Plastics and polymers

Polymers

What is a Polymer?

A polymer is a molecule that consists of certain type of arrangement of atoms that is repeated over and over. The result is a very large molecule that can consist of 2000 or more of the base compound. The base compound is referred to as a monomer, or a single unit of a polymer. When a large number of monomers are joined together they form a polymer.

Ie.

Mer + mer + mer + mer + mer = mermermermermermermermermer

Monomer units POLYMER

Polymers are sometime referred to as macromolecules, because they are very large, thousands of time larger than molecules such as water.

Different types of polymers

Natural polymers

These are polymers or from natural materials such as tree resin.

Semi Synthetic

These are man made polymers that contain a component from natural materials.

Syntheic polymers

Man made polymers

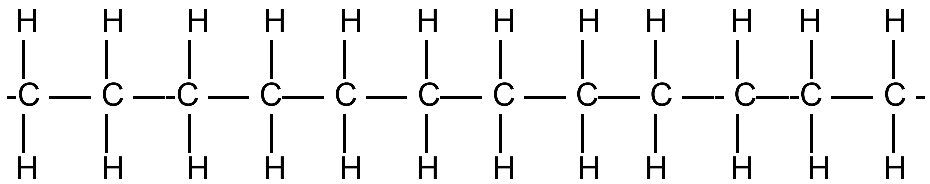
Thermo set and thermoplastic polymers

Polymers can also be classified based on their physical characteristics. Most polymers are categorised into one of two groups based on their physical properties after heating. Thermo set plastics are plastics that once made through a curing process, set in a hard solid state, were additional heating causes changes in the chemical nature of the material. A thermoplastic is a plastic that softens to a molten state when heated and hardens again to a solid state when cooled. Thermoplastics can generally go through many heating and cooling cycles with no appreciable change in the chemical nature of the material.

Which polymers does Glad use in its Plastics?

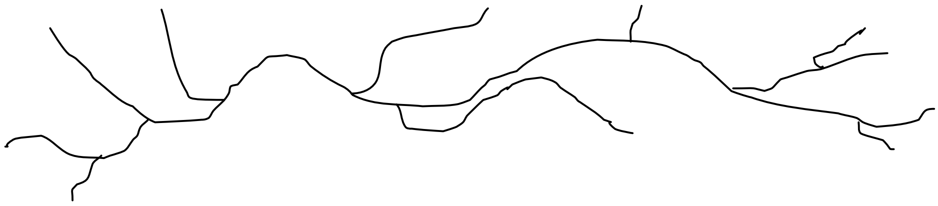
Polyethylene (PE)

Polyethylene is a simple example of a polymer, and is one of the most common and widely used polymers.

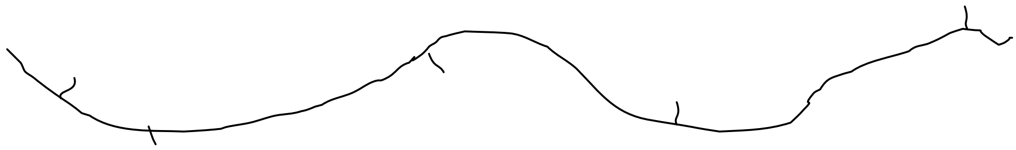


Polyethylene

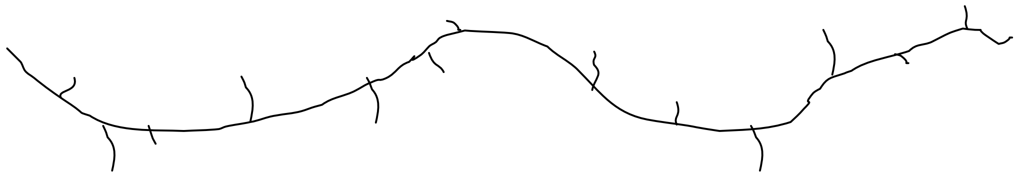
Polyethylene has a number of different forms with different mechanical properties. The properties of the different forms of polyethylene are governed by branching, crystallinity and most of all molecular weight. The three main types of polyethylene are high density polyethylene (HDPE), low density polyethylene (LDPE), and linear low density polyethylene (LLDPE). These different types are based on the structure of the molecule of the polyethylene, which in turn effects its density, hence the name. The molecules of polyethylene are similar to long strands of spaghetti.



In LDPE some of the carbon atoms are attached to three carbon atoms instead of two, this causes a branch on which other polyethylene chains are attached. These branches are relatively long and intertwine and link with other polyethylene molecules. LDPE is like one long piece of spaghetti, with lots of large pieces of spaghetti attached to it.



HDPE is a more linear molecule where there are very few side chains caused by branching, and these side chains are usually very short compared to LDPE. HDPE is like a normal piece of spaghetti with little bumps on it.



LLDPE as the name suggests is a more linear, low density polyethylene molecule. It still has a large number of side branches, however these branches are shorter.
The molecules of LLDPE are like spaghetti with lots of very small pieces of spaghetti attached to it.

Making small changes to these molecules brings about the ability to make an huge range of characteristics. The mechanical, chemical, electrical and thermal properties can be varied in a huge range of possibilities, this usually done by changes during manufacture. For all of the types of polyethylene they have the following properties:

- Polyethylene is an insulator, which means that it does not conduct electricity. In fact polyethylene is one of the best insulating materials available.
- Polyethylene's are chemically stable and inert. This means that they do not readily react with other chemicals.
- Polyethylene's are strong and lightweight.
- Due to the differences in structure, HDPE is stronger and has a higher melting point than LDPE, with LLDPE generally between the two.

Manufacturing/Processing
There are 3 main polymerisation reactions used to make the different types of polyethylene. The first is a free radical polymerisation, this type of polymerisation is used to make the highly branched LDPE. The manufacture of LDPE using this method is done at high pressures, between 1000 to 3000 atmospheres (that's 1000 to 3000 times the normal air pressure at sea level), and temperatures of 150-300ºC. Another less intense process is used to make HDPE and LLDPE. This process is the Ziegler-Natta polymerisation, named after it's inventors, that uses transition metal catalysts at temperatures of around 70 to 150ºC and pressures less than 10 atmospheres.

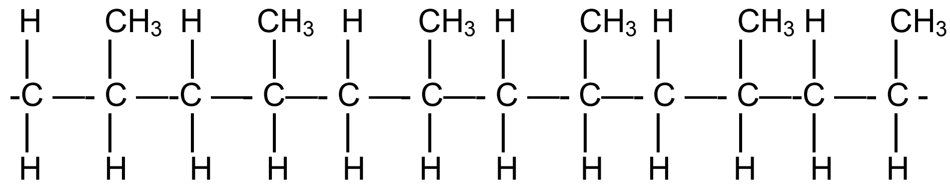
The last of the polymerisation techniques is metallocene catalyst polymerisation. This type of polymerisation uses metallocene molecules, which are metal ions sandwiched between two carbon-based rings, as the catalyst. These catalysts are highly valued because they are very good at allowing the manufacturer to control the exact structure of the polyethylene. They are commonly used to increase the strength of LDPE and HDPE, but are also able to make Ultra High Density Polyethylene (UHDPE) that is very strong, almost bullet proof, even stronger than Kevlar (the material currently used in bullet-proof vests).

Which plastic is used where?
HDPE is the type normally found in shopping bags and kitchen tidy bags. It is also used to make plastic furniture, insulation on wires and milk bottles. It is slightly harder and stiffer than the other types of polyethylene, it feels crinkly and rough to touch, and has a matt and opaque appearance. Items that have this symbol are made from HDPE.

LDPE is soft and is waxy, is smooth to touch, and has a shinny appearance. It is normally used in garbage bags, cling wrap, sandwich bags, squeezable bottles. LDPE usually carries the number 4 symbol below.

LLDPE is half way between the above two. It is mostly used in small amounts in mixtures with one of the above.

Polypropylene (PP)
Polypropylene is another important polymer widely used today. It is seen as polyethylene's closest relative in structure and uses.



Polypropylene

Polypropylene has very similar mechanical and chemical properties to it's PE cousin. Structurally PP forms a large amount of crystals, making it stronger than polyethylene. The different structure also gives PP a higher melting point, around 160ºC. It is also relatively chemically inert and resistant to chemical attack from most solvents, bases and acids. Like PE, PP also has high electrical resistance, making it a good insulator.

Polypropylene is manufactured by metallocene catalysis similar to the process used in PE. Also similar to PE, this process can be used to control the structure of the molecule, which can give the PP different physical properties.

Uses of PP.
Did you know that our Australian banknotes are made from a special type of polypropylene?
Polypropylene is relatively cheep to make and is probably the second most widely used plastics behind PE's. This superior strength and higher melting temperature mean it is used in applications where PE is inappropriate. Due to it's strength PP is widely used in the automotive industry to make lightweight parts for car, which makes the car more energy efficient. PP is also used in medical devices that are sterilised at high temperatures in an autoclave, where it's high melting point stops the device from warping or cracking. This feature of PP is also used in households where it's high temperature resistance means that it is used to make dishwasher safe food containers.

Other applications of PP include making piping, filter material, speaker cones, and other plastic products that require a higher quality than polyethylene. Polypropylene products can be identified with the symbol below.

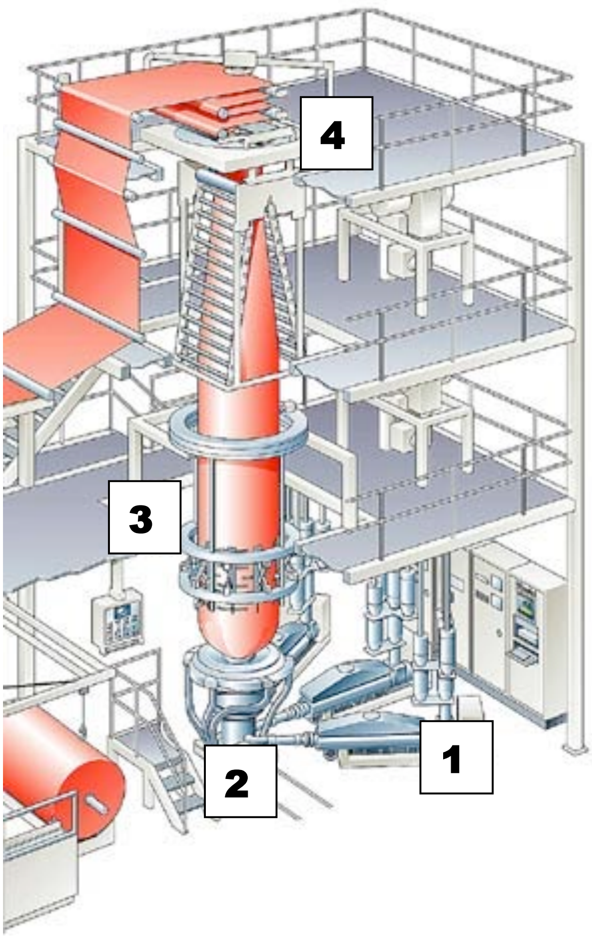
Making GLAD Wrap, Food Bags and Garbage Bags.

Plastic film is made by pushing molten Polyethylene resin pellets through a narrow outlet called a die, not unlike making fresh spaghetti except the plastic comes out thin and flat. This process is called extrusion, there are two types of film extrusion methods, blown film and cast film.

Extrusion begins with the hard Polyethylene resin pellets fed into one end of a rotating screw encased in a heating barrel. As the resin pellets travel along the screw they are heated up gradually increasing in temperature along the barrel to between 200-230° C at the end. The screw is the most important part of the extruder and the design of the screw must ensure that molten polyethylene is pushed through the die at a constant rate. Once the polyethylene is pushed through a die it is pulled through and cooled.

In a blown film extrusion the die is round and the plastic is pulled upwards until it forms a three storey bubble it is then clamped at the top by nip rollers. As the plastic film travels upwards towards the nip rollers it cools down from 230° C to room temperature and becomes solid plastic sheeting.

Blown Film Extruder

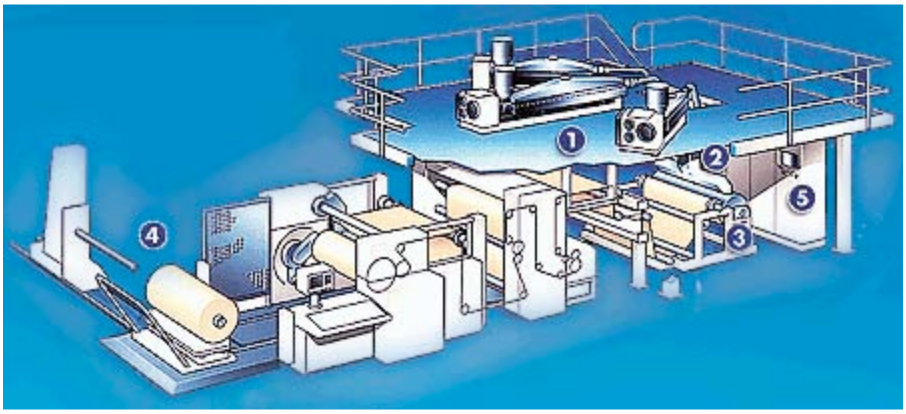


Source, www.bpf.co.uk/bpfindustry/process_plastics_blown_films.cfm

1. Barrel & Screw
2. Die
3. Bubble
4. Nip rollers

In cast film extrusion the die is a long flat slit and the plastic is pushed though this and drawn onto a highly polished water cooled chill roller cooling the film to about 50° C, it then passes over a second roller further cooling it to about 20° C.

Cast Film Extruder



1. Top Platform
2. Die
3. Chill Rollers
4. Winder

History of PE/PP

Polyethylene (PE) was first synthesized by the German chemist Hans von Pechmann, who prepared it by accident in 1898 while heating diazomethane. The polymer was largely forgotten until 1933 when it was produced agin by accident by Reginald Gibson and Eric Fawcett at the time working at the British industrial giant Imperial Chemical Industries (ICI). The pair where experimenting by applying extremely high pressure (several hundred atmospheres) to a mixture of ethylene and benzaldehyde. However their had been a leak in their testing apparatus and trace oxygen contamination initiated a reaction which produced a white waxy material. As they where unaware of the containination they found the experiment difficult to reproduce. It was not until 1935 that another ICI chemist, Michael Perrin, developed this accident into a reproducible high-pressure synthesis for polyethylene that became the basis for industrial LDPE production beginning in 1939.

PEs are cheap, flexible, durable, and chemically resistant. They evolved into two forms, "low density polyethylene" (LDPE) which is used to make films for food warping and packaging materials, and "high density polyethylene" (HDPE) which is used for containers, plumbing, and automotive fittings.

Further evolutions have evolved around developing several types of catalyst that promote ethylene polymerization at more mild temperatures and pressures. These also have implications for the properties of the polymer that is produced by the different catalysts. The first of these was a catalyst discovered in 1951 by Robert Banks and John Hogan at Phillips Petroleum, called the Phillips catalyst. Then in 1953, the German chemist Karl Ziegler developed a catalytic system that worked at even milder conditions than the Phillips catalyst. The third type of catalytic system, one based on organometallic compounds called metallocenes. These were discovered in 1976 in Germany by Walter Kaminsky and Hansjörg Sinn.

Polypropylene

The insights into polymer chemistry gained by discoveries such as polyethylene aided in the production and discovery of other polymers. Polypropylene (PP) was separately

invented about nine times in a short space of time, in the earily1950s, by a number of different research teams. This caused a number of legal battles over who were the original inventors. It wasn't until 1989 that two American chemists J. Paul Hogan and Robert Banks, were credited as the "official" inventors, however another scientist Giulio Natta is also often given credit as the inventor of polypropylene.
Polypropylene is similar to its ancestor, polyethylene, and shares polyethylene's low cost, but it is much more robust. It is used in everything from plastic bottles to carpets to plastic furniture, and is very heavily used in car manufacturing.

Degradable and Biodegradable Polymers.

In the last 20 years a number of polymers have been developed to degrade and biodegrade. As society has become more environmentally aware, there has been a growing demand for more environmental solutions to conventional petrochemical based polymers.
This has resulted in a range of different polymers based on starch, degradable petrochemicals and even biotechnology derived polyesters. The different types of polymers have been accepted with varied success as their complex nature has yielded more challenges in their implementation than benefits.

There are so many different types of plastics and uses for plastics. Most of the information contained in this student pack comes from the following sources, for more information visit the website.

Macrogalleria

www.pslc.ws/mactest/index.htm

Answers.com

www.answers.com

Quenos

www.quenos.com.au

Plastics resources

www.plasticsresource.com

Wikipedia

www.wikipedia.org

About.com (inventors.about.com)
www.about.com

History of GLAD

The GLAD brand originated in the USA and in 1963 the polyethylene plastic film was launched into the market as GLAD Wrap. Production in Australia commenced and in 1966 GLAD Wrap was introduced to the Australian public as “The Amazing New Plastic Wrap” that is see through, keeps food fresher and clings to containers as well as itself. Demonstrations of how this wrap worked were on display in the main windows of Woolworths’ in George and Pitt St Sydney and GJ Coles in Bourke St Melbourne.

The demonstrations aimed to show the public that food kept for 3 days under GLAD wrap was just as good as freshly prepared food that day. To ensure there was no tampering with the food the demonstrations were kept under armed guard for three days. The public were amazed to find that the wrapped food was as fresh as it had been before it was wrapped.

Since the launch of the revolutionary GLAD Wrap other products have been added to the range, including resealable food bags, foil products, Baking & Cooking paper, ice-cube bags, plastic containers and of course garbage bags.

GLAD plastic film products are made from polyethylene with the exception of the GLADWare tubs made from polypropylene and GLAD baking and cooking paper is a non-stick paper different to the waxed and greasproof papers available in the supermarkets. For more detail on each of the products visit our website on http://www.glad.com.au/

GLAD as a brand is owned by Clorox Australia Pty Ltd a subsidiary of Clorox USA and is one of many well known quality brands owned and manufactured by or on behalf this company. Other brands include OSO, CHUX, ArmorAll, STP, ASTRA and Clorox.