Plastics - History, Types & Processing

Note: This resource has been adapted from An Insight Into Plastics,
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Introduction

Most of the basic materials from which we make the implements used in everyday life have been known from the earliest times. They include wood, stone, metals, glass, clay, ceramics, animal skins and vegetable fibres. But while some of these materials occur naturally, others, like metal and glass, are converted from raw materials by some form of chemical process.

Similarly, although plastics as we know them are essentially products of this century, plastics in their naturally occurring forms have also been used for thousands of years, ever since man first began to make bowls, utensils and bricks of clay, and waterproof his sailing vessels with asphalt.

The term "plastic", derived from the Greek word "plastikos" actually applies to any pliable substance that can be shaped or moulded, for example, wax, clay, asphalt and amber.

Most of the plastics we use today have been developed within the last 50 years or so. The majority of them are man-made and are usually described as synthetic products, or in other words, they are made by a process of building up from simple chemical substances.

Today's plastics are generally made by industrial chemists from various chemical compounds derived from lime, salt, water, petroleum or coal. Their special properties are light weight; high impact and tensile strengths; resistance to corrosion, salt water and most chemicals; suitability for use over a wide range of temperatures and for electrical insulation. Some plastics are not fully synthetic as they are produced simply by modifying natural materials. Examples are celluloid and cellulose acetate, both derived from cellulose (as in cotton wool) and plastics derived from casein, a complex protein which comes from cow's milk.

The History of Plastics

One of the very first experiments with synthetic plastics took place about 1835 when the French chemist, Regnault, caused a chemical called vinyl chloride to turn into white powder. This was the very earliest form of polyvinyl chloride, which we know as PVC, but it was not commercially developed for almost another century. There were many other plastics, the development of which was delayed for equally long periods. The main reason for this delay was that until well into the 20th century, it was impossible to obtain sufficient quantities of the necessary raw materials to make chemicals for the new products.

It was in 1862 that the first synthetic plastic material was introduced to the public. It was shown at the Great International Exhibition, London, by Alexander Parkes. The new product was then called "Parkesine" and had been made by mixing camphor (the chemical used in mothballs) with nitrocellulose (used in many modern lacquers for motor car bodies).

However the same discovery was made some years later by an American, John Hyatt who christened the new material "celluloid". His incentive was a prize from a billiard ball maker to find a substitute for ivory. What he discovered, celluloid, made lousy billiard balls, but great table tennis balls. He did not win the prize. Celluloid enabled the movie industry to boom, for it was the first material which could be imprinted with an image, and yet be flexible enough to feed through a movie projector. It had a serious drawback however, and that was its flammability, the reason many old theatres went up in flames. Along with other cellulose nitrates, celluloid was also used to make, denture plates, shirt collars and cuffs, and car windows.

Gradually, appreciation of the uses of the results of scientific research increased as did people's need for more goods, and of course more chemicals, steel and power to make them. Laboratories, regarded for so long as eccentric curiosities, were at last recognised as being useful to society. It was also realised that many new chemicals could be produced from what was merely waste residue from other industrial processes.

It was this change in people's attitudes towards science and manufacturing that really paved the way for the development of plastics on a commercial scale.

In 1909 came the next major advance with the introduction of phenol-formaldehyde, more commonly known as "Bakelite" after its discoverer, Dr. Leo Henrik Baekeland, a Belgian working in the United States.

The tempo of plastics development accelerated rapidly from this time onwards. Each decade saw the introduction of several new varieties of plastics:

1920-21 urea-formaldehyde and the vinyls, eg polyvinyl chloride (PVC);

1931-40 the acrylics, polyvinyl acetate (PVA), nylon, polystyrene, melamine formaldehyde;
1941-50 polyesters, polyethylene (polythene), silicones, epoxy, acrylonitrile butadiene, styrene (ABS);
1951-60 polyurethane, polypropylene.

Since 1960 many new and more specialised plastics have been developed and the list continues to grow, until today there are many different "families" of plastics, each with numerous members.

The History of Plastics in Australia

The plastics industry began in Australia about 1917. Buttons were among the first products made and were moulded from imported phenol-formaldehyde powder, which two years later was used for electrical insulation.

Progress initially was slow ; because of the country's lack of secondary industries, chemical companies making fertilisers and drugs had little incentive to extend their operations to plastics.

Additionally, local moulders had to import raw materials. There was a lack of skilled die-makers to produce the intricate dies used to shape extruded plastics like pipes, rods, tubes or continuous sheet. However by 1926, several companies were moulding buttons, knobs, jewellery, radio parts, and electrical fittings.

During the depression of the 1930s, development again slowed down although the expanding radio and electrical industries continued to create demand for plastic components. Towards the end of the depression the relatively new automotive and aircraft industries also stimulated demand for plastic components.

Australian-built plastics processing equipment was being built by the end of 1945. In fact World War II gave great impetus to the industry. The difficulty in obtaining many conventional materials fostered interest in plastics as possible substitutes. Airmen required parachutes and silk, the traditional material used, could not be produced in sufficient quantities so a synthetic fibre was developed. Plastics were often superior to the materials they replaced, and were cheaper to produce. In post-war years, the newly developed materials found new demand, and many ladies were able to afford stockings made from parachute type fibres.

The Australian plastics industry has grown rapidly since the war. Plastics that boomed during the 1970s and 1980s were high density polyethylene (HDPE) used to make film, bags, milk and fruit juice bottles; polypropylene, used in outdoor furniture and automotive components; PET, used for soft drink bottles and carpet fibre; and ABS, used in TV cabinets, telephones and automotive parts. In addition, a number of specialised engineering plastics, as well as composite plastic-based materials reinforced with exotic synthetic fibres are used in aircraft components.

The Australian plastics industry employs about 80,000 people in more than 2000 workplaces, with a production output of about $5.6 billion every year.

Types of Plastic

Introduction

Describing the types of plastics is a bit like looking at a giant family tree; unless you know some of the people it does not make much sense. This section will help you get a general idea of the various types, and how they are related. The resource: ‘curing’ explains the basic chemistry of plastics, and describes the difference between thermoplastic and thermoset plastics. They are like two branches of the family, and this section deals with the largest branch, thermoplastics.

One difficulty with describing plastics, is that the same material with the addition of just a single additive like a blowing agent or plasticiser, can make what appears to be a very different material. Take polyurethane for example. It can be used as a clear coating like varnish, expanded and rigid to form the core of a surfboard, and with a plasticiser it can become a soft car seat.

With plastics there are about 45 basic families, many with hundreds of offspring. We will look at five main branches, mainly because they are plastics which you will be familiar with. The five branches are; polyethylene, polypropylene, polystyrene, vinyl, and polyethylene terephthalate. Let’s look at them in a bit more detail.

Five Main Types

Polyethylene - most plastic household packaging is made from polyethylene. It is a versatile wax-like thermoplastic in almost a thousand different grades with varying melting temperatures, density and molecular weights. It has three main forms:

Form	Acronym	Recycle Code	Characteristics	Common Uses
high density	HDPE	2	hard to semi-flexible, waxy surface, opaque	fertiliser bags, car petrol tanks, gas pipe, tanks and rope
low density	LDPE	4	soft, flexible, waxy surface, translucent	packaging film, bags, waterproof membranes, wire sheathing, pipes
linear low density	LLDPE	4	flexible, translucent, glossy, strong	shopping bags, stretch wrap, greenhouse film

Polypropylene - was developed in Italy in 1954 from catalysts used to form HDPE. It is very versatile, and makes up about 12 per cent of the plastics used in Australia.

Form	Acronym	Recycle Code	Characteristics	Common Uses
polypropylene	PP	5	hard, flexible, translucent, dry feel	containers, appliances, toys, plumbing

Polystyrene - is one of the lower cost plastics to produce and is the easiest to shape. Packaging for a variety of products uses most of the plastic.

Form	Acronym	Recycle Code	Characteristics	Common Uses
polystyrene	PP	6	clear, glossy, rigid, brittle	margarine containers
high impact	HIPS	6	opaque, tough, rigid	refrigerator liners
Expanded	EPS	6	foamed, lightweight, insulating	stubby holders moulded packaging
styrene acrylonitrile	SAN	7	rigid, clear, tough	mixing bowls, food containers
acrylonitrile butadiene styrene	ABS	7	rigid, tough, glossy opaque	hard hats, computer cases, wheel covers

Vinyls - are among the most versatile of all thermoplastics, ranging from soft pliable films to rigid structural forms. They are cheap to make because about half the raw material comes from rock salt.

Form	Acronym	Recycle Code	Characteristics	Common Uses
Plasticised	PVC	3	flexible, clear, elastic	car linings, blood bags, floor covering
In-plasticised	PVC	3	hard, rigid, clear	pipe, cordial bottles, credit cards

Polyethylene terephthalate - is one of the more recent plastics, and it is being used for an increasing array of products. One reason for this is a ready supply of raw material (a petroleum by-product) and the only waste from the process is steam.

Form	Acronym	Recycle Code	Characteristics	Common Uses
Fibre	PET	1	clear, tough, heat resistant	fabrics and carpets
Sheet	PET	1	clear, tough glossy, heat resistant	soft drink bottles, audio video tapes

The use of plastic for soft drink bottles was not allowed for a long time. It was considered unsuitable because aerated water could build up pressure and split a plastic bottle, and besides, plastic was not clear like glass bottles. Polymer chemists responded to the challenge, developed both the material (PET) and the process to produce a clear bottle. Normally, blow moulded bottles are not rigid enough around the opening to hold a screw top against pressure which may build up with soft drink. Plastics engineers developed a process to inject the plastic under high pressure to form the top of the bottle, making the plastic very dense and strong. The remaining molten plastic is cooled quickly so it solidifies in a transparent state. The plastic is reheated and then blown against the surface of the mould. You may have wondered why cutting a plastic bottle is easy, except anywhere around the opening. The difference is in density of the material. PET bottles exceed the performance of glass in several respects. A PET bottle of softdrink can be dropped without releasing the contents, and the container/product weight ratio of 7% to 93% results in major fuel savings in transport compared to the ratio of 43% to 57% for glass bottles. (Manufacturing Plastics: The Process and Environmental Impact, PACIA, Melbourne, 1992)

Processing of Plastics

One of the most important characteristics of plastics is the ease with which they can be formed into intricate shapes. Although the various machines which process plastics are very different, the process of softening, shaping and cooling the plastic material is common to each one. The main methods of processing plastic are described here. Your school library will certainly have books on plastic where these processes are illustrated.

Blow moulding - is used for hollow containers like milk bottles. Plastic is melted into a hollow tube and placed between the halves of the mould. As the mould closes, compressed air forces the plastic against the walls of the mould.
Blown film - is the process of molten plastic being blown like a huge balloon which is being drawn upwards at the same time into rollers which cool the film and press it flat. This is how thin plastic film like shrink wrap is made.
Calendering - is where molten plastic is poured and evenly squeezed between several sets of rollers until it cools.
Extrusion - is the process used for forming pipes and various sections like spouting and curtain track. Plastic granules are fed into a large revolving screw which forces the granules past a heating chamber where they melt. The molten plastic is forced through a hole, called a die, which is the shape of the finished section, and as the continuous section passes coolers it becomes rigid.
Injection moulding - is a common processing method for mass producing plastic parts. Plastic granules are heated in a chamber and an exact amount of molten plastic is forced into the mould which is made in two or more sections, held tightly together with a hollow the shape of the finished product inside. Plastic model kits have many parts moulded at the one time, the molten plastic being forced from one part to the other through the tiny section which keeps the parts together.
Rotational moulding - uses a hollow mould which is heated, and rotates through every axis. The plastic granules melt against the surface of the mould as it rotates, spreading an even thickness against the mould surface. The mould cools and when the parts are separated, the product such as a beach ball or rainwater tank is taken out. Easter eggs are made in rotational moulds, and sometimes they are thicker on one end because the rotating mould stopped while some chocolate was still able to run to the lowest point.

Further Reading:

Manufacturing Plastics: The Process and Environmental Impact, Plastics and Chemicals Industries Association (PACIA), Melbourne, 1992.
Know Your Plastics, Plastics and Chemicals Industries Association (PACIA), Melbourne, 1992.
Plastics Materials, A Brydson

Useful Websites:

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