Averil Macdonald

Fantastic plastic

Prototype Organic LED television screens. These screens use polymer LEDs to produce the picture; many millions of smaller OLED screens are already in use in mobile phones.

Think of polymers (or plastic) and probably you come up with plastic bags and toys. Think a bit harder and you get to plastic plates and cups, plastic pens and pencil cases. Now look around you. It's very likely that the majority of objects in your room at made of polymers. In this article, Averil Macdonald of Reading University asks: why are people getting more and more excited about what polymers are going to do in the future?

Key words
polymer
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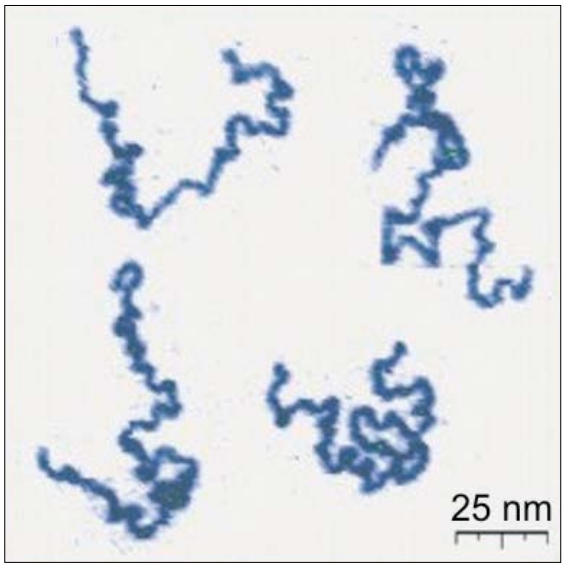
Molecular chains

Polymers, like many other materials, are made of atoms bonded together into molecules. What makes polymers different is that these molecules are then bonded together into long chains.



An unusual sight - this photograph shows four individual polymer chain molecules. It was made using an atomic force microscope.

The exciting thing about polymers is that we can make polymers behave in so many different ways by organising their long chain molecules in different ways – polymers are the ultimate designer material.

For example, scientists have developed improved house paints consisting of a polymer solution so that now they last longer between repainting and are more waterproof, while in the kitchen your non-stick pans only work because they are coated in a polymer called Teflon.

How polymers are processed can make big differences to their properties. All of these items are made from polystyrene.

Polymer families

Most of the materials we call 'plastic' are made from one of five 'families'.

- PE: polyethylene e.g. carrier bags
- PP: polypropylene e.g. drinks cups, kettles
- PS: polystyrene and expanded polystyrene (EPS) e.g. insulating cups, packaging
- PVC: poly(vinyl chloride) e.g. window frames
- PET: poly(ethylene terephthalate) e.g. transparent water bottles

Polymers from different families: milk bottle (polyethylene), fast-food container (polystyrene), pipe (PVC) and rope (nylon).

Then there are the polymers with trade names like Nylon™, Polythene™ and Kevlar™ (bullet-proof vests are made from Kevlar™ – designed to be the strongest material on Earth!).

Choosing the right polymer

When a company chooses the right polymer for its product it will take account of all of its different properties such as

- the melting temperature – we can't have a cup that melts when warm water is poured into it
- do we need it to be a good thermal insulator – this is important for food containers so we often use expanded polystyrene
- do we need it to be a good electrical insulator - some plastics can conduct electricity! PVC is often used as an insulator in household cables but isn't good enough for high voltages up to 500 000 V where we have to use cross-linked polyethylene
- how easy it is to mould into shapes – if it is a hard, inflexible plastic then you can't use it for something that has to be flexible so you would add lots of 'plasticiser' such as phthalates to PVC
- does it have to be transparent – PET is used for bottles as it is easy to make transparent
- does it have to be easy to add colours to – if you want an attractive product you have to be able to colour it – PVC is good for colouring
- does it matter if it becomes brittle when is it left outside or in the cold – crates made of polypropylene may become brittle after a while if left in the cold because this material becomes very hard below -5°C
- should it be degradeable – some plastic bags are degradeable because a special ingredient is added to the mix so that the long chains begin to fall apart after a while and the bag will simply turn to dust
- and, of course, the cost of the polymer.

Future polymers

In the future we will be using many more polymers. This worries some people as they know that most polymers are made from oil products and they are concerned that we will run out of oil. In fact we only use 4% of our oil to make polymers and we can always burn the polymer after use in the same way as we burn oil in power stations to generate electricity. This means we have had the use of the polymer and we get the energy out of it at the end of its life.

But scientists are always thinking about the future. A team of scientists are already working on a way to genetically modify the chloroplasts of a cress cell so that when it photosynthesises it doesn't produce starch (starch is the food of the plant and is a natural polymer). Instead the plant produces another polymer called polyhydroxybutyrate or PHB which we can use to make useful things but which also biodegrades naturally at the end of its life.

Carlos Muñoz-Yagüe/Eurelios/SPL

The Biocomposites Centre at the University of Wales, Bangor, is developing plastic materials derived from plants. This researcher is examining a polymer material extracted from plant cell walls.

Barak Brudo/Bigstockphoto

Plastic crates like these, exposed to the elements, gradually degrade.

Polymers will also make a big difference in medicine. We already use plastic lenses in people's eyes if they have developed cataracts – the surgeon simply cuts round the iris, pops out the patient's cloudy lens and puts in a new clear plastic one before sewing the flap back onto the eye.

Surgeons also use replacement plastic heart valves for people with heart disease, and replacement plastic hip or knee joints for people with arthritis or who have damaged their joints playing sport. They are also working on plastic replacement skin for burns victims and plastic replacement veins to be transplanted into people who have suffered thrombosis (a blockage in the vein due to a large blood clot).

In the future we can look forward to the possibility of plastic organs such as livers and kidneys for people who have life-threatening diseases and require a transplant. The big advantage here is that, if scientists can get this to work, patients will be able to have a transplant as soon as they become ill. They won't have to wait for a donor to die. Some people spend years on kidney dialysis before they get a compatible donor and some die waiting!

John Cole/SPL

This model, photographed at the Glasgow Science Centre, shows some of the many applications of polymers in medicine – artificial hips and knees, breast implants, stents to prop open collapsing blood vessels, and even artificial voice boxes (larynges).

Getting hi-tech

Another big area where plastics will make a difference is in hi-tech goods. This year will see the first really flat screen television launched. The screen will be only 3 mm thick – much thinner than present flat screen TVs. Also it will be much more energy efficient than plasma screen TVs. These will be very different from present day televisions. They will be made of Organic Light Emitting Diodes (OLEDs). This means a polymer that conducts electricity but this polymer also acts like a semiconductor so it is possible to make a diode from it which emits light at a particular colour. The television picture is made up of lots of dots of the three primary colours of light – red, green and blue, just like a conventional television. Wait another couple of years and we could well have televisions that are so thin and flexible you can roll them up and carry them under your arm!

Finally plastics will make a big difference to climate change. A polymer called Nafion™ is an important part of hydrogen fuel cells. These cells can generate electricity from hydrogen and oxygen. The Nafion is the barrier or electrolyte between the two gases. The protons from the hydrogen go through the Nafion but the electrons cannot. If a wire is provided linking one side of the Nafion to the other, then the electrons flow through the wire to catch up with their parent protons on the other side. This makes an electric current which can power the car. The hydrogen and oxygen combine to make water which drips slowly out of the exhaust pipe.

If we can get the hydrogen by electrolysing water, using solar power, this means we can have electric cars that run on water! And we can power our houses using water too. We won't need petrol for cars or power stations to generate electricity. We won't need overhead cables either as we will each have our own hydrogen fuel cell in the house generating our heat and power. This means that we won't have the problems of pollution and greenhouse gas production that we get from cars and power stations at the moment – and that has to be good!

Martin Bond/SPL

This London bus is powered by hydrogen. You can see steam emerging from the exhaust (top left); this results from the oxidation of hydrogen in the polymer-based fuel cells.

So when you look at plastic items and think they are boring, remember that plastic is going to make a big difference to your life. There will be millions of jobs working on all these new and exciting developments and products in the future – solving the problem of climate change or improving medical care or simply making more exciting electronic gadgets. Only people with science qualifications need apply!

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