

DEVELOPMENT OF UP MODIFIED EPOXY FOR APPLICATIONS ON ANTI CORROSIVE COATINGS

Submitted in partial fulfillment of the requirements for the award of

Bachelor of Technology degree in
Chemical Engineering

By

GOWRI SHANKAR M (Reg. No. 38190004)

SHANNON STALIN S (Reg. No. 38190013)



DEPARTMENT OF CHEMICAL ENGINEERING

SCHOOL OF CHEMICAL ENGINEERING

SATHYABAMA

INSTITUTE OF SCIENCE AND TECHNOLOGY

(DEEMED TO BE UNIVERSITY)

Accredited with grade "A" by NAAC

JEPPIAAR NAGAR, RAJIV GANDHI SALAI, CHENNAI – 600119

MAY 2022



SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Accredited with "A" grade by NAAC
Jeppiaar Nagar, Rajiv Gandhi Salai, Chennai - 600 119
www.sathyabama.ac.in



DEPARTMENT OF CHEMICAL ENGINEERING

BONAFIDE CERTIFICATE

This is to certify that this Project Report is the bonafide work of **GOWRI SHANKAR M (Reg. No. 38190004) SHANNON STALIN S (Reg. No. 38190013)** who carried out the project entitled "**DEVELOPMENT OF UP MODIFIED EPOXY FOR APPLICATIONS ON ANTI CORROSIVE COATINGS**" under my supervision from September 2021 to April 2022.

Internal Guide

Dr. D VENKATESAN M.E, Ph.D

Head of the Department

Dr. S SATHISH Ph.D
HEAD OF THE DEPARTMENT
DEPARTMENT OF CHEMICAL ENGINEERING
SATHYABAMA
INSTITUTE OF SCIENCE AND TECHNOLOGY
(DEEMED TO BE UNIVERSITY)
Jeppiaar Nagar, Rajiv Gandhi Salai
Chennai - 600 119

Submitted for Viva voce Examination held on _____

Internal Examiner

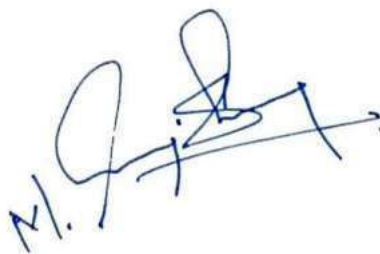
External Examiner

DECLARATION

I **GOWRI SHANKAR M (38190004)** hereby declare that the Project Report entitled “**DEVELOPMENT OF UP MODIFIED EPOXY FOR APPLICATIONS ON ANTI CORROSIVE COATINGS**” done by me under the guidance of **Dr. D VENKATESAN M.E, Ph.D** is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Chemical Engineering.

DATE: 19.04.2022.

PLACE: CHENNAI



SIGNATURE OF THE CANDIDATE

DECLARATION

I SHANNON STALIN S (38190013) hereby declare that the Project Report entitled "DEVELOPMENT OF UP MODIFIED EPOXY FOR APPLICATIONS ON ANTI CORROSIVE COATINGS" done by me under the guidance of Dr. D VENKATESAN M.E,Ph.D is submitted in partial fulfillment of the requirements for the award of Bachelor of Technology degree in Chemical Engineering.

DATE: 19/04/2022

PLACE: CHENNAI



SIGNATURE OF THE CANDIDATE

ACKNOWLEDGEMENT

We are pleased to acknowledge our sincere thanks to Board of Management of **SATHYABAMA** for their kind encouragement in doing this project and for completing it successfully. I am grateful to them.

We convey our sincere thanks to **Dr. S SATHISH, Ph.D.**, Head of the Department, Department of Chemical Engineering for providing me necessary support and details at the right time during the progressive reviews.

We would like to express our sincere and deep sense of gratitude to our Internal Guide **Dr. D VENKATESAN, M.E, Ph.D** and to our external guide **Dr. GINILMON, Ph.D** for his valuable guidance, suggestions and constant encouragement paved way for the successful completion of my project work.

We also express our thanks to all Teaching and Non-teaching staff members of the Department of Chemical Engineering who were helpful in many ways for the completion of the project.

ABSTRACT

Epoxy resin is great adhesive product used widely in industries due to its heat resistance relative high toughness, high electrical resistivity, low shrinkage, good environmental resistance, good miscibility and compatibility while blending which improves the impact resistance. These resins are synthesized based on the addition of two different types of modifiers. Toughing agents are added to support and render the damage tolerance and improve the thermal properties of epoxy. Morphological analysis was also done to study the structural characterization, mechanical, tensile, compression and flexural properties of the blended resins produced. Unsaturated polyester modified epoxy matrix filled have been synthesized. The synthesized polymer is characterized using SEM, FT-IR, TGA, XRD in order to find the elemental composition, surface morphology, thermal stability and structure. Mechanical properties are tested in order to study its tensile strength & modulus, flexural strength & modulus and hardness. Then, application studies are done using a metal plate in order to prove it as an Anti-corrosive agent.

	TABLE OF CONTENTS	
CHAPTER NO	TITLE	PAGE NO
	ABSTRACT	vi
	LIST OF FIGURES	x
	LIST OF TABLES	xi
1	INTRODUCTION	1
	1.1 COMPOSITE MATERIAL	1
	1.2 POLYMER MATRIX COMPOSITE(PMC)RESIN SYSTEM	2
	1.3 POLYMER NANOCOMPOSITES	3
	1.4 EPOXY RESIN	3
	1.4.1 CLASSIFICATION OF EPOXIDE RESINS	4
	1.5 CURING AGENTS	4
	1.6 EPOXY NANOCOMPOSITES	6
	1.7 POLYESTER	7
	1.8 POLYESTER NANOCOMPOSITES	8
	1.9 UNSATURATED POLYESTER MODIFIED EPOXY MATRIX	9
	1.10 CHARACTERISATION OF POLYMER NANOCOMPOSITES	10
	1.10.1 FOURIER TRANSFORM INFRARED SPECTROSCOPY(FT-IR)	10
	1.10.2 X-RAY DIFFRACTION ANALYSIS	11

	1.10.3 THERMO GRAVIMETRIC ANALYSIS (TGA)	12
	1.10.4 MECHANICAL CHARACTERISTICS	13
	1.10.4.1 TENSILE PROPERTIES	13
	1.10.4.2 FLEXURAL PROPERTIES	13
	1.10.4.3 HARDNESS	14
	1.10.5 SCANNING ELECTRON MICROSCOPE	14
	1.11 OBJECTIVES OF THE PRESENT INVESTIGATION	15
2	LITERATURE REVIEW	17
3	AIM AND SCOPE	22
	3.1 AIM	22
	3.2 SCOPE	22
4	MATERIALS AND METHODS	23
	4.1 MATERIALS	23
	4.2 METHODS OF PREPARATION	23
	4.2.1 PREPARATION OF EPOXY MATRIX	23
	4.2.2 DEVELOPMENT OF UNSATURATED POLYESTER MODIFIED EPOXY MATRIX	25
	4.3 CHARACTERISATION	27
	4.3.1 FT-IR SPECTRA ANALYSIS	27
	4.3.2 X-RAY DIFFRACTION ANALYSIS	27
	4.3.3 THERMOGRAVIMETRIC ANALYSIS	27
	4.3.4 TENSILE PROPERTIES	27

	4.3.5 FLEXURAL PROPERTIES	28
	4.3.6 HARDNESS	28
	4.3.7 SCANNING ELECTRON MICROSCOPE (SEM)	28
5	RESULT AND DISSUCTION	29
	5.1 SPECTROSCOPIC ANALYSIS	29
	5.2 X-RAY DIFFRACTION ANALYSIS	31
	5.2.1 WIDE-ANGLE X-RAY SCATTERING (WAXS)	31
	5.3 THERMOGRAVIMETRIC ANALYSIS	33
	5.4 MECHANICAL PROPERTIES	36
	5.4.1 TENSILE PROPERTIES	36
	5.4.1.1 UNSATURATED POLYESTER MODIFIED EPOXY MATRIX.	36
	5.4.2 FLEXURAL PROPERTIES	36
	5.4.2.1 UNSATURATED POLYESTER MODIFIED EPOXY MATRIX	36
	5.5 MORPHOLOGY	38
	5.5.1 MICROSCOPIC INVESTIGATION	38
	5.6 APPLICATION	40
6	SUMMARY AND CONCLUSION	42
	REFERENCE	43

	LIST OF FIGURES	
FIGURE NO	TITLE	PAGE NO
1.1	EPOXIDE GROUP	3
1.2	STRUCTURE OF DGEBA	4
1.3	SCHEME OF REACTION	6
1.4	CHEMICAL STRUCTURE OF UNSATURATED POLYESTER	8
4.1	FORMATION OF UNSATURATED POLYESTER MODIFIED EPOXY MATRIX	24
4.2	MOULD	25
4.3	PURE EPOXY-EP	25
4.4	UNSATURATED POLYESTER MODIFIED EPOXY-EUP	26
5.1	FTIR SPECTRA OF (A) EPOXY, (B) UP MODIFIED EPOXY	30
5.2	XRD PATTRENS OF EPOXY	31
5.3	XRD PATTERNS OF UP MODIFIED EPOXY	32
5.4	TGA OF EPOXY	34
5.5	TGA OF UP MODIFIED EPOXY MATRIX	35
5.6	SEM IMAGE OF EPOXY	38
5.7	SEM IMAGE OF UP MODIFIED EPOXY	39
5.8	COATED METAL PLATE IMMERSSED INTO ACID	41
5.9	CORROSION AFTER IMMERSSED INTO ACID	41

	LIST OF TABLES	
TABLE NO	TITLE	PAGE NO
5.1	THERMOGRAVIMETRIC ANALYSIS	48
5.2	MECHANICAL PROPERTIES OF UP-EPOXY BLENDS	51

--	--	--

CHAPTER 1

INTRODUCTION

The development of civilization depends on new materials. This statement remains true in today's modern world of technology and will undoubtedly continue to be valid in future. Polymer composites are considered to an important and indispensable high performance engineering materials which replaces many of the conventional materials. The major advantages of polymer composites are their ease of fabrication into complex structural shapes, replacement of conventional materials with considerable weight reduction, improved reliability and increased fuel economy in the case of vehicles. The modern technology development needs reliable high performance composites materials having light weight with excellent thermal and mechanical properties. Epoxy resins based on diglycidylether of bisphenol-A has been used extensively as thermosetting matrices in the development of high performance fiber reinforced composites.

A wide spectrum of various composites have emerged with almost tailor made properties to cater the needs of not only the aircraft and aerospace industry but also other industries like marine, automobile, electrical, chemical and household applications. Composite materials technology exploits the high specific moduli and strength of reinforcing fibers to produce low-density high performance structures.

1.1 COMPOSITE MATERIALS

Based on the sorts of matrices used, composites are divided into four categories. Polymer matrix composites (PMCs), ceramic matrix composites (CMCs), metal matrix composites (MMCs), and carbon-graphite composites are the four types of composite materials. When materials in these categories combine the traits of high strength and stiffness, low weight, corrosion resistance, and, in certain situations, specific electrical properties, they are referred to as "advanced." Advanced composites are particularly appealing for aircraft and aerospace structural parts because of their combination of characteristics. Filament (long fibers), short fibers, platelets, flakes, and particles are all examples of matrix system suitable reinforcement. Fibers and whiskers are the most popular reinforcing options.

Powder metallurgy, which involves solid or liquid state sintering or impregnation of molten metal, is used to create metal composites. Because of their inert nature, hardness, and thermal stability, metallic, intermetallic, and non-metallic oxides are employed in ceramic composites.

1.2 POLYMER MATRIX COMPOSITE (PMC) RESIN SYSTEMS

In polymer composites, Metals, ceramics, or polymeric fibers with a higher modulus than the matrix are utilized as reinforcement in polymer composites. Because of their light weight, higher working temperature, greater rigidity, improved dependability, and affordability, polymeric composites continue to have a significant impact on the materials world as proven by several recent developments and exotic uses. More than 90% of all composites used in advanced applications are fiber reinforced polymer composites. One of the most significant advantages of employing polymers in structural composites is the simplicity with which complex structural shapes may be created. Aerodynamically efficient structural designs can be easily fabricated in aerospace applications without the need of time-consuming and expensive fabrication techniques.

Thermoplastic and thermosetting polymeric resin systems are utilized to make advanced composites. Thermosetting resins, on the other hand, now prevail, whereas thermoplastics play a minor part in the production of advanced composites. Epoxies, polyester, vinyl ester, phenolics and amino resins, polyimides and polyamides are some of the most prevalent thermosets. Epoxies are the most widely utilized of these in the polymer matrix composites (PMC) sector today. Reliable, high-performance composite materials with outstanding thermal and mechanical qualities are required for structural components and devices employed in modern technological applications. Epoxy resins based on bisphenol-diglycidyl A's ether have been widely used as thermosetting matrix in the production of high-performance, light-weight fiber reinforced composites.

1.3 POLYMER NANOCOMPOSITES

A new category of composites has recently evolved in which the reinforcing material has dimensions of one billionth of a meter, resulting in nano composites. On a nano scale, the reinforcing phase of polymer metal nano composites, in the shape of whiskers, has two dimensions. Due to the large surface area and amount of dispersion of metal nanoparticles in the matrix strength, metal particles reinforcement boosts both strength and toughness. They also have excellent barrier qualities, as well as improved electrical and thermal properties.

1.4 EPOXY RESINS

Epoxy is a chemical group that consists of an oxygen atom bound to two carbon atoms that have already been joined in some fashion. Any molecule with more than one epoxide group capable of being transformed to a useful thermoset form is referred to as epoxy resin. The epoxide group, commonly known as oxirane or ethoxyline, is illustrated below (Figure 1.1).

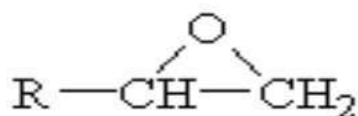


Fig: 1.1 Epoxide group

Thermosetting polymers are employed as adhesives, high-performance coatings, and potting and encapsulating compounds. These resins have excellent electrical properties, low shrinkage, good adhesion to a variety of metals, and moisture, heat, and mechanical shock resistance. Other essential qualities of epoxy resins include viscosity, epoxide equivalent weight, and molecular weight.

Epoxy resins, which are the most common thermosetting polymers, are frequently employed as structural adhesives and matrices for fiber composite materials. Curing or crosslinking transforms linear epoxy resins into a three-dimensional cross-linked thermoset network. Although these cross-linked epoxy resins have outstanding thermal, electrical, and mechanical properties, they are brittle materials with poor fracture propagation resistance.

1.4.1 Classification of Epoxide Resins

Epoxy resins are divided into two categories: glycidyl epoxy and non-glycidyl epoxy resins. Glycidyl epoxies are divided into three types: glycidyl-ether, glycidyl-ester, and glycidyl-amine. The epoxy resins that aren't glycidyl are either aliphatic or cycloaliphatic. Non-glycidyl epoxies are made by peroxidizing the olefinic double bond, while glycidyl epoxies are made by condensation of appropriate dihydroxy molecule, dibasic acid, or a diamine with epichlorohydrin. The most often used epoxies are glycidyl-ether epoxies such as diglycidyl ether of bisphenol-A (DGEBA) and novolac epoxy resins. Bisphenol-A is converted to diglycidyl ether of bisphenol-A (DGEBA) by reacting bisphenol-A with epichlorohydrin in the presence of sodium hydroxide. DGEBA's structure is depicted in Figure 1.3.

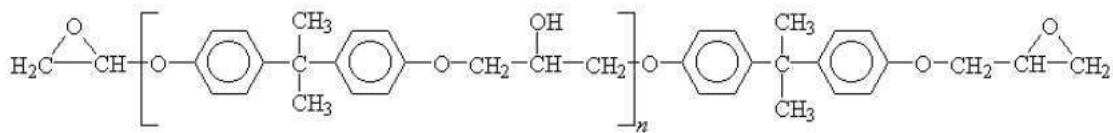


Fig: 1.2 Structure of DGEBA

The qualities of DGEBA resins are determined by the value of n , which is the number of repeating units generally referred to as polymerization degree. The number of repeating units is determined by the synthesis reaction's stoichiometry. In many commercial items, n usually varies from 0 to 25.

Filament winding, pultrusion, vacuum impregnating, contact moulding, and the production of prepregs from glass and carbon fibers all require DGEBA resins. They can be treated with a variety of curing chemicals at both ambient and high temperatures using a variety of curing agents.

1.5 CURING AGENTS

The term 'curing' is used in epoxy resin technology to describe the process by which epoxy resins are changed from low molecular weight molecules into a highly cross connected network by adding a curing agent. The network might be made up of

segments that just use epoxies or segments that use both epoxy resin and curing agent (hardner).

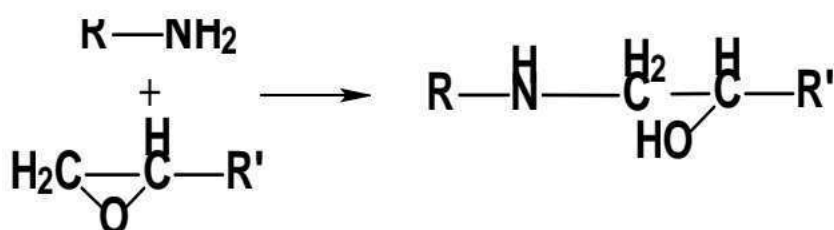
Epoxy resin reacts with active hydrogen compounds such as phenols, alcohols, thiols, primary and secondary amines, carboxylic acids, and acid anhydrides in general. The type of curing agent has a significant impact on epoxy resin characteristics. It has a significant impact on the mechanical properties and morphology of cross-linked epoxy. Cure temperatures have a considerable impact on the morphological and mechanical properties of the material.

The most commonly used curing agents are aliphatic, primary and secondary amines, aromatic primary and secondary amines, polyamidoamines and acid unhydrides.

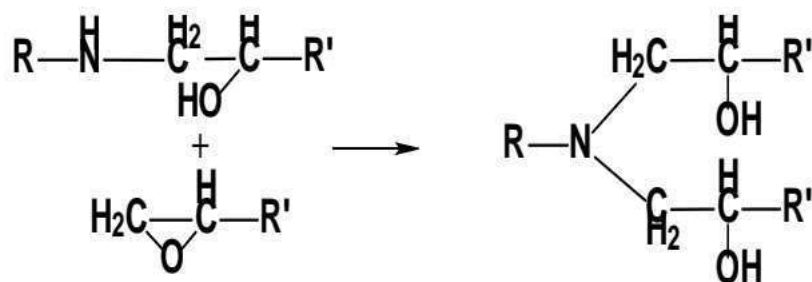
Step 1 depicts the simplified cure reaction of an epoxy resin with an amine hardner. During the first conversion, the two functional groups react and produce a linear or branched polymer. When a primary amine is added to an epoxide group, a hydroxyl group and a secondary amine are formed, which continue until the primary amine groups are depleted.

Step 2 depicts the cross connecting of macromolecules by adding secondary amines with epoxy groups, resulting in a three-dimensional network. Etherification, in which a hydroxyl group combines with an epoxide group to generate an ether bond and a subsequent hydroxyl group, is one of the most prevalent side reactions. The degree to which the resin and hardener etherify during cure is determined by the structure and chemistry of the resin and hardener, as well as the cure conditions.

Step 1:



Step 2:



Step 3:

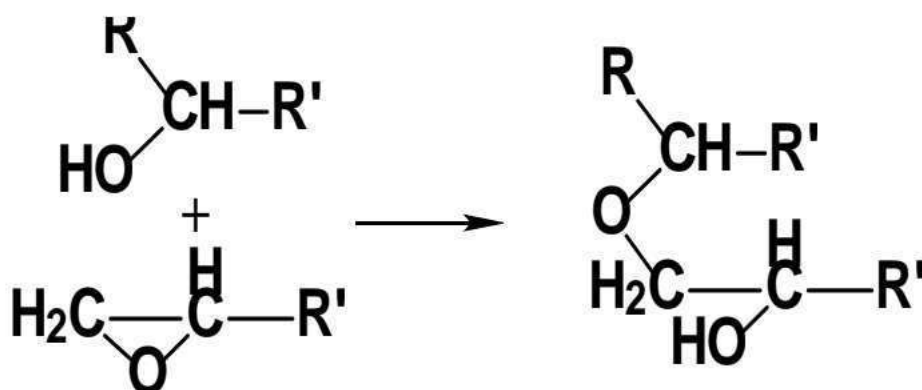


Fig: 1.3 Scheme of Reaction

1.6 EPOXY NANOCOMPOSITES

Over the last three decades, the use of polymer matrix composite (PMC), has increased tremendously and this dramatic growth is expected to continue in the future. These composites possess many useful properties such as high specific stiffness and strength, dimensional stability, adequate electrical properties and excellent corrosion resistance. The implications are easy transportability, high payload for vehicle, low stress for rotating parts, high ranges for rockets and missiles, which make them attractive for both the civil and defense applications. The composite industry is currently dominated by thermosetting resins namely epoxy, vinyl ester, unsaturated polyester, phenolic, polyimides, cyanate ester etc. This is because of their availability, relative ease of processing, lower cost of capital equipment for processing and low material cost.

Thermoset epoxy composites are most often used in high performance application

on account of their unique performance to cost ratio compared to polyester based composites. They generally possess excellent properties and are suitable for a large number of processing techniques. This results from the different chemistries, blending components and pre-polymerisation stages that can be used.

Epoxy and epoxy based composites are preferred insulating materials for several electrical applications, especially printed circuit boards, bushings, GIS spacers, generator ground wall insulation system and cast resin transformers. Recently, epoxy based nanodielectric systems are being increasingly investigated for their electrical properties, since the introduction of nanofillers demonstrate several advantages in their properties when compared with the similar properties obtained for epoxy systems with micrometer sized fillers.

1.7 POLYESTER

Unsaturated polyesters are buildup polymers framed by the response of polyols (otherwise called polyhydric alcohols, natural mixtures with numerous liquor or hydroxy practical gatherings) and polycarboxylic that contain twofold securities. Regular polyols utilized are glycols like polyethylene glycol or polypropylene glycol. The standard polycarboxylic acids utilized are phthalic corrosive and maleic corrosive.

Unsaturated polyesters vary from soaked polyesters, for example, polyethylene terephthalate which establishes the polyester movies and strands of trade in that acids or glycols having twofold security unsaturation are remembered for the equation to give receptive olefinic unsaturation in the unsaturated polyester alkyd.

Polyester sap is utilized for projecting, auto body fix, wood filling, and as a cement. It has great wear and cement properties, and can be utilized to fix and bond together various sorts of materials. Polyester gum has great life span, fair UV opposition, and great protection from water. Polyester gums attachment to certain materials can be brilliant, for example, in fiber glass composites yet others, for example, wood the bond is a lot more vulnerable.

Polyester gums are thermosets, frequently in fluid structure, utilized for the creation of glass-supported plastic. For this situation, an impetus (methyl ethyl ketone

peroxide (MEKP) (otherwise called butanone peroxide) is utilized to start the polymerization response; benzoyl peroxide is a fairly less unsafe option appropriate for a few different purposes. The Figure 1.7 shows the romanticized substance design of an unsaturated polyester.

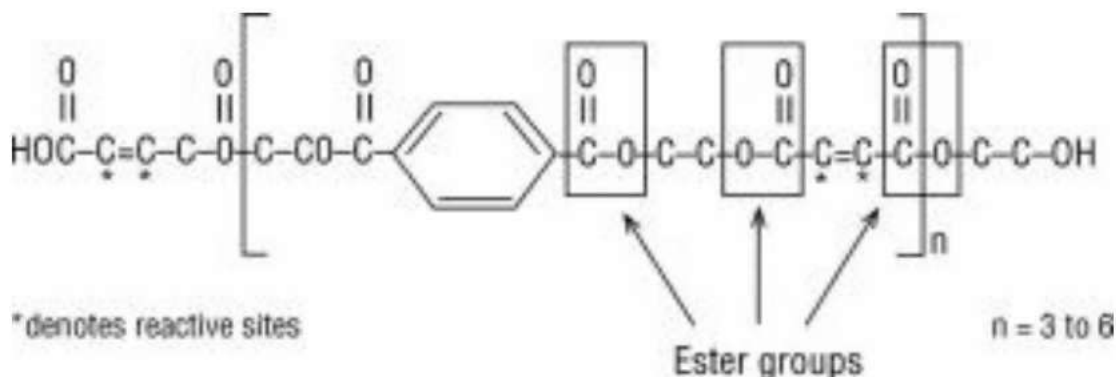


Figure 1.4 Chemical structure of unsaturated polyester

1.8 POLYESTER NANOCOMPOSITES

The rule that utilizes a nanometer material to upgrade or work on the properties of a polymer framework is explored by many individuals [9]. Many examination bunches have revealed the arrangement of polyester nanocomposites by utilizing in situ intercalation polymerization. This method empowers the arrangement of polymer nanocomposites with a palatable level of peeling. In situ intercalation polymerization is additionally especially appealing a result of its adaptability and similarity with the utilization of responsive monomers, and is starting to be utilized in business applications.

Nano filler materials are utilized widely with polyester saps for an assortment of reasons including, lessen the expense of the trim, work with the embellishment cycle, significant explicit properties to the trim. Nano fillers are many times included amounts up to half of the gum weight albeit such expansion levels will influence the flexural and elasticity of the cover. The utilization of nano fillers can be valuable in the overlaying or projecting of thick parts where generally impressive exothermic warming can happen.

1.9 UNSATURATED POLYESTER MODIFIED EPOXY MATRIX

Joining at least two polymers by mechanical or compound limitless blending strategies structures polymer mixes. These subsequent polymeric frameworks frequently show properties that are better than any of the part polymer alone. The primary downside of epoxy gums is their intrinsic fragility. The greater part of the strategies utilized for development of properties depend on the expansion of rubbers or thermoplastic modifiers. Among elastic modifiers, the most utilized are responsive fluid butadiene and acrylonitrile rubbers. One fundamental worry with butadiene and acrylonitrile rubbers is the elevated degree of unsaturation in their design, which gives destinations to debasement responses in oxidative and high temperature conditions.

One more opportunities for fortifying epoxies is the utilization of superior operational efficiency thermoplastics, for example, poly (ether imide), polycarbonate, poly (phenylene oxide), and poly (ether sulfone).

1.10 CHARACTERISATION OF POLYMER NANOCOMPOSITES

1.10.1 Fourier Transform Infrared Spectroscopy (FT-IR)

FT-IR has been used to investigate the mechanism of specific interactions involved in polymer nanocomposites. Simple observation of bond shifts is often used to identify the interacting chemical groups.

In Fourier change technique, an equal light emission is guided from the source to the interferometer, comprising of a pillar splitter and two mirrors. The shaft splitter is a plate of appropriately straightforward material (for example Potassium bromide) to reflect only 50% of the radiation falling on it. Consequently a portion of the radiation goes to one of the mirrors, and the leftover half to other mirror. The radiations get back from both these mirrors along a similar way, and is then recombined to a solitary pillar at the splitter. Assuming monochromatic radiation is produced by the source, the recombined bar shows helpful or horrendous impedance relying upon the way lengths. Consequently in the event that the way lengths are indistinguishable or vary by an essential number of frequencies, useful obstruction gives a brilliant pillar leaving splitter assuming the thing that matters is a half-necessary number of frequencies, the shafts drop at splitter. Reflect is moved flawlessly towards or away from splitter; thusly, an identifier sees radiation exchanging in force.

Since FT-IR spectroscopy is done as a solitary pillar method, this foundation variety should be considered for every range. Assuming the pillar from such a source is coordinated through an example prior to arriving at the finder, test retentions cause holes in the recurrence circulation which after change, will show up as down-going pinnacles.

1. The entire range is acquired across the whole recurrence range on the double.
2. The absolute examining time for FT-IR is impressively not exactly that expect to create a dispersive range of a similar responsiveness and goal.
3. It is feasible to quantify the mirror position, henceforth the recurrence precisely.
4. The settling force of a FT instrument is steady over the whole range.

1.10.2 X-Ray Diffraction Analysis:

X-Ray Diffraction is a good way to evaluate the spacing between the polymer layers. The sample preparation relatively easy and so the X-ray analysis can be performed with in a few hours.

X-ray diffraction plays had a focal impact in recognizing and portraying solids since the early piece of this long time. The idea of holding and the functioning models for recognizing short-range and long-range request of translucent courses of action from the formless substances are to a great extent got from X-ray diffraction and subsequently it stays as a helpful instrument to get underlying data.

The X-ray diffraction technique is an integral asset for researching methodical game plans of particles or atoms through the communication of electromagnetic radiation to give obstruction impacts with structures, equivalent size to the frequency of the radiation. Assuming the designs are organized in a systematic exhibit of grid, the impedances are honed so the radiation is dispersed or diffracted distinctly under unambiguous trial conditions. This data gives the math of the dispersing structures. The Wavelength of X-ray is tantamount to between nuclear distances in gems; the data acquired from dissipating at wide points portrays the spatial game plans of the molecules. Low-point X-ray dispersing is helpful in distinguishing bigger periodicities, which might emerge from lamellar crystallites.

Whenever a monochromatic X-ray light emission λ is projected onto glasslike material at a point, diffraction happens just when distance went by the beams reflected from progressive planes. The exploratory 2θ worth is the point between the diffracted and approaching X-ray waves. Utilizing Bragg's condition, interlamellar dividing can be determined.

X-rays are typically delivered by assaulting a metal objective with a light emission voltage electrons. Decision of the objective metal and the applied voltage decides the frequency of X-rays delivered. Then, X-rays illuminate the level surface of the example and those diffracted by reasonable situated crystallites in the example at a point 2 merge to a line at the getting films or through a radiation counter and electronic gear taking care of information to a PC.

It is accustomed to comprehension of the actual properties of polymeric materials, metals and different solids. X-ray diffraction is right now of prime significance in explaining the designs of complicated nature items. It gives a data about the game

plans and the dividing of particles in translucent materials has been resolved straightforwardly from diffraction studies.

1.10.3 Thermo Gravimetric Analysis (TGA)

Thermo Gravimetric Analysis (TGA) is a strategy by which the mass of the example is observed as a component of temperature or time while the example is exposed to a controlled temperature program.

In thermo gravimetric investigation, a touchy equilibrium is utilized to follow the weight changes of the example as an element of temperature. Run of the mill applications incorporate the appraisal of warm soundness and decay temperature, degree of fix in buildup polymers, arrangement and a few data on succession dissemination in copolymers and structure of filled polymers.

It is established by a recording balance, a heater and a temperature regulator. The example (regularly not many mg) is set in that frame of mind inside the heater. The difference in example mass makes diversion the pillar, which mediates a light shade between a light and one of two photodiodes. The subsequent awkwardness in the photodiode is intensified and taken care of into a loop which is arranged in the middle of the shafts of a super durable magnet. The attractive field created by the current in the curl reestablishes the pillar to its unique position. The enhanced photodiode current is checked and changed into mass or mass misfortune data by the information securing framework. Examination can be performed under various sorts of environment and at temperature unto 200oC/MIN. It ought to be noticed that the example size and shape impact the thermo gravimetric bend called thermogram.

There are three temperature ranges

- Room temperature to 1200°C channel wire wound heating.
- Room temperature to 1600°C platinum alloy wire wound heating
- Room temperature to 1700°C molybdenum disilicide heating element

The majority of the joined copolymers are regularly warmed from encompassing to the greatest temperature at a warming pace of 2oC each moment. Slow warming rates are liked, so the weight change can happen over a smaller stretch of time and

temperature range. The subsequent bend is more extreme and the beginning temperature is nearer to change over a more extensive period of time and temperature range produce best steep bends shift the beginning temperature over the real. The product shows the test progress in the screen, stores the information and empowers the client to perform investigation on the information. For polymeric materials, TGA test are typically performed at air in encompassing temperature. In united copolymers, TGA tests are intended for encompassing air temperature with idle environment.

1.10.4 Mechanical Characteristics

Mechanical properties such as tensile strength, tensile modulus, flexural strength, flexural modulus and harness of polymer matrix samples are studies as per ASTM standards.

1.10.4.1 Tensile Properties

Tensile strength is an estimation of the capacity of a material to endure powers that will generally pull it separated and to decide to what expand the materials extends prior to breaking. Elastic modulus, a sign of the overall solidness of a material, still up in the air from a stress-strain diagram.

Tensile strength or tenacity is the stress at the breaking point. Tensile strength is obtained from the maximum load applied in breaking a tensile test piece divided by the original cross-sectional area of the test piece. Originally quoted as tons/sq.in. it is now measured as Newtons/sq.mm. Also termed Maximum Stress and Ultimate Tensile Stress.

1.10.4.2 Flexural properties

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, is measured in terms of stress, and thus is expressed in units of pressure (or stress, the two being equivalent). The value represents the highest stress experienced within the material at its moment of rupture. In a bending test, the highest stress is reached on the surface of the sample.

1.10.4.3 Hardness

Hardness of the composite materials are estimated involving Durometer-Type D according to ASTM D2240. Examples with 3 mm in thickness. The outer layer of the example is level over adequate region to allow presser foot to contact the example over an area having 6 mm sweep for the indenter point. The example is put on a hard flat surface. The durometer is stood firm on in a foothold in the mark of indenter somewhere around 12 mm from any edge of the example. The durometer has a pointed indenter projecting beneath the foundation of the presser foot. When the indenter is squeezed in to the example so the base lays on the plastic surface, how much indentation enrolls straightforwardly on the dial marker. Not set in stone at five unique situations on the example something like 6 mm separated and number juggling mean is taken.

1.10.5 Scanning Electron Microscope (SEM)

The scanning electron microscope is equipped for creating high goal pictures of an example surface. SEM pictures have a trademark three layered appearance and are valuable for making a decision about the surface construction of the example.

Little electron test is framed by an electron weapon and a bunch of three of additional electromagnetic focal points. The electron firearm comprises of a warmed tungsten fiber. Tungsten is utilized in light of the fact that it has the most elevated liquefying point and lower fume tension, everything being equal. The significant boundary of the weapon is its splendor which is given by the complete number of electrons coming from a unit region of the source into a unit strong point. To build the splendor, it is feasible to expand the discharge current by supplanting tungsten with lanthanum hexaborite. The electron pillar, which normally has an energy going from two or three hundred eV to 100keV, is engaged by a couple of condenser focal points into a shaft with an exceptionally fine central spot measured 0.4 nm to 5 nm. The shaft goes through sets of examining curls or sets of redirector plates in the electron optical section, normally in the objective focal point, which divert the pillar evenly and in an upward direction so it checks in a raster design over a rectangular region of the example surface. At the point when the essential electron shaft interfaces with the example, the electrons lose energy by continued dispersing and assimilation inside a tear molded volume of the example known as the association

volume, which stretches out from under 100nm to around 5µm into the surface. The size of the connection volume relies upon the electron's arrival energy, the nuclear number of the example and the example's thickness. The energy trade between the electron shaft and the example brings about the discharge of electrons and electromagnetic radiation, which can be distinguished to deliver a picture.

At the point when the electron bar strikes the example, both photon and electron signals are produced. The signs most ordinarily utilized in SEM are the optional electrons, the backscattered electrons and X-rays.

As examples are immersed by a flood of electrons, a charge will generally aggregate except if the example is earthed. This is normally accomplished by covering the items with a nano-meter thick layer of gold utilizing falter coater, subsequent to mounting them on a metal stub or carbon film.

Regions going from roughly 1 cm to 5 microns in width can be imaged in a filtering mode utilizing ordinary SEM methods 9magnification running from20x to around 30,000x, spatial goal of 50 to 100 nm).The SEM is likewise equipped for performing investigations of chosen point area on the example. This approach is particularly helpful in subjective or semi-quantitatively deciding synthetic creations, glasslike design and gem directions. The SEM is regularly used to create high goal pictures of states of articles and to show spatial varieties in substance arrangements.

1.11 OBJECTIVES OF THE PRESENT INVESTIGATION

However these investigations result more valuable data yet it requires more alteration and efficient way to deal with assess the general presentation of the changed frameworks. A definite work is expected to foster the unsaturated polyester changed epoxy half and half grid frameworks to acquire lattice frameworks with high malleable and flexural properties, hardness and great warm soundness. With this in view, the goals of the current examination are

- To foster unsaturated polyester altered epoxy cross breed network framework.
- To concentrate on the primary qualities of unsaturated polyester altered epoxy grid utilizing FT-IR spectroscopy
- To concentrate on the impact of unsaturated polyester content in epoxy grid on the mechanical properties like elasticity, ductile modulus, flexural strength,

flexural modulus and hardness.

- To concentrate on the warm way of behaving of unsaturated polyester altered epoxy frameworks.
- To concentrate on the unsaturated polyester altered epoxy lattice by X-Ray Diffraction studies.
- To concentrate on the morphological qualities of unsaturated polyester adjusted epoxy lattices utilizing checking electron magnifying lens.

CHAPTER 2

LITERATURE REVIEW

Battistella et al. (2008) concentrated on the qualities of epoxy gum mixed with seethed silica nanoparticles (0.1, 0.3 and 0.5 vol%) with various surface medicines utilizing AMEO and GLYMO). The level of scattering and the interfacial grip were examined by TEM and SEM. Ductile and crack durability properties were talked about along with weariness under various method of stacking. The break durability altogether increments and a positive pattern towards the improvement in the break spread edge under exhaustion was noticed.

Sridhar Alapati et al. (2008) considered of electrical treeing peculiarities of epoxy sap as the base polymer and silica as the nano filler. Treeing tests were led at a steady ac voltage of 20kV, 50Hz on epoxy tests with practically no fillers and with 1% by weight of nano silica fillers. Time for tree commencement as well as tree development designs were contemplated. The outcomes showed that expansion of modest quantity (1% by weight) of nano silica particles in epoxy gum further develops the treeing obstruction by postponing the tree origin time as well as the time expected by the tree to arrive at the contrary cathode.

Ariadne Juwono et al.(2006) blended epoxy-earth nanocomposites from DGEBA sap and montmorillonite dirt utilizing an in-situ polymerization. Untreated dirt and two sorts of organo mud were utilized to create the epoxy-mud nanocompsotes. The XRD (X-Ray Diffraction) charts, DSC (Differential Scanning Calorimeter) examination and TEM (Transmission Electron Microscope) pictures uncovered that the changed earth epoxy have non-peeled layers while organo adjusted dirt epoxy nanocomposites shows shed layers. Earth totals and a plumage design were found from SEM pictures for the two sorts of nanocomposite materials.

Levchik et al. (2004) arranged phosphorus-containing epoxy as receptive fire retardants. They additionally talked about the actual properties of the new receptive organo phosphorus epoxy tar, extraordinarily intended for electrical and electronic applications.

Sridhar Alapati et al. (2008) considered of electrical treeing peculiarities of epoxy tar as the base polymer and silica as the nano filler. Treeing tests were directed at a steady ac voltage of 20kV, 50Hz on epoxy tests with practically no fillers and with 1% by weight of nano silica fillers. Time for tree beginning as well as tree development designs were considered. The outcomes showed that expansion of limited quantity (1% by weight) of nano silica particles in epoxy tar further develops the treeing obstruction by postponing the tree origin time as well as the time expected by the tree to arrive at the contrary anode.

Ariadne Juwono et al.(2006) orchestrated epoxy-dirt nanocomposites from DGEBA pitch and montmorillonite earth utilizing an in-situ polymerization. Untreated earth and two kinds of organo mud were utilized to deliver the epoxy-dirt nanocomposites. The XRD (X-Ray Diffraction) charts, DSC (Differential Scanning Calorimeter) examination and TEM (Transmission Electron Microscope) pictures uncovered that the altered mud epoxy have non-peeled layers while organo changed dirt epoxy nanocomposites shows shed layers. Earth totals and a plumage design were found from SEM pictures for the two sorts of nanocomposite materials.

Ragosta et al. (2005) concentrated on epoxy-silica nanocomposites by scattering silica-organosol particles in TGDDM/DDS gum combinations. The subsequent materials were examined with regards to synthetic communications, relieving conduct and mechanical and break properties. A response between epoxy gatherings and silanol bunches present on the outer layer of the silica stage was identified, prompting an expanded interfacial grip. The restoring conduct of the epoxy lattice was not impacted by the inorganic stage. A ceaseless increment of modulus and yield strength was found by expanding the silica content.

Santanu Singha et al. (2008) explored the dielectric properties of epoxy nanocomposites utilizing TiO₂, ZnO and Al₂O₃ as nanofillers. The impact of various exploratory boundaries like recurrence, filler size, filler fixation were considered. The rising dielectric attributes for epoxy based nano dielectric frameworks were acquired because of huge volume part of connection points in the majority of the material and the resulting between the charged nanoparticle surface and the epoxy chains.

Fothergill et al. (1996) considered the of dielectric spectroscopy and space charge estimations on epoxy tar loaded up with 10% w/w miniature and nano measured particles of TiO₂, Al₂O₃ and ZnO. The outcomes acquired shows that the nanoparticles are essentially affecting the dielectric properties than miniature particles. It likewise recommend that the dielectric properties of such nano-filled composites are constrained by Stern-Gouy-Chapman layers ("connection zones") around the particles.

Jawahar et al. (2004) arranged polyester earth nanocomposite utilizing natural changed dirt (dodecylamine treated montmorillonite) as the support. Traditional mud (unmodified) filled composite was handled utilizing inorganic dirt (Bentonite) as filler at various weight rate too. The composites were tried for sway, flexural properties and boundary properties. The rate maintenance in sway and flexural properties for organo altered dirt filled polyester nanocomposites are incredibly great when contrasted with expectedly mud filled composites.

Fusheng Luo et al. (2009) decided the penetrability of polyester of poly (ethylene terephthalate) (PET) utilizing various modifiers. Poly (m-xylylene adipamide-terephthalyl amide) (MXD6T) and nanometer silicon dioxide (SiO₂) nanocomposite with various structure were ready and their hindrance properties were read up for making the polyester bottles. There was 3 to multiple times of improved porousness of these polyester grid nanocomposites with this NMXD6T when contrasted with unadulterated polyester pitches.

Jin-Hae Chang et al. (2007) arranged fluorine-based polyester nanocomposites by in situ polymerization utilizing 9, 9' (- dihexylfluorene-) 2, 7-dicarboxylic corrosive and 4, 4' (- dihydroxy-1,4-diphenoxybutane (DPB-OH) in presence of octadecyl-montmorillonite (C18-MMT) as an organoclay. They tracked down that the intercalation of the organoclay among the polymer chains which works on the warm properties of the polyester even by the expansion of limited quantity of organoclay. The most extreme upgrade of the warm properties of the fluorine-based polyester nanocomposites was seen with the scattering of 5 wt% of organoclay.

Lapprand et al.(2003) concentrated on miscibility and restoring conduct of mixes of poly(vinyl acetic acid derivation) (PVAc) and diglycidyl ether of bisphenol A (DGEBA) tar utilizing 4,4'- - diaminodiphenylsulphone (DDS) as relieving specialist. The PVAc part was utilized as a potential sturdiness modifier. Double combinations DGEBA + PVAc show total miscibility over the entire organization range. It was additionally observed that stage partition happens in DGEBA, DDS and PVAc mixes. In the last restored material has two stages: an epoxy stage and a PVAc stage independently. It was additionally observed a log jam of the response when PVAc was available.

Cicala et al. (2008) detailed the thermomechanical and rheological properties of epoxy mixes altered with various rates of a hyperbranched polyester. The cryo-cracked surfaces of the relieved examples were examined by filtering electron microscopy which showed that the mixes didn't have stage detachment. This outcome was additionally upheld by unique mechanical testing (DMTA) demonstrating a solitary unwinding top for every one of the definitions considered.

Benny cherian et al. (2007) concentrated on the physical, mechanical and warm properties of the restored mixes epoxy and unsaturated polyester tars (UPR). Epoxy pitches show great miscibility and similarity with the UPR tar on mixing and the co - relieved sap showed significant improvement in the strength and effect obstruction. Extensive upgrade of rigidity and durability are seen at exceptionally low stacking of epoxy. Thermogravimetric investigation (TGA), Dynamic mechanical examination (DMA) and Differential filtering calorimetry (DSC) were utilized to concentrate on the warm properties of the hardened epoxy pitch. The epoxy/unsaturated polyester mixes showed significant improvement in warm steadiness as obvious from TGA and damping information. The break conduct was confirmed by checking electron microscopy (SEM).

Varada Rajulu et al. (2003) arranged untreated and 2%aqueous NaOH treated bamboo filaments with epoxy, unsaturated polyester (UP) and their mixes. The synthetic obstruction of these filaments to acidic corrosive, nitric corrosive, hydrochloric corrosive, sodium hydroxide, ammonium hydroxide, sodium carbonate, benzene, toluene, carbon tetrachloride and water were examined. The mix covered

strands showed preferable compound obstruction over uncoated bamboo filaments. The mix covered filaments had higher elasticity which was credited to the hydrogen holding between the unsaturated polyester and epoxides bunch.

Yeng-Fong Shih et al. (2002) concentrated on the impact of carbon dark as fire retardants to further develop the fire obstruction of the interpenetrating polymer organizations

(IPNs) in view of unsaturated polyester/epoxy at raised temperatures. The consequences of DSC uncover that the T_g of the IPN became indistinguishable as the carbon dark was added. It was additionally found from adiabatic calorimeter concentrates on that the hotness of ignition of the IPN test was diminished by the option of carbon dark. The outcomes shows that the corruption interaction of IPN was restrained as the carbon dark was added to the IPN which lower atomic weight compounds and furthermore delivers less types of debasement items.

Tsotras et al. (2004) arranged electrically conductive mixes by blending a Polyaniline - dodecylbenzenesulfonic corrosive (PANI-DBSA) salt with epoxy pitch (EP). The warm, mechanical, and electrical properties of mixes containing various measures of PANI-DBSA were contemplated. The flexural properties were not fundamentally affected by fixations less than 7 wt.% PANI-DBSA, yet after this content they were diminishing strongly. The electrical conductivity of the examples expanded with the expansion of PANI-DBSA, arriving at a worth higher than 10⁻⁷ S/cm with 10 wt.% of PANI-DBSA.

CHAPTER 3

AIM AND SCOPE

3.1 AIM

The important aim is to synthesize epoxy polymer and characterize and study its applications.

3.2 SCOPE

The main scope of this project is to evaluate the obtained epoxy polymer to investigate its properties such as compositions, structure, morphology, mechanical properties, and investigate its applications as anti-corrosive agent using a metal plate.

CHAPTER 4

MATERIALS AND METHODS

4.1 MATERIALS

Materials used for the development of unsaturated polyester modified epoxy matrix are:

- (i) Commercially available diglycidyl ether of bisphenol-A (DGEBA) based epoxy resin LY556 (Ciba-Geigy Ltd., India) having epoxy equivalent of about 180-190, with viscosity of about 10,000 cP.
- (ii) 4,4'-diaminodiphenylmethane (DDM), epoxy curing agent is obtained from Ciba-Geigy Ltd., India
- (iii) Unsaturated polyester (UP) resin (isophthalic acid based, Polyresins, India, viscosity at 25°C = 2300-4000 cP), OH index = 24.4 eq/kg.
- (iv) Benzoyl peroxide (Merck India Ltd, India) as radical initiator.

4.2 METHODS OF PREPARATION

4.2.1 Preparation of epoxy matrix

50 g of epoxy resin and the amine hardner (27 % in accordance with the epoxy resin) are taken. The epoxy resin taken was stirred and heated at 70° C in an oil bath until the removal of trapped air bubbles and moisture. The amine hardner (DDM) was also heated around 95 °C upto melt completely. Both the resin and hardner were mixed with continuous stirring. The mixture was then poured into moulds and cured in an oven at 100 °C for 4 hours and post cured at 140 °C for 3 hours.

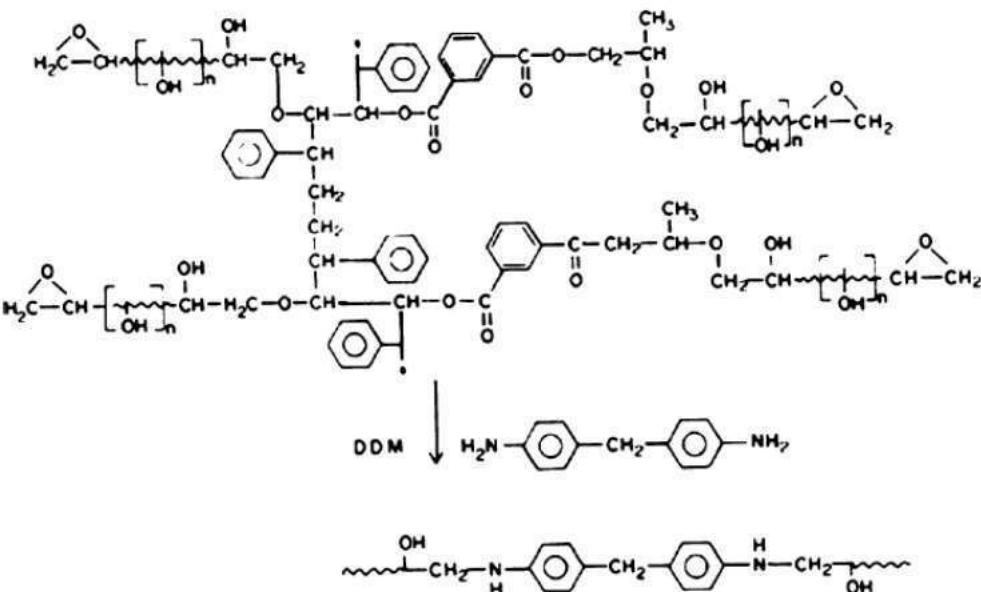


Fig: 4.1 Formation of unsaturated polyester modified epoxy matrix

4.2.2 Development of unsaturated polyester modified epoxy matrix

Unsaturated polyester modified epoxy resin was developed by blending calculated amount of unsaturated polyester (10 wt%) relative to the epoxy resin (100 w/w), stoichiometric amount of 4,4'-diaminodiphenylmethane (27.2 g) with respect to epoxy resin and benzoyl peroxide (2 wt%) using a high speed stirrer at 80 °C for 10 minutes with constant stirring. The hybrid product was then degassed to remove the entrapped air and then transferred into a preheated mould and kept at 100 °C for 4 h and post cured at 140 °C for 3 h.



Fig: 4.2 Mould

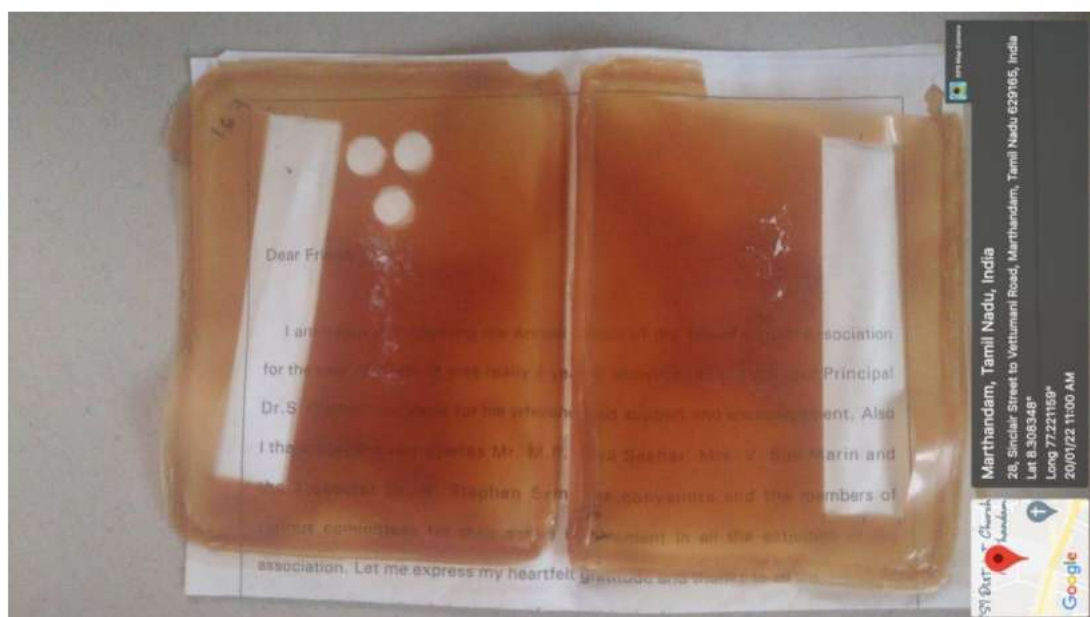


Fig.4.3 Pure epoxy - EP



Fig.4.4. Unsaturated polyester modified epoxy - EUP

4.3 CHARACTERISATION

4.3.1 FT-IR Spectra analysis

The FT-IR spectral analysis was carried out with a Perkin Elmer spectrophotometer using KBr pellets. For viscous liquid samples, the spectra were carried out by placing the sample between two KBr pellets. The samples were scanned from 400 to 4000 cm^{-1} .

4.3.2 X-ray Diffraction Analysis

Wide angle X ray scattering (WAXS) were recorded at room temperature by using X'-Pert Pro diffractometer, with $\text{CuK}\alpha$ radiation, 40kV, 100mA made by PANalytical, The Netherlands. The diffraction patterns were determined over a range of diffraction $2\theta = 0 - 100^\circ$.

4.3.3 Thermogravimetric analysis

Thermo Gravimetric Analysis (TGA) was carried out using thermogravimetric analyzer (TGA) in N_2 atmosphere (2960 SDT V2.2B). Sample was scanned from 10-600°C at a heating rate of 10°C min^{-1} . Changes in the sample weights were recorded electronically by change in voltage output from a linear variable differential transformer. The first derivative of the primary thermogravimetric curves, representing rate of weight loss, were determined from tangents to the weight loss curves.

4.3.4 Tensile Properties

Tensile properties (strength and modulus) were studied as per ASTM-D3039 using universal testing machine (Instron, Model 6025 UK), at 10 mm/minute cross-head speed, using specimen with a width of 25 mm, length of 200 mm, and thickness of 3 mm. The test specimen were prepared by machining operation. Five specimens were tested for each sample.

4.3.5 Flexural Properties

Flexural properties (strength and modulus) are studied as per ASTM-D790 using specimen with dimension 3 mm in depth 10 mm in width and 90 mm in length using universal testing machine (Instron, Model 6025, UK), at 10 mm/min cross-head speed. Five specimens were tested for each sample.

4.3.6 Hardness

Hardness of the composite materials was measured using Durometer-Type D as per ASTM D2240. Specimens were prepared with 3 mm in thickness. Hardness was determined at five different positions on the specimen at least 6 mm apart and arithmetic mean was taken.

4.3.7 Scanning Electron Microscope (SEM)

The fractured surfaces of specimens were coated with gold and examined under a scanning electron microscope (CARL-ZEISS, Model EVO-50).

Fractured surfaces were obtained from tensile tested specimens using universal testing machine (Instron, Model 6025, UK), at a cross-head speed of 2 mm per minute. Excess material was removed from the other faces of the specimens by razor blade.

CHAPTER 5

RESULTS AND DISCUSSIONS

5.1 SPECTROSCOPIC ANALYSIS:

This chapter deals with FT-IR spectral analysis of epoxy resin and unsaturated polyester modified epoxy matrix.

(Fig: 5.1a) presents FT-IR spectrum of epoxy resin and the following results for the respective bands are observed: -OH stretching vibration of epoxy resin at 3420cm^{-1} , -C-H stretching vibration at 2926 cm^{-1} , C-C stretching vibrations at 1181cm^{-1} , asymmetric stretching of epoxy group at 770 cm^{-1} and C-O stretching vibration of epoxide ring at 914 cm^{-1} .

From the FTIR spectrum of unsaturated polyester modified epoxy, the following results are observed: -OH stretching vibration of epoxy and unsaturated polyester at 3419 cm^{-1} , -C-H stretching vibration at 2926 cm^{-1} , C-C stretching vibrations at 1181cm^{-1} , C=C stretching of aromatic ring at $1,600\text{ cm}^{-1}$ and C=O absorption in unsaturated polyester at 1728 cm^{-1} . The epoxide ring of epoxy resin appears at 914 cm^{-1} which attributes the stretching absorption of C-O in the epoxide ring disappeared by curing at $140\text{ }^{\circ}\text{C}$. The network structure formed between unsaturated polyester and epoxy resin shows the reaction of epoxide ring of epoxy resin with the hydroxyl group of unsaturated polyester and is confirmed by the decrease in the intensity of the epoxy band at 914.5 cm^{-1} and the hydroxyl band at $3,510\text{ cm}^{-1}$. An intermolecular hydrogen bonding is formed between the carbonyl group on the polyester and the epoxide ring. The carbonyl group absorption of the polyester linked with epoxide ring is shifted from $1,726$ to $1,730\text{ cm}^{-1}$ (Fig. 5.1b).

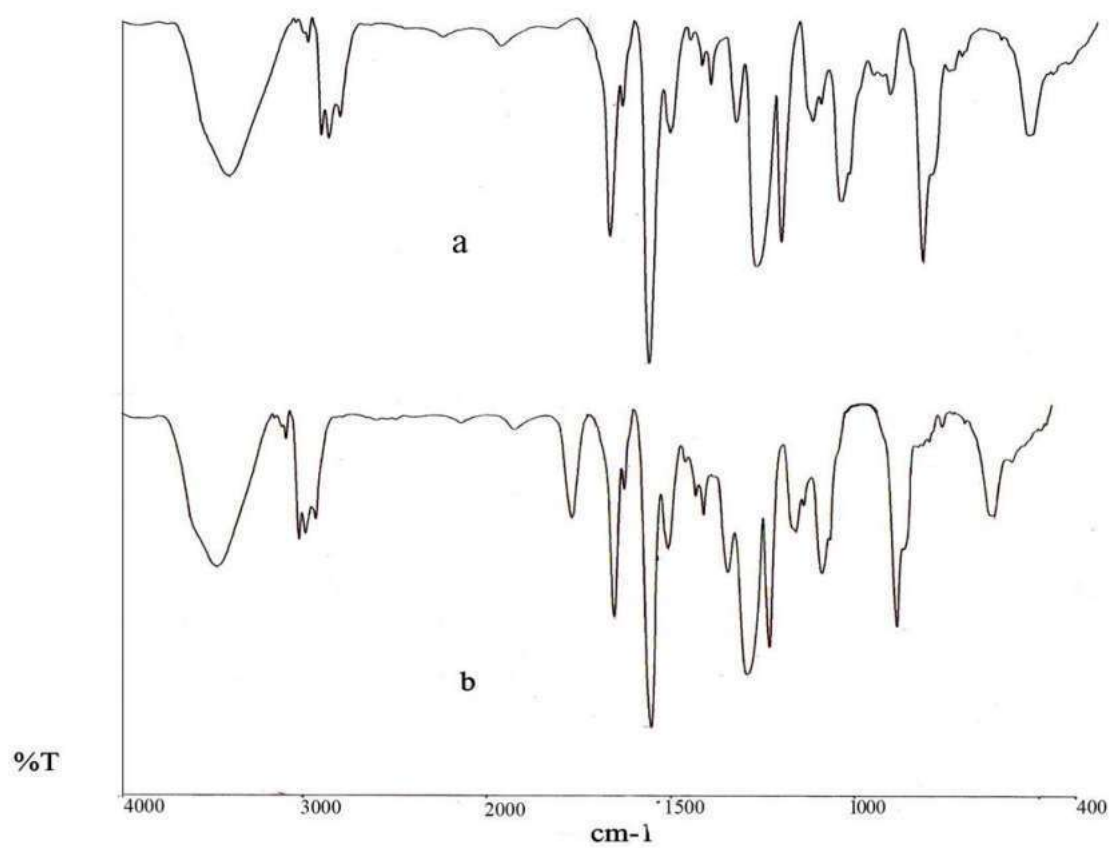


Fig: 5.1 FTIR spectra of (a) epoxy (b) UP modified epoxy

5.2 X-RAY DIFFRACTION ANALYSIS

This chapter deals with the X-ray diffraction studies of epoxy resin, unsaturated polyester (UP) modified epoxy matrix, and unsaturated polyester modified epoxy matrix.

5.2.1 WIDE-ANGLE X-RAY SCATTERING (WAXS)

Fig: 5.2 and 5.3 shows the XRD patterns of pure epoxy resin, unsaturated polyester modified epoxy matrix and unsaturated polyester modified epoxy matrix respectively. The peak position of pure epoxy at 20.6° (2θ) is not shifted due to the modification with unsaturated polyester. From the results, we can conclude that modification of epoxy using unsaturated polyester does not have influence on the average d-spacing.

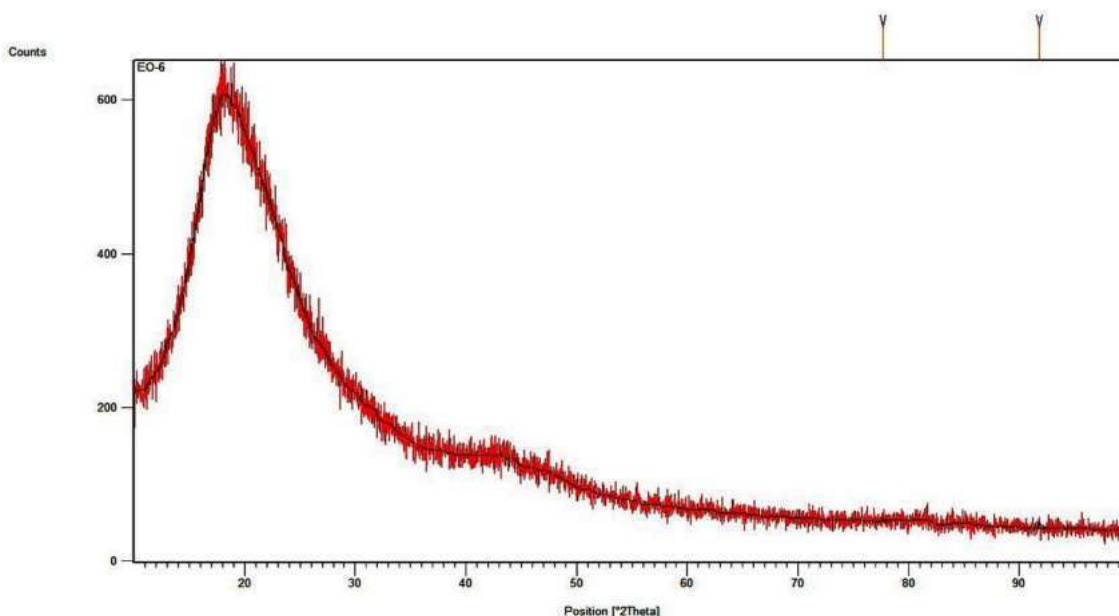


Fig: 5.2 XRD patterns of epoxy

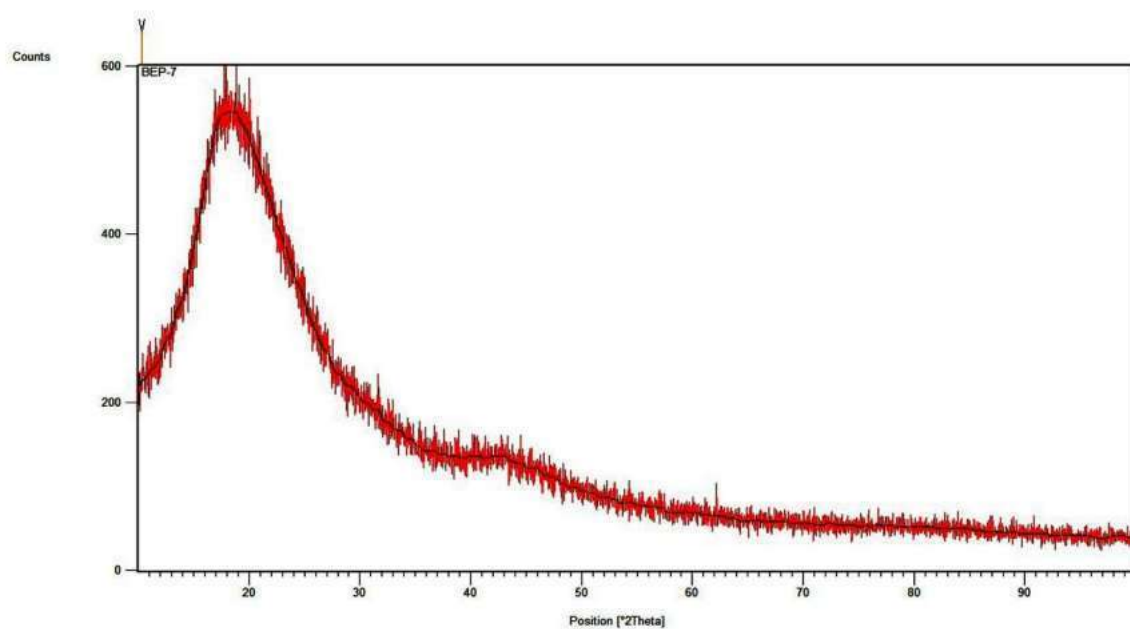


Fig: 5.3 XRD patterns of UP modified epoxy

5.3 THERMOGRAVIMETRIC ANALYSIS (TGA)

This chapter deals with the thermal analysis of epoxy resin, and unsaturated polyester modified epoxy matrix.

Thermograms of epoxy resin, unsaturated polyester modified epoxy matrix, at a heating rate of 10 °C/min are presented in Fig: 5.4 and 5.5. The epoxy and unsaturated polyester modified epoxy matrix have inception decomposition temperature 284.44 and 326.50°C respectively. It is observed that inception decomposition temperature of unsaturated polyester modified epoxy matrix is 14.7% higher than epoxy resin. It is also noticed that the final decomposition temperature of unsaturated polyester modified epoxy matrix is 0.13% less than epoxy resin. The increase in inception decomposition temperature of unsaturated polyester modified epoxy matrix is due to the interpenetrating network formation between them. The weight loss after final decomposition temperature of epoxy and unsaturated polyester modified epoxy matrix are 77.35 % and 78.43 % respectively.

Table 5.1 Thermogravimetric Analysis:

Sample code	Heating rate (°C / minute)	Inception temperature (Ti °C)	Peak temperature (Ts °C)	Final temperature (Tf °C)	Weight loss (%)
E	10	284.44	397.96	592.14	77.35
UP + E	10	326.50	398.51	591.37	78.43

E – Epoxy, UP – Unsaturated Polyester,

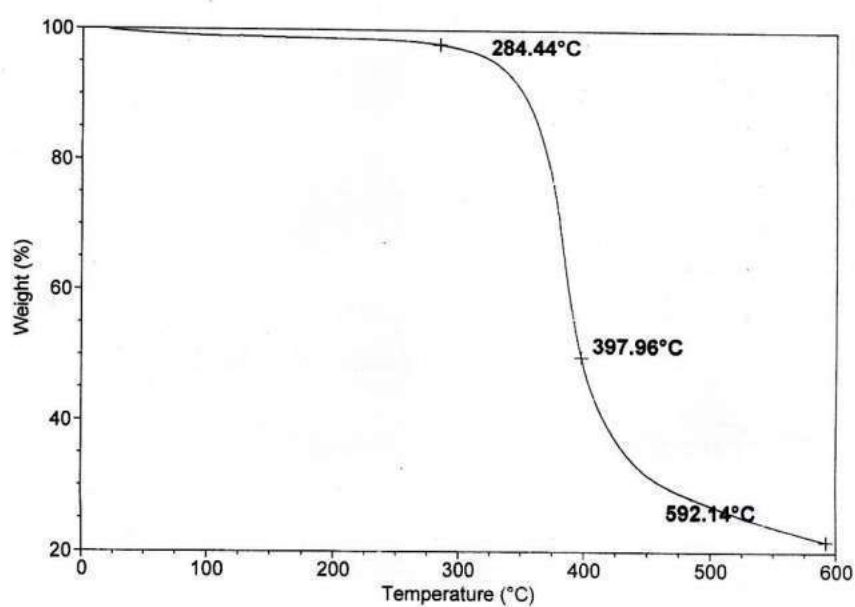


Fig: 5.4 TGA of epoxy

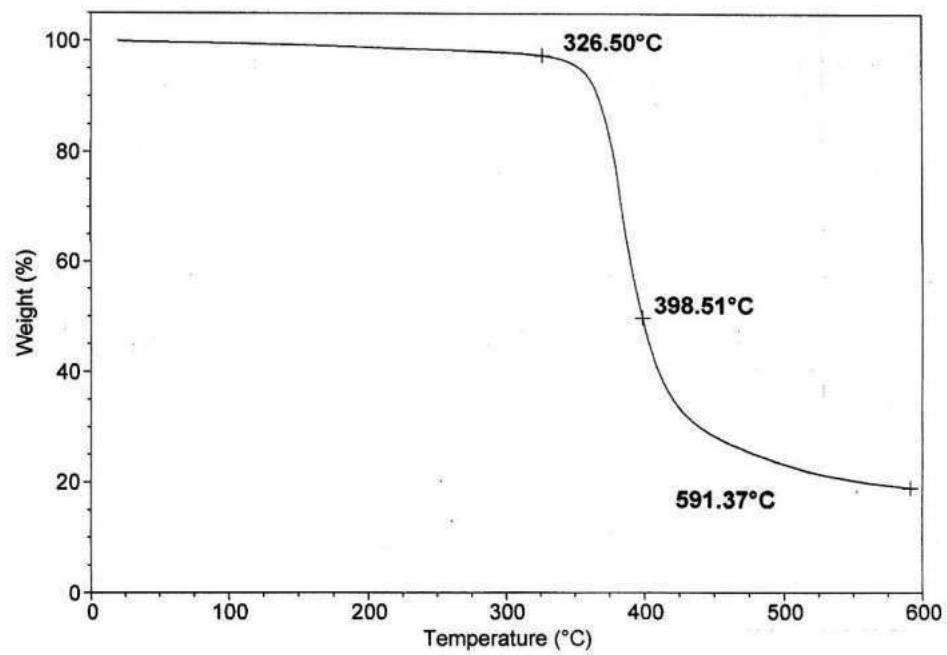


Fig: 5.5 TGA of UP modified epoxy matrix

5.4 MECHANICAL PROPERTIES

This chapter discusses the mechanical properties of epoxy resin and unsaturated polyester modified epoxy matrix.

5.4.1 TENSILE PROPERTIES

5.4.1.1 Unsaturated polyester modified epoxy matrix.

The observed values for tensile strength of epoxy and epoxy modified with unsaturated polyester are presented in the Table 5.2. The introduction of 10% (by wt) of unsaturated polyester into epoxy resin decreases the tensile strength by 16.2%, when compared with unmodified epoxy. This may be explained due to the formation of chain entanglement in the UP–epoxy matrix system. The values of tensile modulus obtained for the unmodified epoxy and epoxy modified with unsaturated polyester are also presented in Table 5.2 and they exhibit similar trend as in the case of tensile strength.

5.4.2 FLEXURAL PROPERTIES

5.4.2.1 Unsaturated polyester modified epoxy matrix.

Flexural behaviour of unmodified epoxy and epoxy modified with unsaturated polyester are presented in the Table 5.2. Introduction of 10% (by wt) of unsaturated polyester into epoxy resin decreases the flexural strength by 1.1%, when compared with unmodified epoxy. This may be attributed to the chain entanglement in the UP–epoxy matrix system. The values of flexural modulus obtained for the unmodified epoxy and epoxy modified with unsaturated polyester are also presented in Table 5.2 and they exhibit similar trend as in the case of flexural strength.

Table: 5.2 Mechanical Properties of UP – Epoxy Blends

E/UP	Tensile Strength (MPa)	Tensile Modulus (MPa)	Flexural Strength (MPa)	Flexural Modulus (MPa)
00/100	58.5	2,277	105.4	1760
100/00	45.7	2,434	NA	NA
50/50	20.9	NA	NA	NA
75/25	35.5	NA	NA	NA
25/75	30.62	NA	NA	NA
100/10	69.75	2,627.5	106.5	1864.2

UP - Unsaturated Polyester

5.5 MORPHOLOGY

This chapter discusses the morphology of the epoxy, unsaturated polyester modified epoxy matrices.

5.5.1 MICROSCOPIC INVESTIGATION

Scanning electron microscope is used to investigate the morphology of matrix systems. SEM micrograph of fractured surfaces of the epoxy and unsaturated polyester modified epoxy matrix systems (Fig: 5.6 and 5.7) reveals smooth, glassy and homogeneous microstructure without any plastic deformation. The fractured surfaces of the unsaturated polyester modified epoxy matrix systems reveal the presence of homogeneous morphology due to the efficient interaction between the unsaturated polyester and epoxy resin.

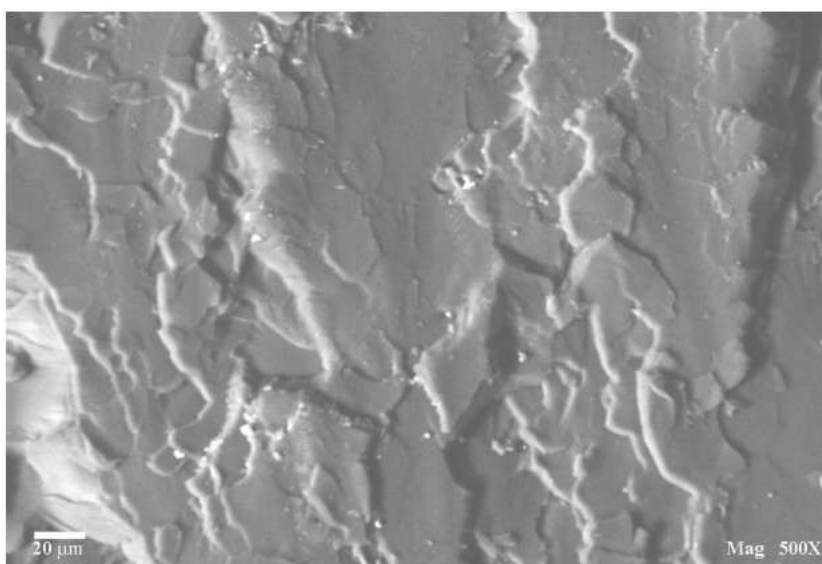


Fig: 5.6 SEM image of epoxy

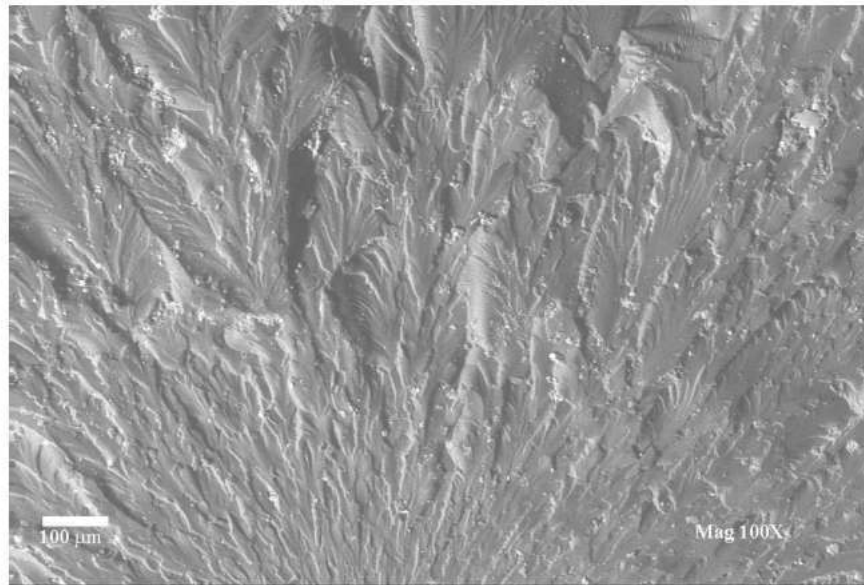


Fig: 5.7 SEM image of UP modified epoxy

5.6 APPLICATION:

- The synthesized epoxy matrix finds application in Anti - corrosive coating.
- A piece of metal plate is taken and one half of the plate is coated with the synthesized epoxy matrix and left for a day for the coating to settle.
- The next day, the whole metal plate is taken and immersed into a test tube containing concentrated sulfuric acid and the setup is left undisturbed for three days.
- After three days, the immersed metal is taken out of the solution and observed.
- It was found that the part of the metal that was coated with epoxy matrix was not corroded while the other part was prone to corrosion which is shown in the Fig: 5.9
- Thus, it was found that the synthesized epoxy matrix acts as a good anti-corrosive agent. It can find application in all areas that uses metal.



Fig: 5.8 coated metal plate immersed into acid



Fig: 5.9 corrosion after immersed into acid

CHAPTER 6

SUMMARY & CONCLUSION

Unsaturated polyester modified epoxy matrix filled have been synthesized. Spectroscopic analysis by FTIR confirm the structural characteristics of unsaturated polyester modified epoxy matrix. From the results of X ray diffraction analysis, we can conclude that modification of epoxy using unsaturated polyester does not have influence on the average d-spacing. Thermogravimetric analysis shows huge increase in inception temperature of unsaturated polyester modified epoxy matrix which confirms the thermal stability introduced by the unsaturated polyester. Mechanical properties shows the decrease of tensile strength & modulus, flexural strength & modulus and hardness. This may be due to the formation of chain entanglement in the UP–epoxy matrix system and physical blend formation without cross linkage. SEM micrograph of fractured surfaces of the epoxy and unsaturated polyester modified epoxy matrix systems reveals smooth, glassy and homogeneous microstructure without any plastic deformation. The bottom-line of this work is the epoxy being one of the highly stable material, gets additional enhancement in property on addition of the unsaturated polyester. This hybrid will have many additional property which will add up its application in diverse areas.

REFERENCES

1. Akarsh Yadav, Akash Rana, Alok Pandey, Amit Kumar, "Mechanical Properties and Reprocessing Behavior of Green Composite from Bio-Degradable Polymers" International Research Journal of Engineering and Technology, Vol. 8, No. 7, pp. 2768-2772, 2021.
2. Anshuman Srivastava, Madhusoodan Maurya, "Preparation and mechanical characterization of epoxy based composite developed by biowaste material", International Journal of Research in Engineering and Technology, Vol. 4, No. 4, pp. 397-700, 2015.
3. Ashish Thakur, Amit Telang, Rajesh Purohit, "Synthesis, Testing & Characterization of Epoxy-CNT-Bamboo Polymer Matrix Hybrid Composite", International Research Journal of Engineering and Technology, Vol. 3, No. 8, pp. 737-744, 2016.
4. Benny Cherian A, Lily Alen Varghese b, Eby Thomas Thachil, "Epoxy-modified, unsaturated polyester hybrid networks", European Polymer Journal, Vol. 8, No. 7, pp. 2768-2772, 2021.
5. Chandresh M. P, Ani Dechamma C. D, Bhavana M, Rameshwara N, Roopa S, "Toughening of unsaturated polyester resin by solid elastomers and liquid rubbers", International Research Journal of Engineering and Technology, Vol. 8, No. 4, 2021.
6. Faisal Gulzar, Danish Ahmad Reshi, Zahid Ahmad Rather, "Mechanical properties of hybrid polymer composites with bamboo and e-glass fiber produced by hand lay-up process", International Research Journal of Engineering and Technology, Vol. 7, No. 11, pp. 745-749, 2020.
7. Joyson Albino A, Navaneethan K.S, "Experimental investigation on strain hardening polymer composite", International Research Journal of Engineering and Technology, Vol. 5, No. 1, pp. 1406-1409, 2018.
8. Pingale Sanjay.S, Mr.Kamble A.G. Mr. Raut Radhesham, Mr. Pawar Saurabh, Mr.Magar Saurabh, "Thermal & mechanical properties of banana fiber reinforced epoxy resin composites added with fly ash", International Research Journal of Engineering and Technology, Vol. 8, No. 1, pp. 1713-1715, 2021.

9. Prajakta Dipak Dhakate, Vasi Shaikh, Deepali Kulkarni, "Polyfurfuryl based Polymer Concrete", International Research Journal of Engineering and Technology, Vol. 7, No. 11, pp. 678-700, 2020.
10. Ravi teja P, prasad rao M Y, Study the Mechanical Properties of Jute and Sisal fiber reinforced Hybrid Composite Materials, International Research Journal of Engineering and Technology, Vol. 6, No. 10, pp. 741-749, 2019.
11. Sanghratna S, Waghmare, Tanvir Arfin, "Defluoridation By Adsorption With Chitin – Chitosan – Alginate – Polymers – Cellulose – Resins – Algae And Fungi", International Research Journal of Engineering and Technology, Vol. 2, No. 6, pp. 1179-1197, 2015.
12. Sanju V, Satheesh S, Selvin Mon S, "An investigation on mechanical properties of glass fiber epoxy composites with filler optimized with response surface method", International Research Journal of Engineering and Technology, Vol. 8, No. 4, pp. 5291-5299, 2021.
13. Sudharsan S, Kalyan K.U, Nithyadharan C, Pranesh A, "Manufacturing of Epoxy-based Hybrid Polymer Composites", International Research Journal of Engineering and Technology, Vol. 8, No. 3, pp. 1786-1789.
14. Syed Usman Husainy, H. Syed Saleem, M.R. Faizan Ahmed, N. Syed Kahmruddin Fazeel C. Neeladharan k Mohan, "Enhancement of Stabilization in Bituminous Roads using Polyethylene and Epoxy Resin", International Research Journal of Engineering and Technology, Vol. 4, No. 4, pp. 2401-2404, 2017.
15. Talikoti C.B, Hawal T.T, Kakkamari P.P, Dr. Patil M.S., "Preparation and characterization of epoxy composite reinforced with walnut shell powder", International Research Journal of Engineering and Technology, Vol. 2, No. 5, pp. 721-725, 2015.
16. Umesh G L, Rudresh B M, Krishnaprasad N J, "Exploring the Sliding Wear Behavior of PA66/PA6 Blend Nano Composites: Influence of Load and Velocity", International research journal of engineering and technology, Vol. 7, pp. 448-455, 2020.
17. Vinita Nema, Anita Dutt Konar, A.K. Bhadoria, "Carbon Fibre Composites using Polyurethanes as Self-healing Agent and Properties Evaluation", International Research Journal of Engineering and Technology, Vol. 7, No. 8, pp. 1278-1285, 2020.

19%

유사성 지표

9%

인터넷 출처

15%

출판물

2%

학생 보고서

일차 출처

1

shodhganga.inflibnet.ac.in

인터넷 출처

2%

2

Sridhar Alapati, M. Joy Thomas. "Electrical Treeing in Polymer Nanocomposites", International Journal of Emerging Electric Power Systems, 2009

출판물

2%

3

K. Dinakaran, M. Alagar. "Preparation and characterization of bismaleimide (N,N'-bismaleimido-4,4'-diphenyl methane)-unsaturated polyester modified epoxy intercrosslinked matrices", Journal of Applied Polymer Science, 2002

출판물

2%

4

P Tsotra, K Friedrich. "Thermal, mechanical, and electrical properties of epoxy resin/polyaniline-dodecylbenzenesulfonic acid blends", Synthetic Metals, 2004

출판물

2%

5

Y. Jaya Vinse Ruban, S. Ginil Mon, D. Vetha Roy. "Mechanical and thermal studies of

1%

unsaturated polyester-toughened epoxy
composites filled with amine-functionalized
nanosilica", Applied Nanoscience, 2012

출판물

6

Subramani Devaraju, Muthukaruppan Alagar.
"Polymer Matrix Composite Materials for
Aerospace Applications", Elsevier BV, 2021

출판물

1 %

7

journals.sagepub.com

인터넷 출처

1 %

8

Garth L. Wilkes, Hao-Hsin Huang, Raymond H.
Glaser. "New Inorganic—Organic Hybrid
Materials Through the Sol—Gel Approach",
American Chemical Society (ACS), 1989

출판물

1 %

9

www.researchgate.net

인터넷 출처

1 %

10

K. P. Ochathevar Mahesh, Muthukaruppan
Alagar, Ramasmy Suresh Kumar. "Synthesis
and Characterization of Polyurethane-
Toughened Epoxy-Bismaleimide Matrices",
High Performance Polymers, 2016

출판물

1 %

11

Lapprand, A.. "Epoxy resins modified with
poly(vinyl acetate)", Journal of Materials
Processing Tech., 20031220

출판물

1 %

12 K Dinakaran, M Alagar, R Suresh Kumar. "Preparation and characterization of bismaleimide/1,3-dicyanatobenzene modified epoxy intercrosslinked matrices", European Polymer Journal, 2003
출판물 1%

13 K. Dinakaran, R. Suresh Kumar, M. Alagar. "BISMALEIMIDES (N, N'-BISMALEIMIDE-4, 4'-DIPHENYLMETHANE AND N, N'-BISMALEIMIDEO-4, 4'-DIPHENYLSULPHONE) MODIFIED BISPHENOLDICYANATE-EPOXY MATRICES FOR ENGINEERING APPLICATIONS", Materials and Manufacturing Processes, 2005
출판물 1%

14 R. Rajasekaran. "Preparation and characterization of 3,3'-bis (maleimidophenyl)phenylphosphine oxide (BMI)/polysulfone modified epoxy intercrosslinked matrices", Polymer Composites, 07/2008
출판물 <1%

15 coek.info
인터넷 출처 <1%

16 ujcontent.uj.ac.za
인터넷 출처 <1%

17 eprints.kfupm.edu.sa
인터넷 출처

<1 %

18

Premkumar, S.. "Studies on thermal, mechanical and morphological behaviour of caprolactam blocked methylenediphenyl diisocyanate toughened bismaleimide modified epoxy matrices", European Polymer Journal, 200808

출판물

<1 %

19

R. Rajasekaran, M. Alagar. "Mechanical Properties of Bismaleimides Modified Polysulfone Epoxy Matrices", International Journal of Polymeric Materials, 2007

출판물

<1 %

20

Rajkumar Josephine Sharmila, Shanmugam Premkumar, Muthukaruppan Alagar. "Preparation and Characterization of Organoclay-Filled, Vinyl Ester-Modified Unsaturated Polyester Nanocomposites", High Performance Polymers, 2008

출판물

<1 %

21

iopscience.iop.org

인터넷 출처

<1 %

22

tel.archives-ouvertes.fr

인터넷 출처

<1 %

23

Richard P. Chartoff. "Dynamic Mechanical Analysis (DMA)", Thermal Analysis of

<1 %

24

K. Dinakaran. "Preparation and characterization of bismaleimide (N,N'-bismaleimido-4,4'-diphenyl methane)-unsaturated polyester modified epoxy intercrosslinked matrices", Journal of Applied Polymer Science, 09/29/2002

출판물

<1 %

인용문 제외

꺼짐

일치 제외

꺼짐

참고 문헌 제외

꺼짐