



Higher College of Technology
Department of Engineering



Mechanical and Industrial Engineering section

POLYMER BLENDING

Submitted in partial fulfillment of the requirements for the degree of

ADVANCED DIPLOMA PROJECT

by

NADHEM MOHSEN

ID 12A163

March, 2019



Higher College of Technology

Department of Engineering



Mechanical and Industrial Engineering section

CERTIFICATE

This is to certify that the project entitled “POLYMER BLENDING” submitted by “Nadhem Mohsen Maalaoui ; ID 12A163” (Mechanical Engineering Section) University of Technology and Applied Science is a record of bonafide work carried out under the supervision of my section, as per the college code of academic and research ethics.

The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university. The thesis fulfils the requirements and regulations of the UTAS and in my opinion meets the necessary standards for submission.

Place: Muscat ,UTAS (HCT)

Date: 30/03/2019

Signature of the Program Coordinator

Signature of the HOS

DECLARATION

I "Nadhem Mohsen Maalaoui ID 12A163" hereby declare that the project entitled "POLYMER BLENDNG" submitted by me, for the award of the degree of *Advanced Diploma in Chemical Engineering* to University of Technology and Applied Science is a record of bonafide work carried out by me under the supervision of Dr. Raju Maliger.

I further declare that the work reported in this thesis has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

Place : Muscat

Signature of the Candidate

Date : 30/03/2019

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ABSTRACT

Blending of Polystyrene and high-density Polyethylene (PS/PE) by injection molding was examined. The variable parameters were pressure and temperature with volume and area being at fixed parameter. For injection molding method, the injection pressure differs from a polymer to another. In addition, the temperature which is the melting point will also differ.

For polystyrene (PS) the melting temperature is 190 °C and the pressure is around 4.4 MPa. In the other hand, high density Polyethylene (HDPE) has a melting point of 140 °C and a pressure nearly to 2MPa.

KEYWORDS: Blending, Injection molding, Temperature, Pressure.



Figure 1.1: Polymers

<https://konkourkomak.com/معارف-رشته-مهندسی-پلیمر/>

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Chapter 1

Introduction

1.1. POLYMER:

Polymers are necessary, we can't imagine life without it, because every material we see are combined components to make that certain material and we use them in the daily basis, like nylon bearings, plastics cups, and bags, polymer-based paints. Polymers are a large category of material it consists of many molecules under the name of monomers, they are linked together to form long chains. Polymers were available since the ancient days, but people did not know about it well until World War II, they were using it to manufacture materials for civilized life. For example, Steel, Glass, Bricks, wood, and fabrics for clothing. As people gain knowledge about these things, Polymers became highly demand and scientist investigated new items and materials, so the number of polymers became incalculable.



Figure 1.1: plastic cups, bags, bottles and papers

<https://www.thrillist.com/drink/new-york/plastic-straw-ban-nyc-what-else-to-ban>

1.2. POLYMER BLENDS:

Polymer mixes of blends of at least two unique polymers blended through a liquefying procedure or blending their answers. The mixed polymers may be miscible or immiscible. There is no exact and clear definition for polymer amalgams, it ideally utilized for metals as they were. If we want to use the term in polymer materials, it works only for compatible polymers. Thus, polymers can be blended to yield different products regardless of their usefulness and compatibility, but only polymer alloys are beneficial and can be utilized and are targeted in the manufacturing industry. The compatibility between polymers is determined through analysis of their solubility, which is a complicated theme in physical science of polymers. [1]

Polymer are blended in a similar fashion to breeding animals, for the sole purpose of improved physical, chemical and mechanical properties to result in better performance of the material. Well, with all complementary properties is obtained, the performance of industrial polymeric materials application improved. [1]

Due to the mainstream mixing of polymers, blends have become the most useful method. It has grown appreciably in the polymer industry, because of simplicity and how it enhances operations.

Thermoplastics for instance are extremely useful and beloved for the low cost that is provided by, as well as the very good attributes that they carry and how useful they are. Simplicity in recycling and manufacturing methods have been directed towards polymer-polymer blending to develop the desired final properties. [1]

The basic idea behind polymer blending is targeting the unique useful properties of distinctive polymers to be used in systems with various components and perform well. Polymer blending is getting more and more acknowledged than basic polymerizing operation due to the special properties that can be achieved in a polymer. The blending of two or more polymers has been a very much-known practice in industries. (Muralisrinivasan, 2017) [1]

1.2.1. CLASSIFICATIONS:

Generally, there are two varieties of the polymer blends:

1. Miscible Polymer Blend (Homogenous):

The miscible blends are mixtures present in a single phase and will be perceived in one glass transition temperature. They are:

- Produce a final product that has good elected attributes and overall high performance.
- Interpenetrating Polymers into each other.
- Expensive, but easy to use approach for investigating and refining polymer combinations.

For example, polystyrene (PS), polyphenylene oxide (PPO), polystyreneacrylonitrile (SAN) and polymethylmethacrylate (PMMA). [1]

2. Immiscible Polymer Blends (Heterogeneous):

The immiscible blends are multi-phases over a range of compositions, pressure, and temperatures, which will be perceived in two glass transition temperature.

A large portion of the polymer mixes with feeble physical qualities are immiscible in correlation with their individual polymers, because of the absence of positive communication between stages. It prompts expansive interfacial pressure in the liquefied mix which makes it hard to disfigure the scattered stage amid blending. They are:

- A blend that is dispersed in a matrix phase.
- Blend having a long repetitive structure.
- Most of the binary polymer mixtures are immiscible.

Such as Polypropylene (PP), polystyrene and polypropylene, and polyethylene (PE). [1]

1.2.2. BLEND PROPERTIES:

Interaction Parameters, Colloidal Properties, morphology, phase separation, Crystallinity, Dispersion, Physicochemical Properties.

1.2.3. SYNTHETIC POLYMERS:

1. POLYETHYLENE (PE): Polyethylene is one of the most widely used domestic polyolefins. It is a simple hydrocarbon with repeating units of $-\text{CH}_2-\text{CH}_2-$. Their properties are melting point at $115-135^\circ\text{C}$ and density $0.88-0.96\text{ g/cm}^3$. They are used for packaging goods like covers, bags and wraps. Polyethylene is acquired in many forms based on its density ; low-density polyethylene (LDPE), high-density polyethylene (HDPE), linear low-density, polyethylene (LLDPE), and polypropylene (PP). [1]

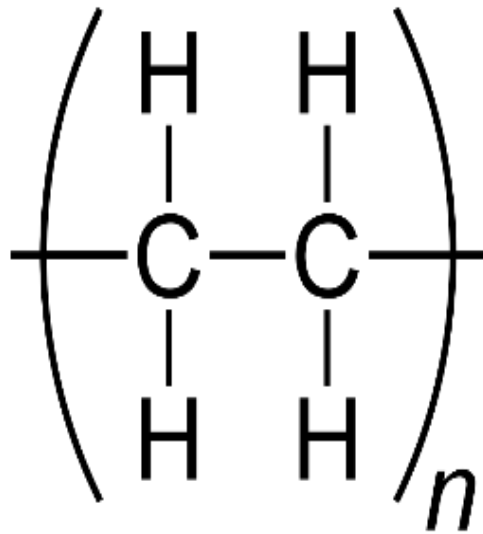


Figure 1.2: The structure of polyethylene

HIGH-DENSITY POLYETHYLENE (HDPE):



Figure 1.3: Polyethylene Containers

<https://www.polytainer.com/pe-containers.php>

Properties	Value
Density	0.96–0.97 g/cm ³
Melt temperature (T _m)	120–150 °C
Glass transition temperature (T _g)	–25 °C
Thermal conductivity	0.44 Wm ^{–1} K ^{–1}
Elongation	15–130 %
Elastic modulus	0.4–0.7 GPa

Table 1: Characteristics of high-density polyethylene (HDPE). (Muralisrinivasan, 2017)

1. POLYSTYRENE (PS):

Is a hydrocarbon polymer made from a monomer called styrene and its chemical formula is $(C_8H_8)_n$. It is in solid state and is a great insulator, it is also aromatic. Also, it is a cheap thermoplastic choice with very good properties. Polystyrene, has great impact resistance and is considered as one of the more known mechanical properties of the material, it is also brittle to an extent. Various uses are there for polystyrene, from construction to packaging goods and insulating boundaries. [1]

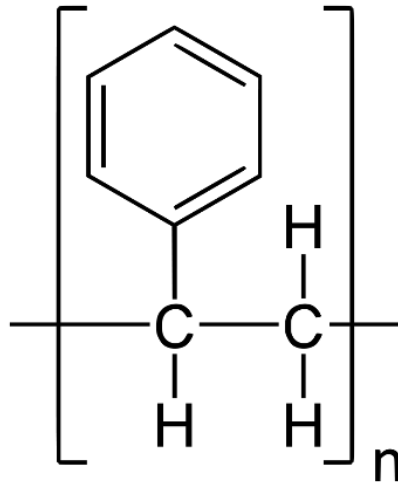


Figure 1.4: The structure of polystyrene



Figure 1.5: polystyrene cups and plates

<http://www.gadgetreview.com/can-you-microwave-styrofoam>

Properties	Value
Density	1.05 g/cm ³
Melt temperature (T _m)	180-200 °C
Glass transition temperature (T _g)	95–100 °C
Thermal conductivity	0.16 Wm ⁻¹ K ⁻¹
Elongation	3–4%
Elastic modulus	1.6–3.3 GPa

Table 2: Properties of polystyrene. (Muralisrinivasan,2017)

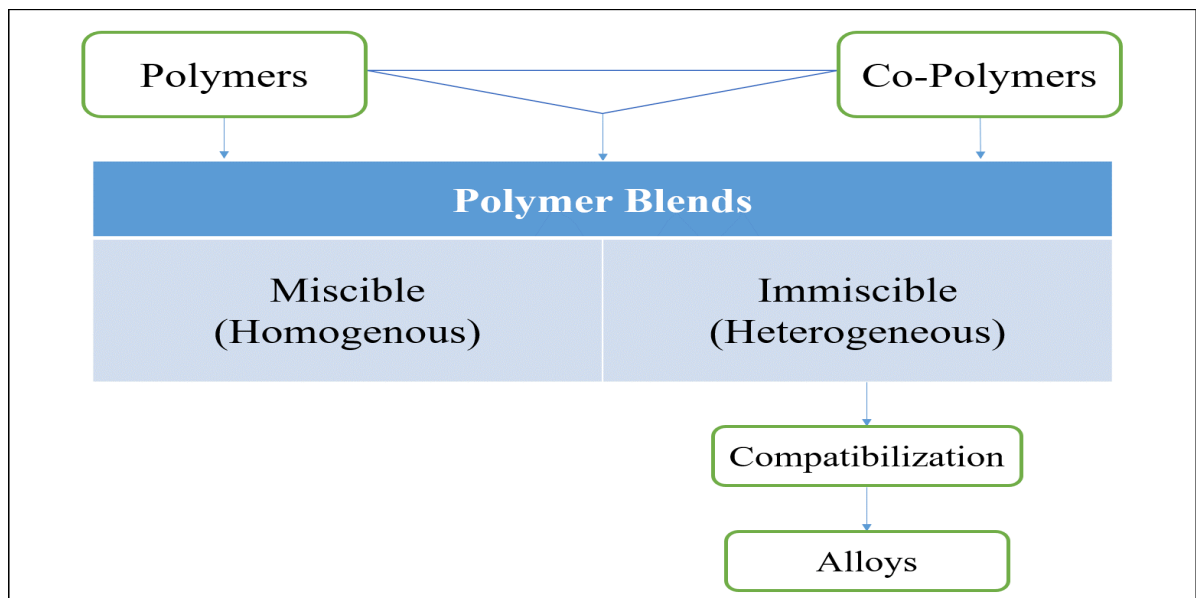


Figure 1.6: Polymer blends

1.2.4. ADVANTAGES & DISADVANTAGES:

CHAPTER 2

Literature Review

2.1. GENERAL OVERVIEW OF POLYMER BLENDING

Polymers have become an advanced material used in our daily life. Most of the materials now are made of polymers. One the polymers type is a polymer blend. The polymer blend is a mixture of more than one polymer which blends together with or without any chemical bonding between them to give a new material with different physical properties. Several methods are used to blend polymers which are:

- Compression Molding
- Injection Molding
- Transfer Molding
- Extrusion Molding
- Blowing
- Thermoforming

In the present days the injection molding and extrusion molding are one of common methods used.

2.1.1. WELD LINES AND MECHANICAL PROPERTIES OF INJECTION MOLDED POLYETHYLENE AND POLYSTYRENE:

A research looked into the effect upon the mechanical attributes of injection molding of high-density polyethylene (HDPE) and polystyrene (PS) blends and their weld lines. The two polymers were mixed in a quantity of 20 % weight HDPE and 80% weight PS at a high temperature of 200°C and it was concluded that the resulted mechanical characteristics were weaker caused by the presence of weld lines. [2]

2.1.2. STRUCTURE AND PROPERTIES OF INJECTION MOLDING OF POLYPROPYLENE AND POLYSTYRENE:

Propylene (PP) was melted to be mixed with 0-30 weight % of three types of polystyrene (PS) with that had a melt flow lower than PP, same as PP and more than PP. the blends were introduced to an injection molding device through a cylinder with a temperature ranging between 200 and 280°C. The yielded properties and structure of the product were analyzed. Even through the Polypropylene molding was whitened, no surface defect or wear was resulted on the Polystyrene. The strength and thermal attributes of the blend was not affected while the rigidity of the molding increased . Simultaneously, fluidity also improved. [3]

2.1.3. JOURNAL OF POLYMER SCIENCE: POLYMER PHYSICS:

Both polymers were studied in their molten states. At a 30% concentration of disperesed phase where the matrix will have a volume percentage of 30 and 70 for Polystyrene and Polyethylene respectively at 200°C , then vice versa in terms of volume % but this time around at 230°C. The enhanced elasticity for PS and PE in the terminal zone with respect to the modulus was observed.

The interconnection force between the two polymers was measured to be between 2 and 5 mN/m at 200°C, also, 4 and 1 mN/m at 230°C. [4]

2.1.4. EFFECT OF PHASE INVERSION ON MOLDING SHRINKAGE, MECHANICAL AND BURNING PROPERTIES OF INJECTION MOLDED OF POLYSTYRENE AND HIGH-DENSITY POLYETHYLENE:

The materials chosen to prepare blends are polystyrene (PS) and high-density polystyrene (HDPE). The PS density was 1.05g/cm^3 at a temperature of 255°C and a weight of 2.16 kg. For HDPE the density was 0.955g/cm^3 at the same temperature and weight. In the end, the polystyrene and high-density polyethylene blend at temperature zone of 230 to 255°C with a rotation speed of 75 rpm. [5]

2.1.5.VULCANIZATION :

A process at which an elastomer such as Rubber is hardened with the addition of sulphur under high temperature condition . It was invented by Goodyear as the polymer was very soft , ductile and malleable at higher temperatures , hence it was called a thermoplastic for it's ability to be machined and formed multiple times when heated . This process is performed upon the material to harden it and reduce it's elasticity . As a result , two sulphur molecules are bonded together in a bridge like shape connecting two chains of the polymer , it's strength and brittleness increases automatically.

2.1.6. DEGRADATION :

The wear and tear that occurs overtime upon the polymers , due to long term exposure to different environmental factors ; heat , light , chemicals .

it's a result of a process called Scission of Polymers by hydrolysis where the material would lose a significant part of it's mass resulting in many physical and chemical changes like ; lighter weight , change in colour , alternating chemical composition , tensile strength and elasticity and significant craze and deformation of the polymer.

2.1.7. POLYMERIZATION :

The process at which multiple smaller units called Monomers are combined together to form polymers , under heat and pressure , multiple chemical reactions occur to form the polymer and glue them together . The bonds of connected monomers also called Macromolecules created form different structural shapes of the polymer ; Linear , Network like structure and Branches .

2.1.8. RMM OF POLYMERS

The relative molecular weight of polymers , unlike other simple chemical compounds , differs so much from one material to another . That because the carbon chains of each individual material varies so much from it`s neighbour chain in terms of the number of monomers it is consisted of by thousands of monomer units . So , experimentally a value is acquired to represent the RMM of polymers which the average molecular weight distributed throughout a polymer , to give a mean value that is the most accurate to describe the polymer molar mass .

2.1.9. REACTIVITY OF POLYMERS AND BIODEGRADATION

Polymers consist of extremely long - monomer packed chains . The molecules that pull all of this together are saturated and have a very strong covalent bond holding them together , which makes it extremely hard for bacteria to break the material up , making it non-biodegradable as for synthetic polymers . The same concept can be considered for reactivity with other chemicals ,hence why Polymers are used to contain toxic and harmful substances like house cleaning products for example and other laboratory substances .

2.2.0. HIGH TEMPERATURE POLYMER BLENDS

These are polymers that are made for the main purpose of withstanding high temperature conditions and are the most researched sector of polymer blends . They are used in the industrial and academic fields . These polymers are not as useful in commercial applications due to their main quality but they are the most famous in aerospace and military applications . The quality standards increase each year for this polymer and Temperatures of 200°C and excess while operating for 100 hours and longer periods of time is more often required than not till this day . Usually polymers that have a service temperature of 175°C and more are considered high temperature polymers , most of them are amorphous but some are semi-crystalline , though , those that have a melting point above 400 °C are the most desired .

2.2.1. DIFFERENT CHARACTERISTICS AND APPLICATIONS OF THE MORE FAMOUS POLYMERS USED AROUND THE GLOBE :

*Polyethylene which was used in our experiment is a very strong polymer and known for being anti-wear , it is most useful in plastic bags .

*Polyvinyl chloride also known as PVC is a very strong and anti-wear polymer and extremely inert, it is also a thermoplastic which can be formed and machined when heated multiple times and it is most useful for piping systems

*Nylon is a flexible polymer which can be made into strips of fiber and is mostly used for casual clothing purposes when mixed with cotton .

*Lycra is very similar to nylon in it`s properties though , it is more elastic and tougher than the last . This polymer is used for the manufacturing of sports goods and accessories .

2.2.2. TESTING OF POLYMERS :

Testing of polymers can be a complicated process in comparison with other materials , though it gives an extremely useful result and a background for the material like it's additives , mechanical , chemical , physical and technical properties , all of which is intended to ensure that a certain polymer is suitable for the application desired . A large variety of tests can be executed on polymers but we chose FTIR , Microscopy and Tensile tests .

2.2.3. NATURAL POLYMERS :

Not all polymers are man made , infact, a lot of polymers occur spontaneously nature where they can be classified into 6 types , namely :

- *Miscellaneous polymer : Ex : shellac .

- *Lignin and coniferyl alcohol materials

- *Polysaccharide : Ex : starch and cellulose .

- *Polyisoprenes also called Natural rubber and is extracted from plants

- *Proteins Also called polyamides which are found in food in general .

- *Polynucleotides : Ex: DNA found in living organisms .

2.2.4. SYNTHETIC POLYMERS

Unlike natural polymers , synthetic polymers are made as a result of various reactions caused by humans to yield the product . There are many different kinds of polymers but the main types which are used domestically can be categorized in 7 types :

- *Low Density Polyethylene (LDPE) .
- *High Density Polyethylene (HDPE) ; which we used in our project .
- *Polypropylene (PP) ; Packaging
- *Polyvinyl Chloride (PVC) ; used for piping
- *Polystyrene (PS) ; which we used in our project
- *Nylon ; used in clothing , plastic bags .
- *Teflon ; coating cooking utensils (like frying pans)
- *Thermoplastic Polyurethane (TPU) ; Films , cable jackets and footwear .

2.2.5. RECYCLING OF POLYMERS :

When exposed to sunlight and other environmental conditions , polymers shall break down over-time into smaller pieces but will never completely fade away ,thus , it is factual that every piece of polymer ever made still exists , unless it's structure is designed to favor biodegradation as we mentioned early . In the 70s of the past century , the revolution of recycling waste started to incline until today where the majority of countries have a certain degree of recycling activities and different policies . Polymers have to be seperated in order for them to be recycled correctly , though , some polymers can be blended with others and utilized later on without any technical issues . With that being said , a general identification coding system invented by The Society of the Plastic Industry

(SPI) in (1988) to identify different forms of polymers to the casual consumers and bigger organizations in simple Abbreviations that represented each polymer , all to help increase the separation efficiency done before the recycling process , which will decrease time consumed and also cost of the operation .

PETE	HDPE	V	LDPE
------	------	---	------

polyethylene
terephthalate

high density
polyethylene

polyvinyl
chloride

low density
polyethylene

PP	PS	OTHER
----	----	-------

polypropylene

polystyrene

polyesters, acrylics
polyamides, teflon etc.



2.2.6. EFFECT OF COMPATIBILIZER ON PLA/ PP BLEND FOR INJECTION MOLDING

Poly lactic acid (PLA) and poly propylene (PP) blends were setup for the application of injection molding items, because the stage partition of PLA and PP. The inclusion of polypropylene graft metallic anhydride as a compatibilizer was considered. The portion for polymer blend of poly lactic acid and polypropylene 80:20 and 20:80 as well as adding in 1,3 and 5 weight percentage of polypropylene-unite metallic anhydride. The preparation of item test of dry mix with injection molding process. Later, they were exposed to thermal, mechanical properties and morphology examinations. The inclusion of polypropylene-unite metallic anhydride of thermal investigation affirmed that it has no impact on crystalline liquefying temperature of the parts just as no impact on the mechanical properties. The polymer blend of the morphology investigation affirmed the bond of poly lactic acid and poly propylene by the help of polypropylene-unite metallic anhydride.[6]

2.2.3. CRITICAL BEHAVIOR IN A POLYMER BLEND

Practices of basic static and dynamic we examined for poly di-methyl-siloxane with molecular weight of 1.91×10^4 blend with poly ethyl-methyl-siloxane with molecular weight of 1.40×10^4 utilizing turbidity, coexistence curve, light dispersing and viscosity measurement. The basic point was resolved absolutely from the coexistence curve as the basic synthesis poly ethyl-methyl-siloxane of weight percentage of 55.04. the basic temperature is 30.662°C. The basic polymer mix. Unmistakable shear impact on the viscosity seen close to the basic point. The dispersion coefficient of the basic part is shown by dynamic scaling function which depends on mode coupling hypothesis. The validity of the dynamic scale idea for the polymer mix was affirmed.[7]

2.2.4. ADVANCED MATERIALS BASED ON POLYMER BLEND/ POLYMER BLEND NANOCOMPOSITES

Poly vinyl chloride (PVC) mixes with poly ethyl-methyl-acryl-ate (PEMA) and poly vinyl chloride, poly ethyl-methyl-acryl-ate and montmorillonite (MMT) composites, conducted by processability, morphology, mechanical properties and rheological. Which is arranged by dissolving in a barbender blender. Test were portrayed utilizing scanning electron microscopy (SEM) mechanical test, dynamic mechanical thermal analysis (DMTA) and a parallel plate rheometer. In examination with those of perfect poly vinyl chloride the plastograms demonstrate that there is recognizable drop of combination times and increment id dissolve consistency torque of both polymer mix and polymer mix nanocomposite. SEM pictures demonstrates that homogenous scatterings are acquired. While, tensile tests demonstrates the PVC with PEMA and PVC with PEMA and MMT tests have more tensile rigidity and flexible modulus and lower stretching contrasted with poly vinyl chloride.[8]

Chapter 3

Methodology and equipment

In order to perform the laboratory experiment and the method analysis the following materials and equipment were used:

3.1. EXPERIMENTAL EQUIPMENT AND INSTRUMENTAL:

- Weighting scale.
- Safety Gloves.
- 50 ml beaker.
- Face Mask.
- Safety Googles.

3.2. ANALYTICAL EQUIPMENT AND INSTRUMENTS:

- Injection molding.
- Microscopy.
- FTIR.
- ASTM.

3.3. CHEMICALS:

- Polystyrene.
- High-density polyethylene.



Figure 3.1: Weighing scale





Figure 3.6: Polystyrene



Figure 3.7: HDPE

3.4.METHODOLOGY:

1. **Gathering Materials:**

- Collect all necessary materials, including the different polymers to be blended, and ensure you have the required tools and safety equipment.

2. **Preparing the Machine:**

- Set up the injection molding machine according to the manufacturer's guidelines. Check for any necessary calibrations and ensure the machine is clean and ready for use.

3. **Setting the Temperature:**

- Adjust the temperature settings on the machine to the appropriate levels for the polymers being used. Ensure that the heating elements are functioning correctly and the temperature is stable.

4. **Dwelling:**

- Allow the machine to reach the set temperature and maintain it for a period to ensure uniform heating of the polymers. This process helps in achieving a consistent blend.

5. **Feeding the Hopper with Pellets:**

- Load the hopper of the injection molding machine with the polymer pellets. Ensure the correct ratio of different polymers as per the experiment's requirements.

6. **Injecting the Molten Polymer:**

- Start the injection process, where the molten polymer blend is injected into the mold cavity. Monitor the pressure and injection speed to ensure proper filling of the mold.

7. **Cooling:**

- Allow the polymer blend to cool and solidify within the mold. This step is crucial for achieving the desired shape and properties of the final product.

8. **Taking Out the Mold:**

- Once the polymer has cooled and solidified, carefully remove the mold from the machine. Ensure that the mold is handled gently to avoid any damage to the formed polymer.

9. **Extraction of Polymer:**

- Extract the polymer blend from the mold. Inspect the final product for any defects or inconsistencies.

10. **Ejection of Leftover Material:**

- Eject any leftover material from the injection molding machine. Clean the machine to prepare it for the next batch or to prevent contamination of different polymer blends.

1) Procedure:

The targeted polymers were first gathered. After that, we start by preparing the machine and determining the desired temperature of the operation (depending on the material) which lies at the range of its melting point.

The pellets are fed to the hopper for an introduction to the machine where they will pass through metal plates processing the temperature of the melting point in a process called "Injection".

The molten product is now laying in the bottom of the machine, and with the help of a scrim or a ramming rod, it is pushed out under high hydraulic pressure into the mold.

At the "dwelling" stage the ramming rod is used to eject extra product into the mold to fill any extra cavities. After that, the polymer is left out to cool down and solidify to be extracted out of the mold after separating the two movable plates. Finally, an air blast or using the ramming rod, ejection of the left out the product in the machine is carried out for safety and maintenance reasons.



Figure 2.8: Injection molding

2) Tests:

➤ Microscopy:

The analysis provides pieces of information and characteristics of polymers at the Micro/Nano levels. Chemical and physical properties are also obtained by optical or electro-microscopy to give insights that can be related to the performance of the material.



Figure 3.9: Microscopy equipment

<https://www.indiamart.com/insta-biotech/lab-equipment.html>

➤ FTIR:

The plastic is placed through an infrared beam where its information is encoded using interferometry. The Fourier's transform analyses the signals received to give a spectrum as feedback where we can study its properties since specific structures exhibit specific IR fingerprints.



Figure 3.10: FTIR test equipment

www.apmtesting.com

➤ Tensile:

Using ASTM, the sample is placed and attached between the clippers in the instrument. A tensile force is applied upon it to determine stretching threshold of the material till the breaking point. A stress Vs strain graph is obtained through a computer connected to the instrument to determine Young's modulus.



Figure 3.11: Universal Tensile Machine

<https://www.indiamart.com/proddetail/tensile-testing-machine-10530216697.html>

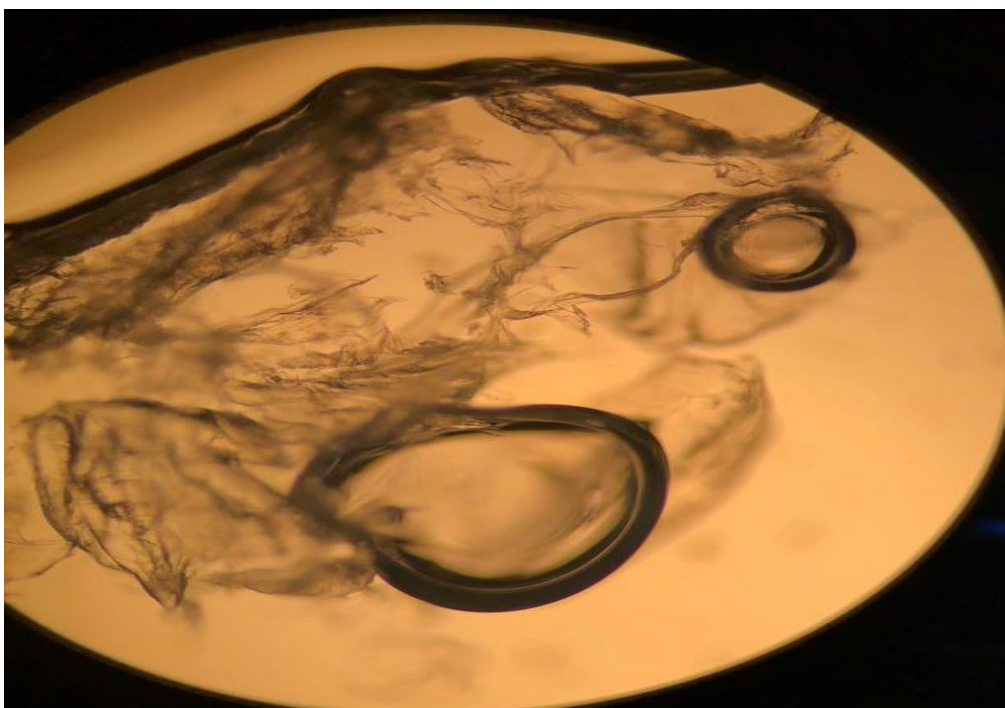
CHAPTER 4

Results and Discussion

1.0.0. Microscopy results: all samples were analyzed at 100X magnification.

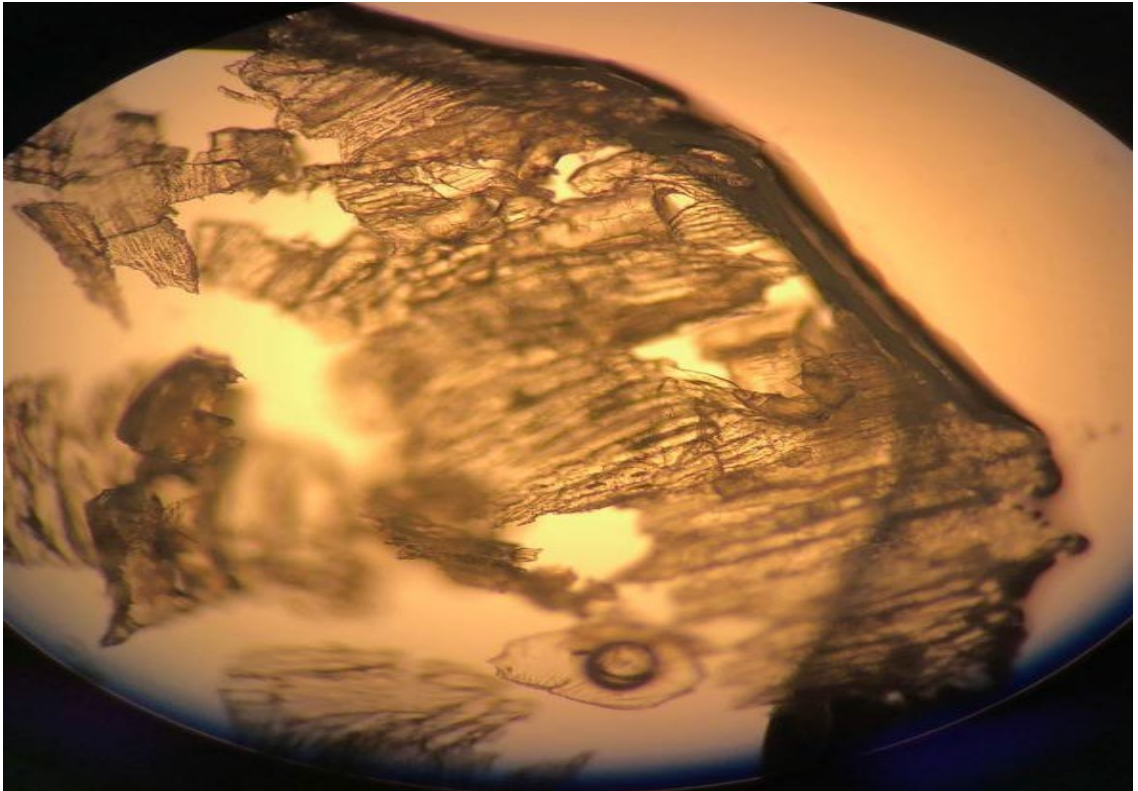
Special thanks to Mr. Steve Fernan Palacio and the applied science department for allowing us to use their equipment and advising us throughout the whole process.

Polyethylene



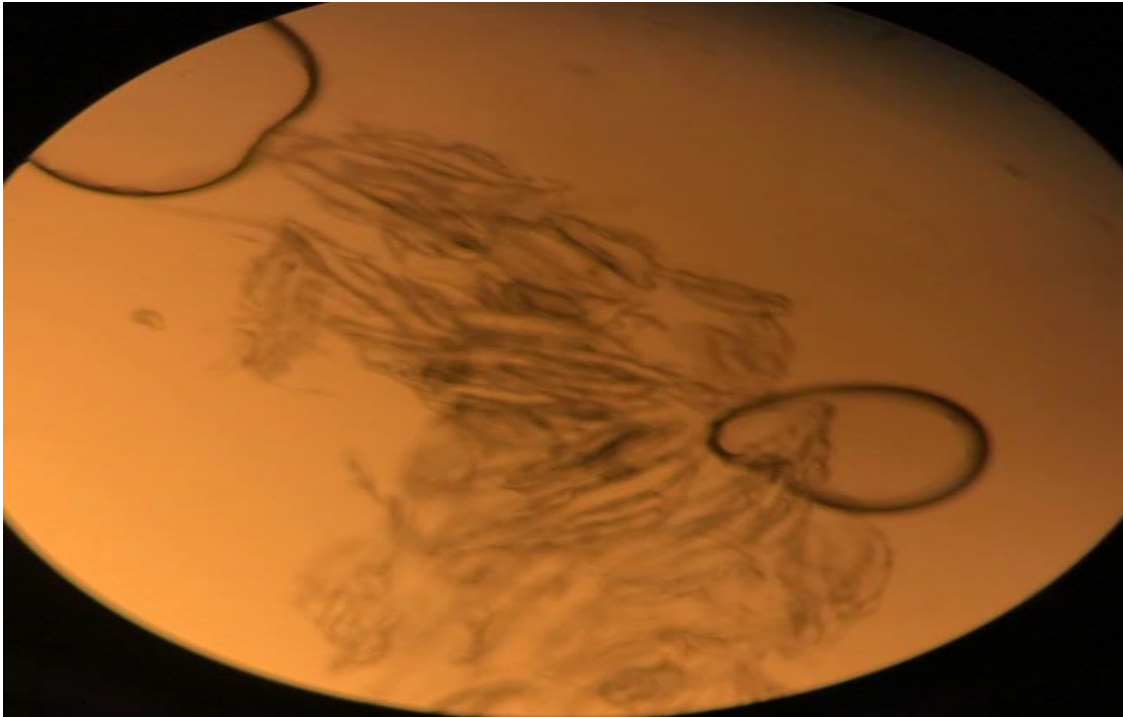
As observed from the sample of polyethylene , it is clear that the structure is foggy looking . Expectedly so ,because this polymer is more whitish in color and resembling of that of a cloud . Light won't pass as easy through it leaving us with minimal details and more of a an erased look .

Polystyrene Sample :



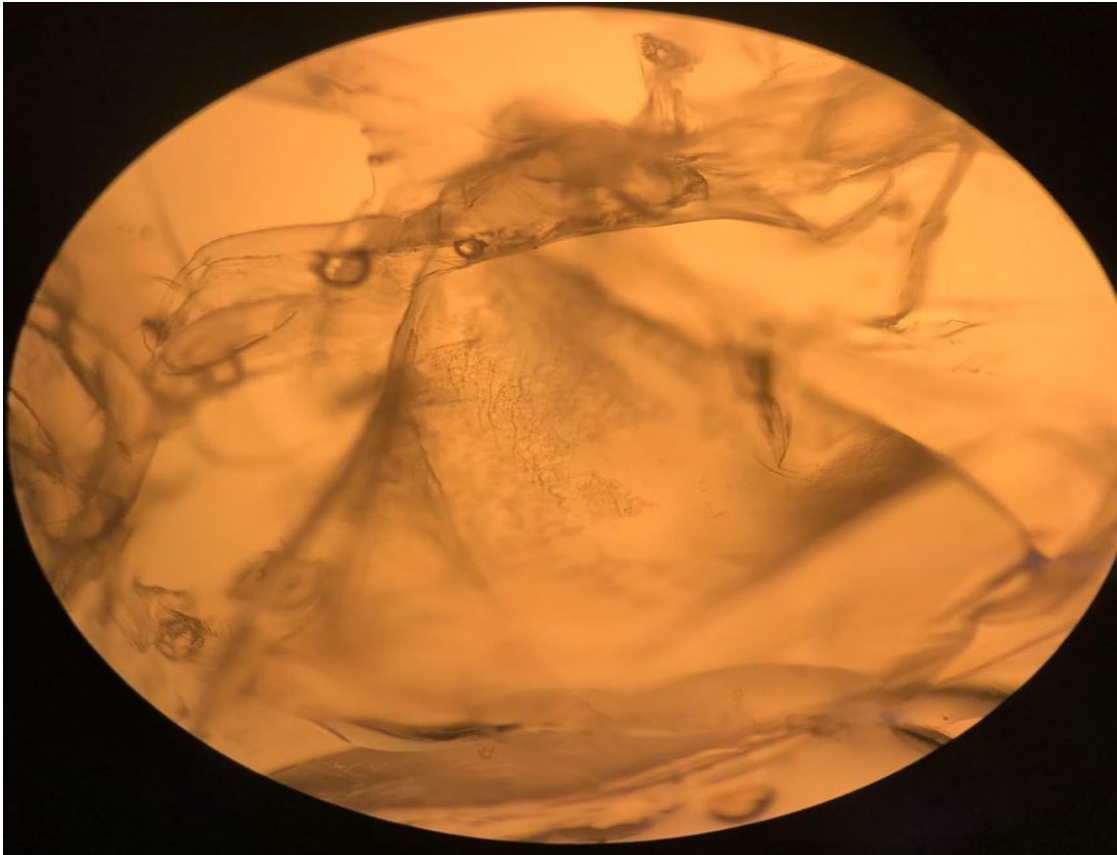
The light through this polymer will pass much faster and easier than polyethylene . As it is more transparent and clear , under the microscope the look given by this sample is very similar to extremely small pieces of shattered glass .

Equal amount of PS and PE sample :



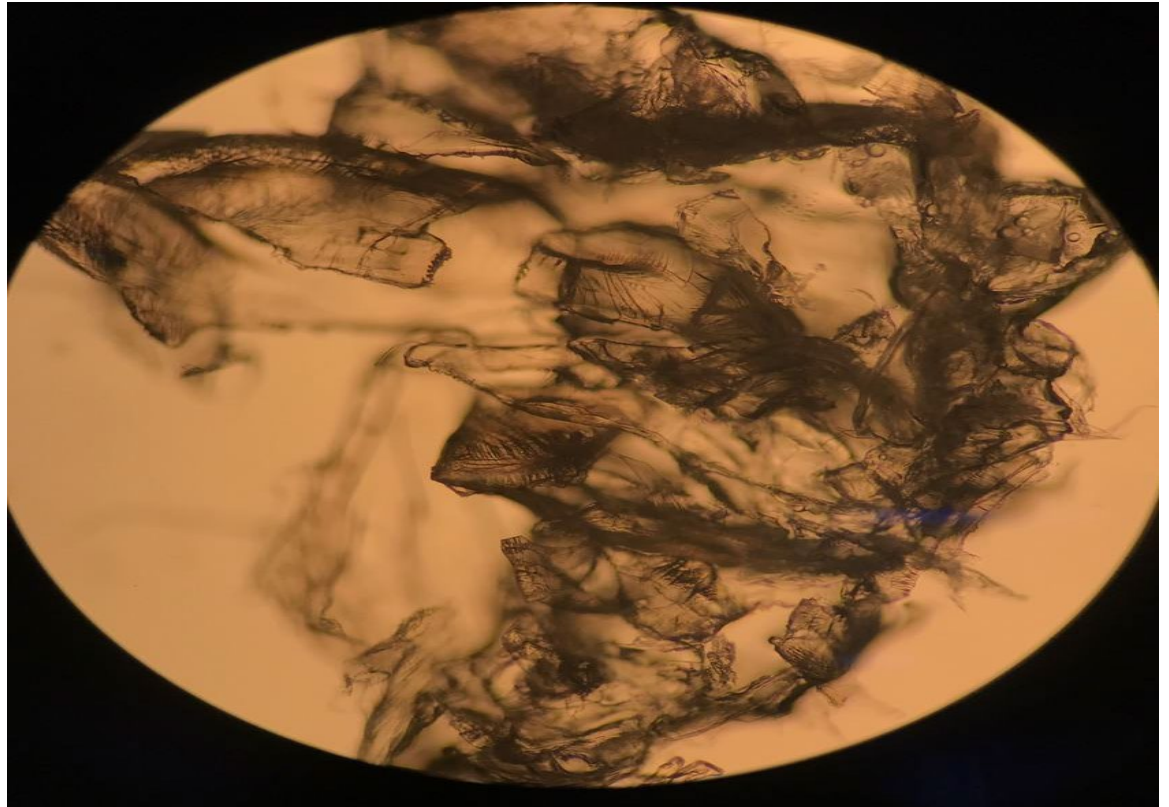
This polymer is much more versatile than the others. Due to its composition being 50% Polyethylene and 50% Polystyrene weight percent. Both reflecting figures and foggy spots are present in this sample picture. Glass like looks is derived from the Polystyrene and the foggiess comes from the polyethylene as both polymers are only physically and microscopically mixed but not chemically bonded to each other. Hence why the homogeneity lacks in this sample.

Polyethylene more than Polystyrene blend sample :



This sample is Polyethylene dominant. The sheer weight fraction of PE in comparison to PS is the direct reason as to why this sample has a cloudy look, not much transparency , though some fine strips do pass light through them and are clearer than others , that is Polystyrene .

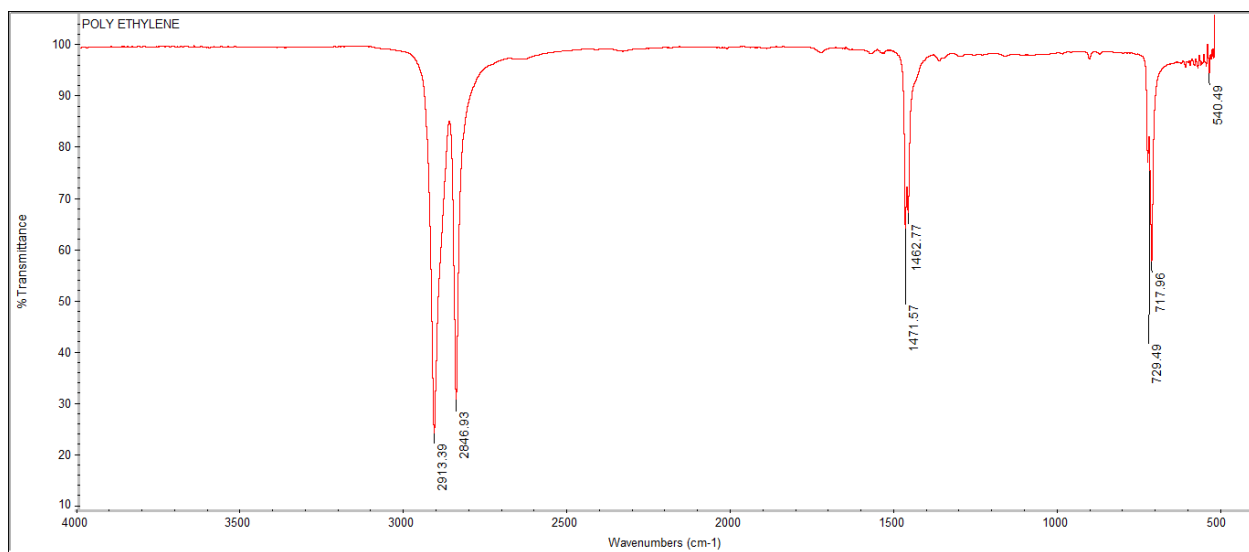
Polystyrene more than Polyethylene sample :



This sample is more Polystyrene dominant, and rightfully so !! The image shows a crystal-like look resembling the polystyrene which has glass like characteristics as we mentioned what was observed from the pure sample and the naked eye earlier. Cloudiness caused by the polyethylene isn't as significant but it definitely is existent in some parts of the image. All due to the composition of this sample.

FTIR TEST

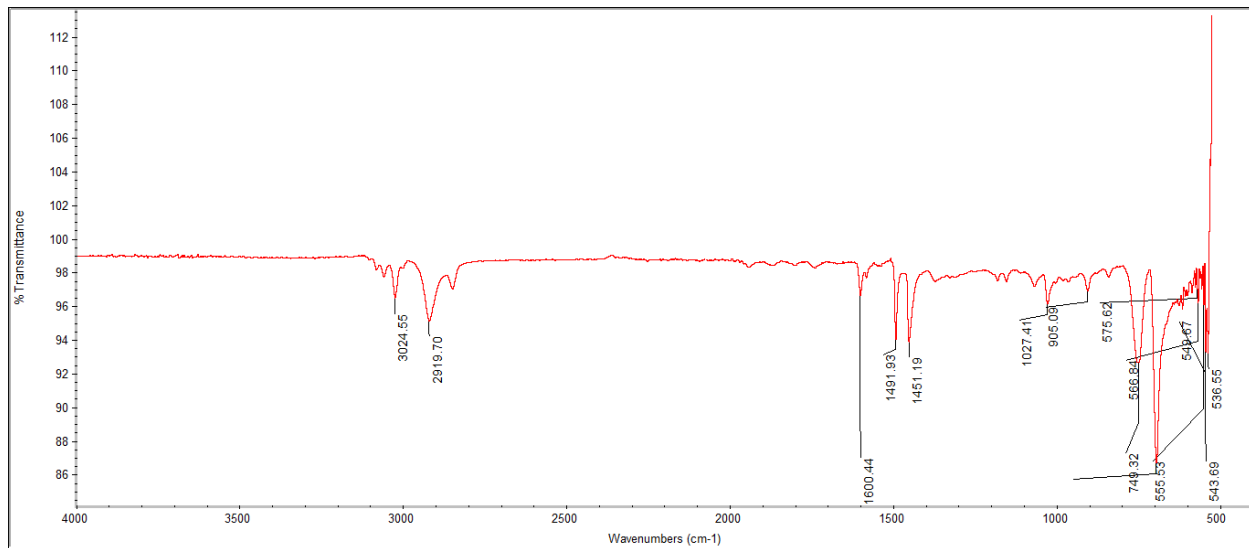
FTIR results for pure polyethylene



Table

Wave number (cm-1)	Functional Group
2913.39	carboxylic acids alkanes
2846.93	Alkanes carboxylic acids
1471.77	aromatics
1462.77	Alkanes
729.49	alkanes
717.96	acid chlorides
540.49	alkyl halides

Pure polystyrene

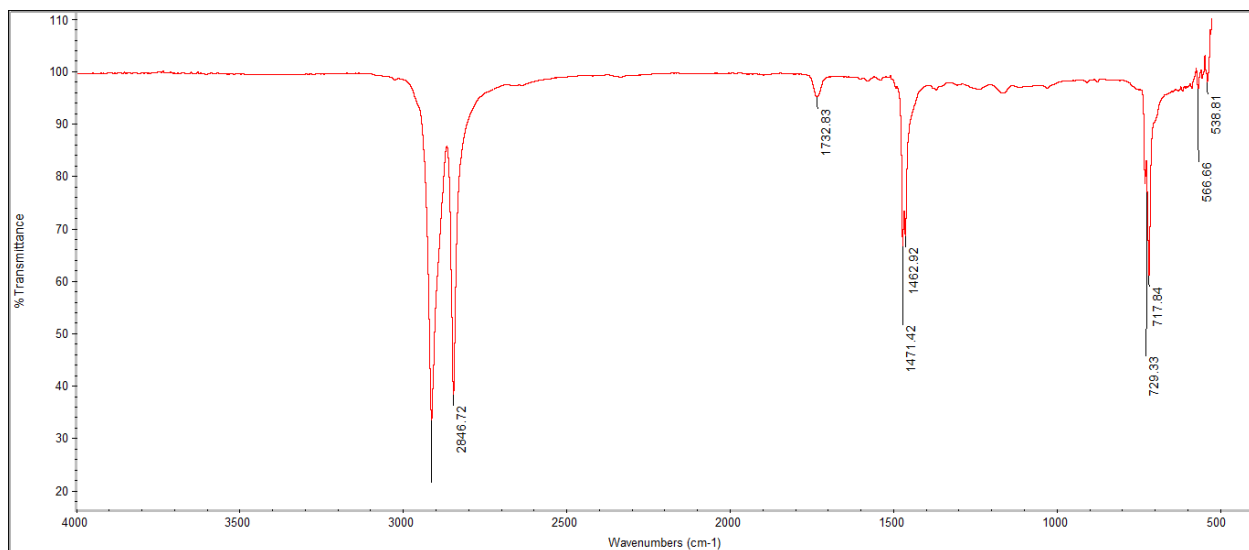


Table

Wavenumber cm-1	Functional Group
3024.55	Alkenes carboxylic acids
2919.70	Alkanes carboxylic acids
1600.44	aromatics amines amides nitro groups
1491.93	Aromatics
1451.19	alkanes
1027.41	alcohols ethers amines alkyl halides phosphines
905.09	Phosphines Sulfonates

	Anhydrides Sulfonates Phosphines
749.32	aromatics alkyl halides
575.62	acid chlorides alkyl halides
566.84	acid chlorides alkyl halides
555.53	acid chlorides alkyl halides
549.67	alkyl halides
543.69	alkyl halides
536.55	alkyl halides

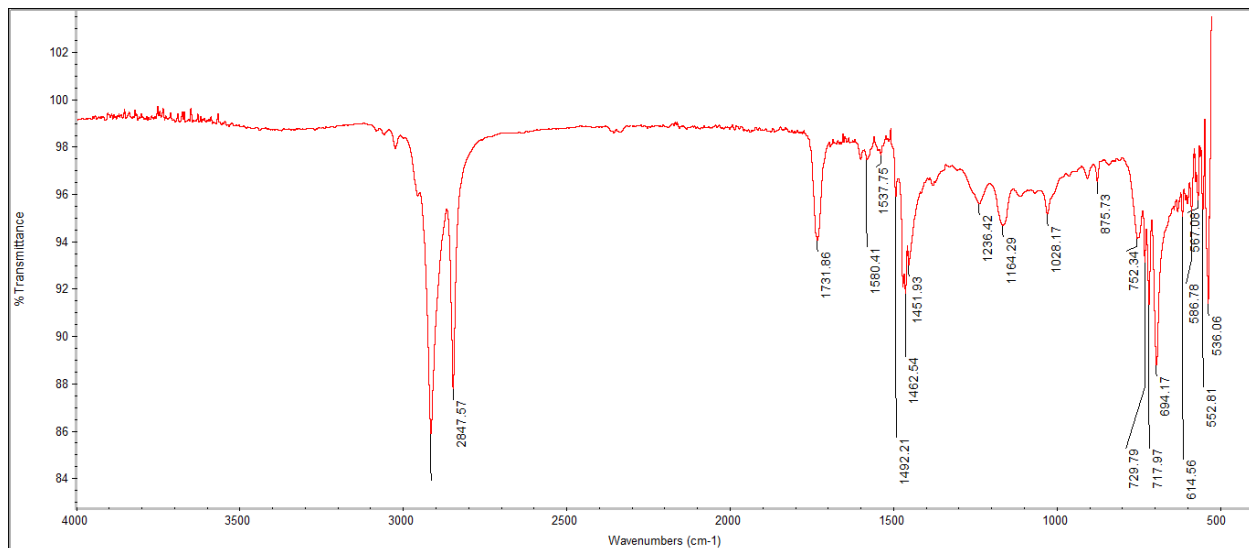
Equal amount of polystyrene and polyethylene



Table

Wave number cm-1	Functional group
2846.72	Alkanes aldehydes carboxylic acids
1732.83	carboxylic acids
1471.42	Aromatics
1462.92	alkanes
729.33	acid chlorides alkyl halides
717.84	acid chlorides alkyl halides
566.55	acid chlorides alkyl halides
538.81	alkyl halides

Polystyrene % greater than polyethylene

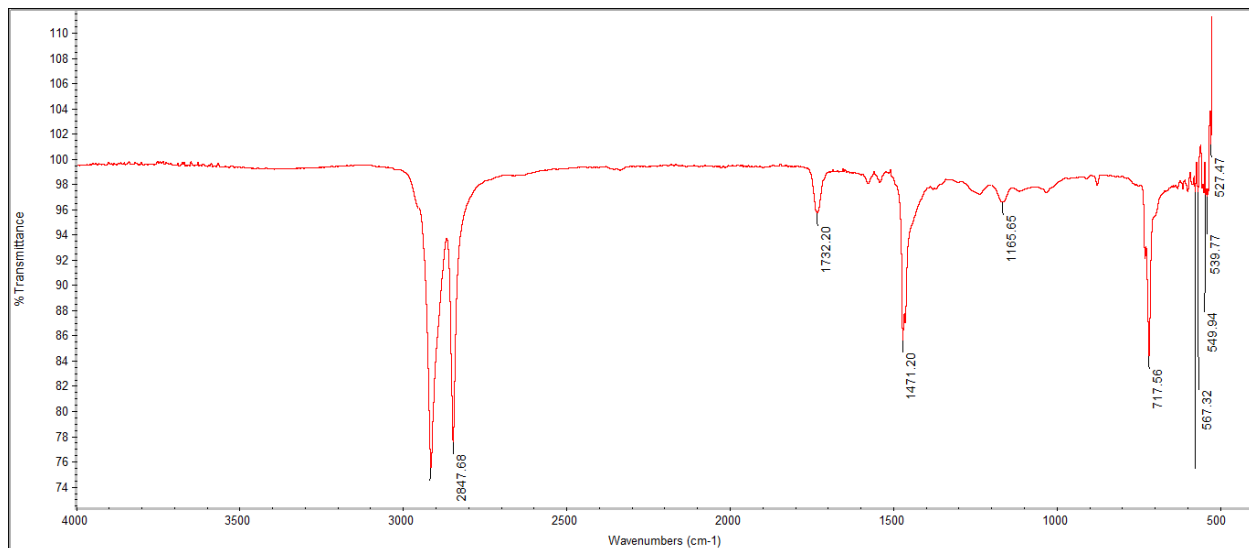


Table

Wave number Cm-1	Functional group
2847.57	Alkanes aldehydes carboxylic acids
1731.86	carboxylic acids esters
1580.41	Amines Amides nitro groups
1537.75	Amines amides nitro groups
1492.21	nitro groups
1462.54	alkanes
1451.93	carboxylic acids
1236.42	Ketones carboxylic acids esters alkyl halides
1164.29	Alcohols Ethers Ketones Esters

	Anhydrides Amines alkyl halides phosphine oxides
1028.17	Alcohols Ethers anhydrides amines alkyl halides phosphines
875.73	sulfonates
752.34	Aromatics alkyl halides sulfonates
729.79	alkyl halides
717.97	acid chlorides alkyl halides
694.17	Aromatics acid chlorides alkyl halides
614.56	Alkynes acid chlorides alkyl halides
586.78	acid chlorides alkyl halides
567.08	acid chlorides alkyl halides
552.81	acid chlorides alkyl halides
536.06	alkyl halides

Polyethylene % Greater than Polystyrene



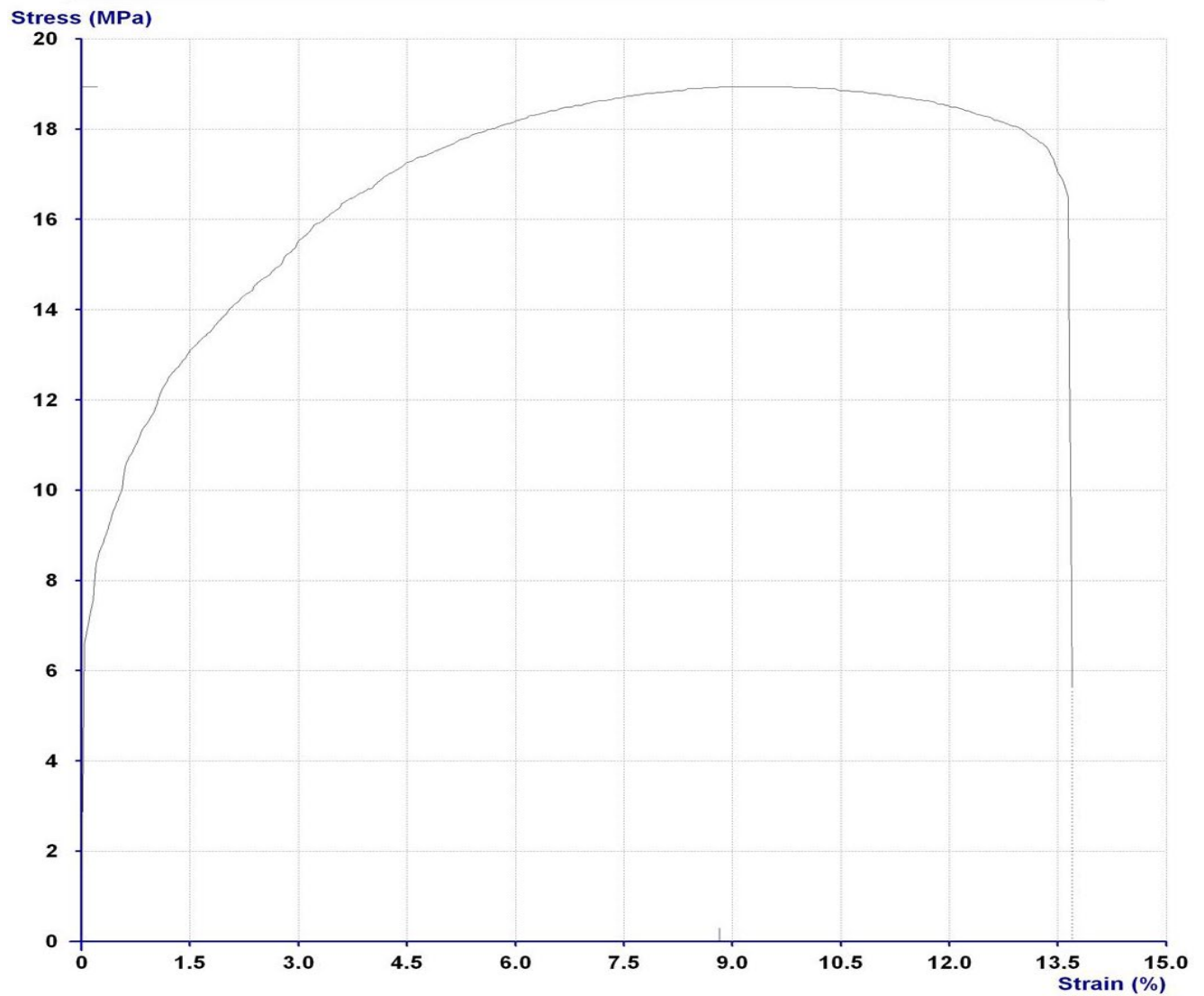
Table

Wave Number (cm-1)	Functional Group
2847.68	Alkane, Carboxylic Acids
1732.20	carboxylic acids
1471.20	aromatics
1165.65	Alcohols, Ethers, Ketones, Esters, Anhydrides, Amines, Alkyl Halides, Phosphine Oxides
717.56	Acid Chlorides, Alkyl Halides
567.32	Acid Chlorides, Alkyl Halides
549.94	Alkyl Halides
539.77	Alkyl Halides
527.47	Alkyl Halides

➤ **Tensile test:**

1. Pure Polyethylene:

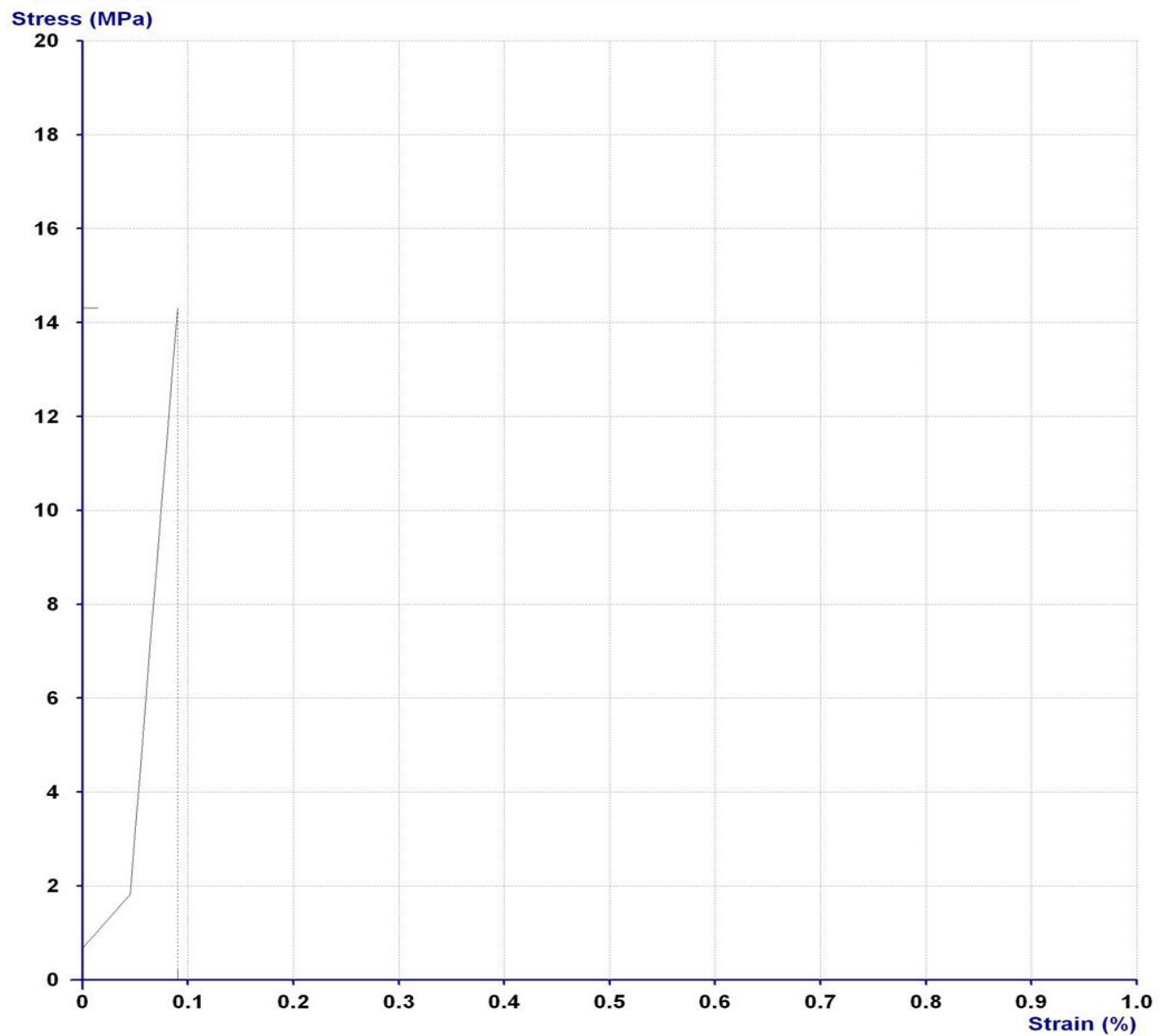
Specimen	Thick mm	Width mm	Tensile MPa	Max Force N	Elong at Max %	Elongation %	Stress at Break MPa	Force at Break N
pure pe	5.25	14.00	18.94	1392	8.82	13.70	5.61	412.5



- Pure Polyethylene has the highest %Elongation before breaking among all samples due to its high ductility property

2. Pure Polystyrene:

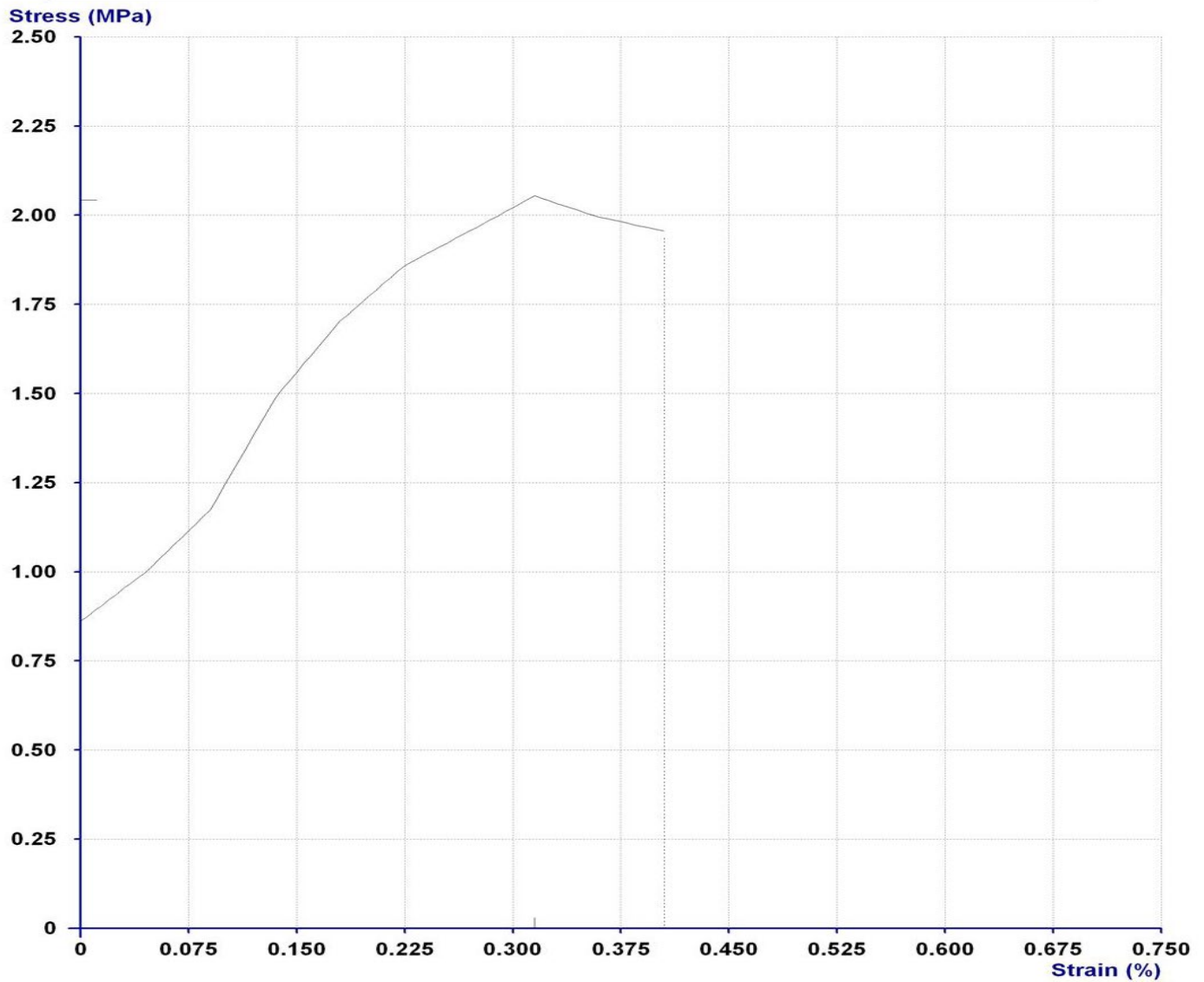
Specimen	Thick mm	Width mm	Tensile MPa	Max Force N	Elong at Max %	Elongation %	Stress at Break MPa	Force at Break N
pure ps	5.60	12.20	14.31	978	0.0900	0.0900	14.31	978



- Pure Polystyrene is the least ductile polymer and it fractured with the least %Elongation amongst all samples. It is more brittle than polyethylene

3. PE more than PS

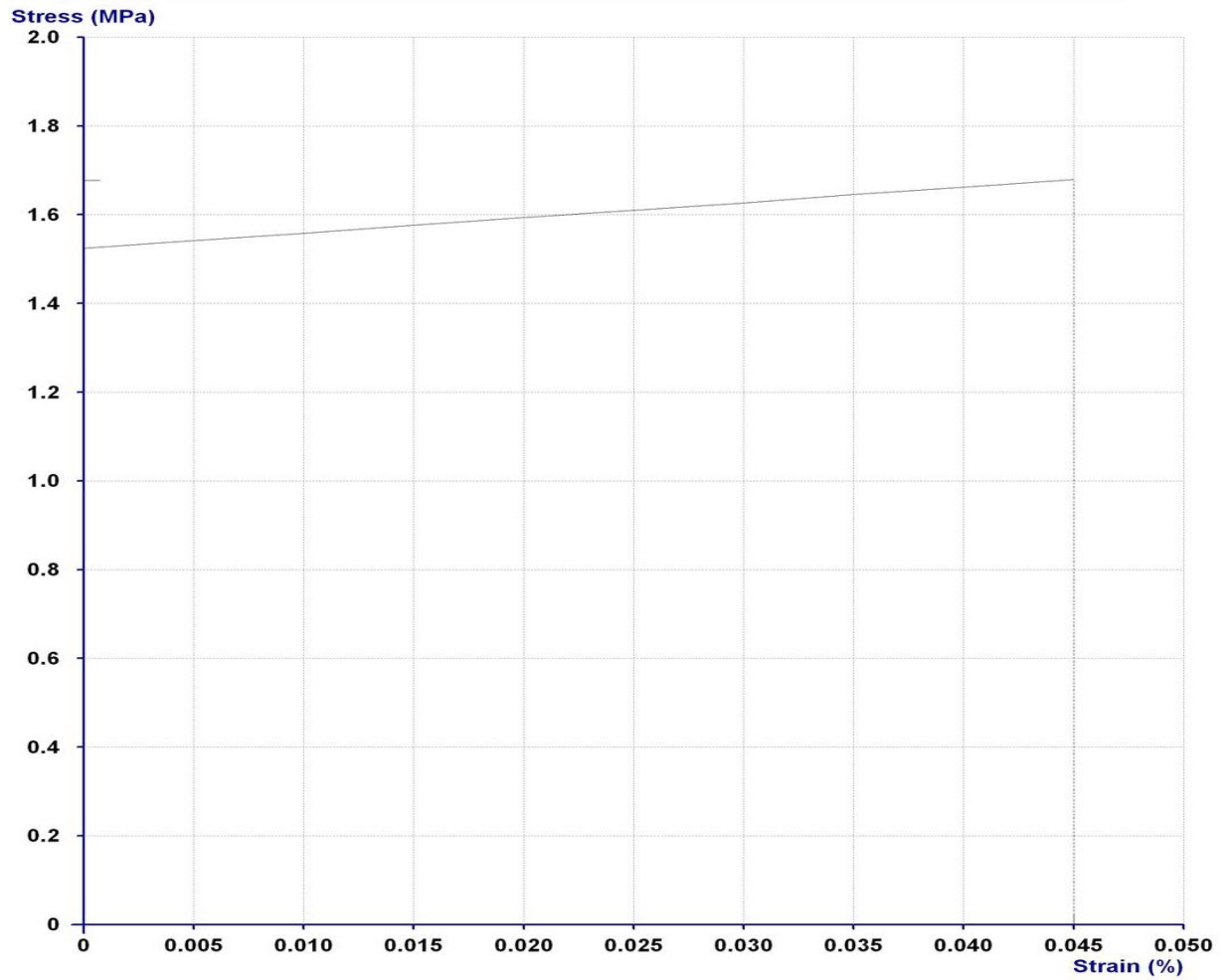
Specimen	Thick mm	Width mm	Tensile MPa	Max Force N	Elong at Max %	Elongation %	Stress at Break MPa	Force at Break N
pe more	3.600	11.90	2.042	87.5	0.3150	0.4050	1.944	83.3



- This blend reaches the maximum tensile strength at 2.042 MPa after a short elongation until it broke down.

4. PE less than PS

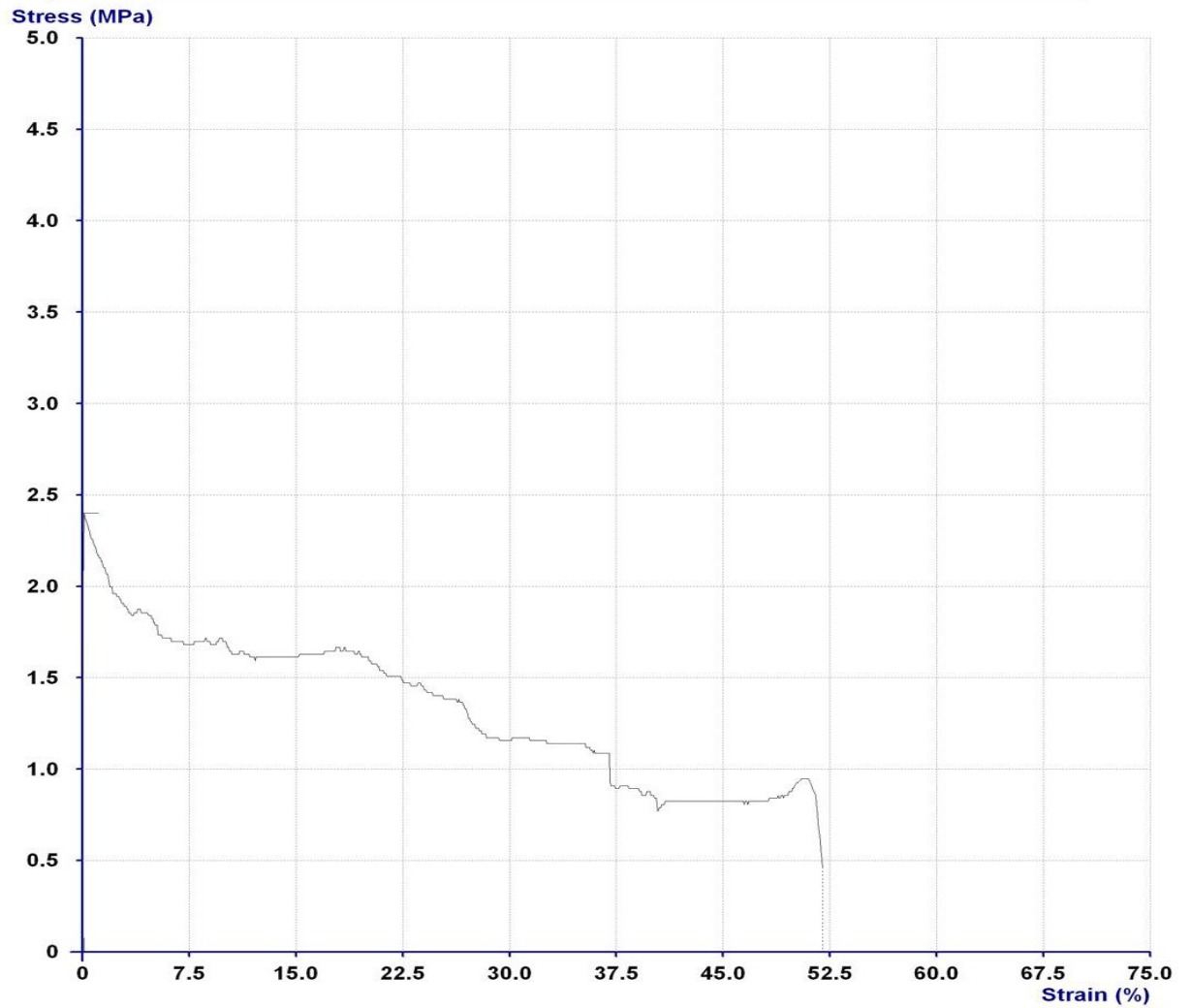
Specimen	Thick mm	Width mm	Tensile MPa	Max Force N	Elong at Max %	Elongation %	Stress at Break MPa	Force at Break N
PE > PS	6.00	13.50	1.677	135.8	0.0450	0.0450	1.677	135.8



- This type of mix has a smooth linear elongation curve caused by the Small percentage of polyethylene Present In The Sample and then the sudden fractures occurs due to the majority composition of polystyrene in it.

5. PE = PS

Specimen	Thick mm	Width mm	Tensile MPa	Max Force N	Elong at Max %	Elongation %	Stress at Break MPa	Force at Break N
ps=pe	3.660	13.00	2.401	114.3	0.1250	52.0	0.4571	21.75



- This blend had a very unusual curve with very high elasticity , the highest among all at 52% .

CHAPTER 5

Statement of achievement

The polymer blending project I undertook was a fun and exploratory experiment, constrained by the types of polymers readily available on the market. From the beginning, my goal was not to create a specific polymer blend that was superior, but rather to experiment with the available polymers and understand the characteristics of each blend. Through this process, I aimed to observe if any of the resulting blends could be useful in industry. This approach allowed me to explore the potential of various polymer combinations and gain insights into their properties and applications. Characteristics like Elasticity, ductility and malleability are extremely important in the manufacturing industries with the mainstream use of polymers in almost every product nowadays from cars to mobile phones, accessories, toys, furniture , instrumentations , cables and about everything we use in our everyday life . By mixing two or more polymers together , we target the best properties that we want from each material as an outcome in one product giving us the most optimum useful polymer that we can utilize as a result of that .

CHAPTER 6

Conclusion

As resulted from the series of experiments that were done in the past period of time, we were able to yield an improved version of a polymer blend made out of Polystyrene and Polyethylene to be potentially utilized in different applications like packaging with more resistance to stress derived from the polystyrene composition and greater heat insulation also coming from the same material, whereas the polyethylene will yield a greater melting point for the blend. A stronger Bending and Axial stiffness to weight ratio is also brought on. Though the shock resistance will almost stay the same as both materials have a similar value of that property.

Chapter 1 introduced some simple information surrounding the polymers in general, their chemical compositions and their physical and mechanical properties .

Chapter 2 talked about various advanced polymer related subjects from its history to the processing and recycling methods , different researches and the methods taken towards dealing with polymers .

Chapter 3 included the actual process done from our behalf to get the resulted polymer blend, equipment and instrumentations that we utilized and the materials used alongside their compositions to be tested and discussed later on in Chapter 4 , where we showed the results of our experiments and analytical facts of the tested samples .

In Chapter 5 , the targeted goal of the whole project was mentioned and and the degree of fulfillment was also mentioned in details in Chapter 4 above it .

Chapter 7

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