

Masters course on Circular Economy for Materials Processing (MC-CEMP)

January 2019

Theme 2 –materials and available resources

Plastics - Methods of production

Plastics are simply chains of molecules linked together, these chains are called polymers. The term “plastics” encompasses all these various polymers.

A polymer is a large molecule made up of chains or rings of linked repeating subunits, which are called monomers.

There are two types of polymerization reactions: addition polymerization and condensation polymerization. Addition reactions are characteristic of monomers that contain either a double bond between two atoms or a ring of from three to seven atoms. The monomers add to one another in such a way that the polymer contains all the atoms of the starting monomers.

Condensation polymerizations are typical of monomers containing two or more reactive atomic groupings.

Plastics are derived mainly from raw materials, i.e. coal, natural gas, salt and, of course, crude oil. Crude oil is a complex mixture of thousands of compounds and needs to be processed before it can be used. The production of plastics begins with the distillation of crude oil in an oil refinery. This separates the heavy crude oil into groups of lighter components, called fractions. Each fraction is a mixture of hydrocarbon chains (chemical compounds made up of carbon and hydrogen), which differ in terms of the size and structure of their molecules. One of these fractions, naphtha, is the crucial compound for the production of plastics. Two main processes are used to produce plastics - polymerisation and polycondensation - and they both require specific catalysts. In a polymerisation reactor, monomers such as ethylene and propylene are linked together to form long polymer chains. Each polymer has its own properties, structure and size depending on the various types of basic monomers used.

The most important manufacturing methods are:


EXTRUSION - continuous process of converting a solid plastic mass, pellet or powder into a melted form where it is pushed through a die into a shape. This shape is then moved through various secondary operations where it is cooled then cut, coiled or experiences a variety of other possible operations.

CALENDERING - calendering of molten polymers is a process for the production of continuous sheet or film by squeezing the melt between a pair of heated counter-rotating rolls

FILMING BLOWING - This process can be included as an specific variety of extrusion. The steps are the same until the die, where the semi-molten polymer extrudes vertically in an upward direction thanks to a bubble of hot air that continuously stretches the plastic




INJECTION MOULDING - The melt mix is driven by the crew into the mould tool using pressurized injection , the part where the desired shaped is defined.

Type of plastic – based on Plastic Europe¹

	<p>Bio-based plastics</p> <p>Bio-based plastics are made in whole or partially from renewable biological resources. For example, sugar cane is processed to produce ethylene, which can then be used to manufacture for example polyethylene. Starch can be processed to produce lactic acid and subsequently polylactic acid (PLA).</p>
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¹ <https://www.plasticseurope.org/en/about-plastics/what-are-plastics/large-family>

	<p>Biodegradable plastics</p> <p>Biodegradable plastics are plastics degraded by microorganisms into water, carbon dioxide (or methane) and biomass under specified conditions. To guide consumers in their decision-making and give them confidence in a plastic's biodegradability, universal standards have been implemented, new materials have been developed, and a compostable logo has been introduced.</p>
	<p>Engineering plastics</p> <p>Engineering plastics exhibit higher performance than standard materials, making them ideal for tough engineering applications. They have gradually replaced traditional engineering materials such as wood or metal in many applications because, not only do they equal or surpass them in their weight/strength ratio and other properties, but they are also much easier to manufacture, especially in complicated shapes.</p>
	<p>Epoxy resins</p> <p>Epoxy resins have been around for more than 50 years, and are one of the most successful of the plastics families. Their physical state can be changed from a low viscosity liquid to a high melting point solid, which means that a wide range of materials with unique properties can be made. In the home, you'll find them in soft-drinks cans and special packaging, where they are used as a lining to protect the contents and to keep the flavour in. They are also used as a protective coating on everything from beds, garden chairs, office and hospital furniture, to supermarket trolleys and bicycles. They are also used in special paints to protect the surfaces of ships, oil rigs and wind turbines from bad weather.</p>
	<p>Expanded polystyrene</p> <p>Expanded polystyrene, or EPS, is one of the most widely used commodity polymers. It has been a material of choice for more than 50 years because of its versatility, performance and cost effectiveness. It is widely used in many everyday applications.</p>
	<p>Fluoropolymers</p> <p>Fluoropolymers are a family of high-performance plastics. The most well-known member of this family is PTFE. PTFE is inert to virtually all chemicals and is considered to be the most slippery material in existence. These properties have made it one of the most valuable and versatile materials ever invented, contributing to significant advancement in areas such as aerospace, communications, electronics, industrial processes and architecture.</p>
	<p>Polyolefins</p> <p>Polyolefins are a family of polyethylene and polypropylene thermoplastics. They are produced mainly from oil and natural gas by a process of polymerisation of ethylene and propylene respectively. Their versatility has made them one of the most popular plastics in use today.</p>
	<p>Polystyrene</p> <p>Polystyrene is a synthetic aromatic polymer made from the monomer styrene, a liquid petrochemical. It is a thermoplastic polymer which softens when heated and can be converted into semi-finished products such as films and sheets, as well as a wide range of finished articles.</p>

	<p>Polyurethanes</p> <p>Polyurethane (PUR) is a resilient, flexible and durable manufactured material. There are various types of polyurethanes, which look and feel very different from each other. They are used in a very broad range of products. In fact, we are surrounded by polyurethane-containing products in every aspect of our everyday lives. While most people are not overly familiar with polyurethanes because they are generally 'hidden' behind covers or surfaces made of other materials, it would be hard to imagine life without them.</p>
	<p>Polyvinyl chloride</p> <p>Polyvinyl chloride (PVC) was one of the first plastics discovered, and is also one of the most extensively used. It is derived from salt (57%) and oil or gas (43%). It is the world's third-most widely produced synthetic plastic polymer, after polyethylene and polypropylene. PVC comes in two basic forms: rigid (sometimes abbreviated as RPVC) and flexible.</p>
	<p>Thermoplastics</p> <p>Thermoplastics are defined as polymers that can be melted and recast almost indefinitely. They are molten when heated and harden upon cooling. When frozen, however, a thermoplastic becomes glass-like and subject to fracture. These characteristics, which lend the material its name, are reversible, so the material can be reheated, reshaped, and frozen repeatedly. As a result, thermoplastics are mechanically recyclable. Some of the most common types of thermoplastic are polypropylene, polyethylene, polyvinylchloride, polystyrene, polyethylenetheraphthalate and polycarbonate.</p>

Metals

Elements that form cations (positively charged ions) when their compounds are in solution are metals. The mining and metals industry is an integral part of any foreseeable economy and society. As a provider of employment and essential materials, it is connected to almost all industry value chains. Metal production refers to all the processes involved in the conversion of a raw material to a final form. Metallurgy studies the best way to get metal from minerals. Metals occur in nature as compounds and must be converted to their elemental state. They may be treated in order to make them usable in different ways:

Mining: process of removing the metal from earth's surface.

Purification: separate the metal from rest of components

Reduction: chemical reaction opposite to oxidation

Alloys: combining pure metals.

Metal properties

- Most metals are very good conductors of electricity and heat.
- Most are crystalline solids at room temperature with a shiny, metallic luster.
- Most are malleable (can be beaten into a sheet without breaking easily) and ductile (can be drawn into a wire without breaking easily).
- Most are hard and have high physical strength.
- Most are denser than water.

The metals and mining sector is the industry dedicated to the location and extraction of metal and mineral reserves around the world.

Global reserves of metals and minerals are mined for profit and then used in:

- Electronics: smartphones, fridges, TV, etc.
- Medicine: carry oxygen by blood, broken bones
- Building constructions: iron and steel used in buildings
- Jewellery: gold and silver are symbol of financial status
- Machinery: most of the industrial machinery and automobiles, including here all transportation

- Farming: tools for tilling the land
- Cooking: cooking utensils made of steel, aluminum, copper
- Furniture: made of wood but strengthen with metal
- Security system: Locks, lockers, cupboards, etc.
- Bullion market: gold is a safety option for investors.



Figure 1. Types of metals