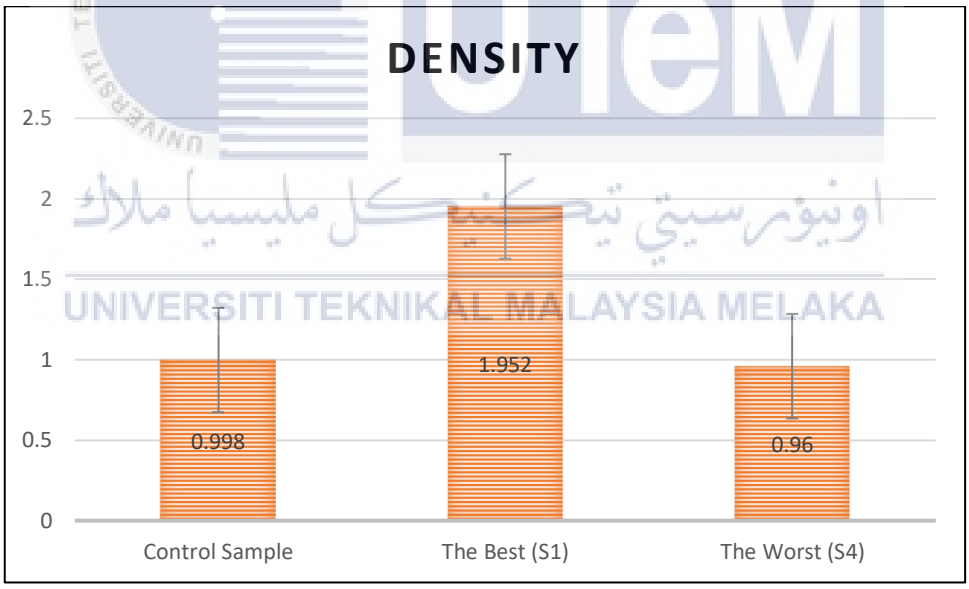

Figure 4.11: Graph of density

4.6 Surface Resistivity Results

Surface resistivity is obtained by measuring the resistance of insulating material against current leakage along the surface of the material. The measurement of surface resistivity is done along the surface of materials and is denoted by the unit of Ohm/sq. The test was conducted on all 8 samples with a portable Monroe resistivity meter. The obtained experimental results summarized and presented in the following Table 4.9. The value resistivity obtained for all samples falls within 8.0 x 10^4(Ω/sq) to 2.0 x 10^{14} (Ω/sq). The highest reading recorded was obtained by sample control sample with the value of 1.9 x 10^{11} (Ω/sq) and the lowest was obtained by sample 4 with the value of 2.1 x 10^6 (Ω/sq) while the rest displayed reading between the range. A higher value of surface resistivity indicates a better insulation property of materials. The tests were conducted to all 8 sample including the controlled sample for a minute under room temperature with varying humidity range from 50 - 70%.

Table 4.9: Surface Resistivity results based on the test performed on all SnO_2/NRL nanocomposites samples

Samples	**SnO_2 Nanofiller Loadings (wt.%)**	**Horn Sonication Period (minutes)**	**Surface Resistivity (Ω/sq)**
Control sample	0	30	1.9 x 10^{11}
Sample 1	1	10	1.9 x 10^9
Sample 2	7	10	5.8 x 10^6
Sample 3	1	50	2.5 x 10^6
Sample 4	7	50	2.1 x 10^6
Sample 5	4	30	1.5 x 10^7
Sample 6	4	30	1.9 x 10^7
Sample 7	4	30	2.6 x 10^7

4.7 Summary

In summary, the entire experimental testing were successfully conducted toward NRL based matrix in order to determine the high performance of tensile strength. all parts of the analysis are comprehensively explained and justified at the respective paragraph. NRL based matrix were characterized using XRD whereby the existence of SnO_2 particles has been proven by the observation of FTIR analysis and SEM characterization method. In addition, through SEM it was visually evident that SnO_2 nanofiller are scattered uniformly over the NRL matrix, where good dispersion of filler loadings over the entire area of composites bodies are well noticed.

SnO_2/NRL nanocomposites shows the best performance at the lowest filler loading in tensile strength testing and surface resistivity. In tensile testing, the composites shows better performance at the lower filler concentration which was at 1 wt.%. this was due to ideal amount of nanofiller loadings that could optimally effect the tensile strength of produced insulator to yield good filler-matrix interaction at the interphase and interface, due to well dispersion and homogeneous distribution of an added filler in NRL based composites. in overall, the entire gathered experimental results are ample to justify the potential of this new advanced material candidates for wide application in the industry especially to produce electronic packaging.

CHAPTER 5
CONCLUSION AND RECOMMENDATIONS

This chapter consists of the conclusions towards overall significance of study and the findings in this research as in line with the achievement of research objectives. Future, the recommendation for future studies are included for the improvement purpose in related work.

5.1 Conclusion

The natural rubber latex (NRL) based composites are developed consisting of stannic oxide nanofiller type of reinforcement SnO_2 nanocomposites to study their mechanical and electrical properties. The effects of different wt.% of filler loadings were fully investigated. In this study, three (3) samples of the total experimental samples which is the best, the worst and controlled sample were chosen to study their physical properties.

The optimum formation for nanofiller was determined via mechanical and electrical testing. By conducting the mechanical tensile test, the NRL/SnO_2 nanocomposites at the filler loading of 1wt.% was enough to provide better tensile strength as compared than other amount of filler loadings. However, the horn sonication period play an importance role to the effect of producing the best tensile strength value. SEM observation was provided to support the result obtained. From the perspective of electrical testing under surface resistivity properties, the testing has revealed that the electrical properties of the composites increased alongside with an decrease of filler loading. The highest value of measured properties for the electrical testing shown by NRL/SnO_2 nanocomposites sample at 1 wt.% filler loading. This was due to good dispersion of the nanofiller which proven the grip between the filler and matrix and fill the interstitial spaces inside NRL matrix.

Stannic oxide (C) has been successfully produced using horn sonication method and has proven via X-ray Diffraction (XRD). The phase identification shows that the highest percentage of relative intensity can be found at the best sample which is sample 1 with 1 wt.% of nanofiller loading was at the position at 16° of 2 theta. There is only one (1) peaks listed was identified using this method. Besides, the worst sample which is sample 4, it can be seen that are three (3) peak involved due to crystal formation process. SnO_2 nanofiller does exist a peak due to the reaction occurred during the horn sonication process. The presence of SnO_2 element in the composites proven by using Fourier Transform Infrared Spectroscopy Result (FTIR) analysis. The nanofiller loading to the natural rubber latex matrix have been successfully produced using this method.

In this study, SnO_2 nanofiller also dominated the best performance in terms of mechanical, electrical and physical properties even when the matrix itself have strong properties. Based on this findings, it was suggested that at the filler loading of 1 wt.% is good enough for the better tensile strength mechanical properties. This is due to agglomeration occurred at large amount of fillers loading which cause weak tensile performance. However, the horn sonication period also give a big impact to the production of the composites. Researcher figure out that, the longer the horn sonication period, the weaker the tensile strength mechanical properties. This proven by sample 4 which the increasing of filler loadings and horn sonication period, the composites produce lower value tensile strength. The longer horn sonication period produced heat energy from the wave energy and effect the agglomeration of the nanofiller. This due to the agglomeration occurred at large amount of filler loading which causes weak tensile performance.

While for the electrical surface resistivity testing, NRL/SnO_2 nanocomposites possessed the highest value at 1 wt.% of filler loadings and 10 minutes of sonication period meanwhile the lowest surface resistivity value was obtained by NRL/ SnO_2 nanocomposites sample at 7 wt.% filler loadings with 50 minutes of horn sonication period. It should be noted that higher surface resistivity value indicate a better insulating materials attribute with small leakage current possibilities.

Overall, the best parameter was possessed by sample 1 at 1 wt% nanofiller loadings for the mechanical tensile testing and electrical surface resistivity testing. Thus, the parameter be chosen depends on application and situation.

5.2 Contribution to knowledge

This study focused with respect to comprehend on the reinforcement of various filler loadings on the natural rubber latex, specifically on their mechanical, physical and electrical insulation properties. There are eight (8) samples of different filler loadings including the controlled sample with 0 wt.% filler loading as a benchmark. It is found that sample 1 with 1 wt.% filler loading had better mechanical properties compared to other samples. The amount of filler loading with the sonication period had high tendency to hold the composites for a better bonding. Thus, their tensile properties were better compared to other amount filler loadings. However, larger amount of fillers also caused an agglomeration between filler and matrix. this is mainly due to weak bonding when too large amount of fillers was added onto the matrix.

In addition, through electrical insulation testing, in terms of surface resistivity, it proven that the controlled sample which is unfilled NRL sample is way better among all. However, the amount of filler loading does not cause any much drop of electrical insulation testing result. As the filler loading decreased, the value of surface resistivity increase. Due to the high insulation properties of the natural rubber latex (NRL), the small amount of filler does not give big effect to the insulation properties of the NRL itself. However, it can be conclusively shown that the filler loadings and types of mineral filler added has played an important role in enhancing the electrical insulation performances which is good for the high voltage application.

5.3 Recommendation

Based on the experimental findings and interesting discoveries throughout this research, for recommending similar researches to be conducted, the recommendation has been made based on the following:

a. To perform the feasibility study on the potential of natural rubber latex (NRL) for similar purpose of electronic packaging. This will provide hint on the NRL competitiveness as Malaysia is one of the biggest producers and commodity exporter in the world. This will value add our local natural resources.
b. To perform statistical design through DOE as to optimize related processing and material parameters. By having the DOE results, it will further ease the execution of research and at the same time will give numerical and related equation based on the result with the coefficient of determination value.
c. To develop and test the real product and prototype made from optimum selected formulation of NRL/SnO_2 nanocomposites in real situation to be test for the electronic packaging. This will further create the understanding of the working mechanism of insulator made from the polymer-based element.
d. To further the principle of macromolecules materials for such specific application as an insulator for the electronic packaging.

5.4 Complexity

In this study, the material chosen as filler to develop as a new material is stannic oxide. Thus, the uniform hybrid nanofiller networks strongly absorbed by Natural Rubber Latex (NRL) macromolecules can significantly enhance the mechanical properties of nanocomposites. Since there is no previous research about the combination of stannic oxide and natural rubber latex, the biggest challenges began in collecting information, especially in producing multiscale nanocomposites. During the experimental, issues on the dispersion of nanoparticles within natural rubber latex as matrix occur which lead to the dispersion problem which is the particles are agglomerated after the stannic oxide was added to the natural rubber latex. Agglomeration should be avoided because the particles that having the

dead ends will cause the composites becoming an insulator since it does not conducting any path for the electric current. From the observation during the critical time, agglomeration occurred during the horn sonication period. This happened due to the heat energy produced by horn sonication machine during conversion from the electrical energy into heat energy. However, the amount of stannic oxide also may be a factor on agglomeration during the mixing with natural rubber latex.

Since the matrix based was in latex formed, the bubble production should be avoided because it tend to weaken the composite properties strength. That is why, there is a need to place the mixture into the pressure oven to suck the unrequired bubbles. Besides, the right temperature required to dry the mixture also play an important role to make it successfully becoming a solid composite. Initially, the first trial for this experimental, the temperature was set at 160°C for a duration of 12 hours. However, it was not successful, there was a sign of burnt composites for the preparation of the nanocomposites; potentially due to high temperature and longer duration period. Since this study had not been done before, several trial and error efforts were conducted. Finally, the temperature was changed from 160°C to 60°C for a 24 hours duration and successfully able to produce the solid preparation of natural rubber latex reinforced with stannic oxide nanocomposites.

5.5 Sustainability Elements

Natural rubber latex is well-known as renewable bio-based polymer that has been widely used in a wide variety of applications. It is also known for its strong, elasticity and super stretchy material that can be in form of natural or synthetic. Natural rubber used in this study is produced by the milky white sap formed by Hevea Brasiliensis and also known as rubber tree. In this study, natural rubber latex is used without adding any others chemical to cure. In order to meet the complete concept of green growth and sustainable development, the used of non-toxic chemicals are avoided and replaced with distilled water. As we know, to produce best, harder and stronger rubber, the adding of sulphur in vulcanization process is a must to create a good bonding structure of the rubber itself. When the latex is vulcanized, the added sulphur atoms help to form extra bonds between rubber molecules which known as cross-links. This cause the molecules is gathered and making them much harder to pull

apart. However, in this research, elasticity and tear resistant are needed to fulfil the requirement of producing material that suit the miniature component. So, natural state of rubber is used because of the molecules are long chains that are tangled up and only weakly linked together. It result relatively easy to pull them apart and producing stretchy and elastic material.

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