Conducting plastics information sheet

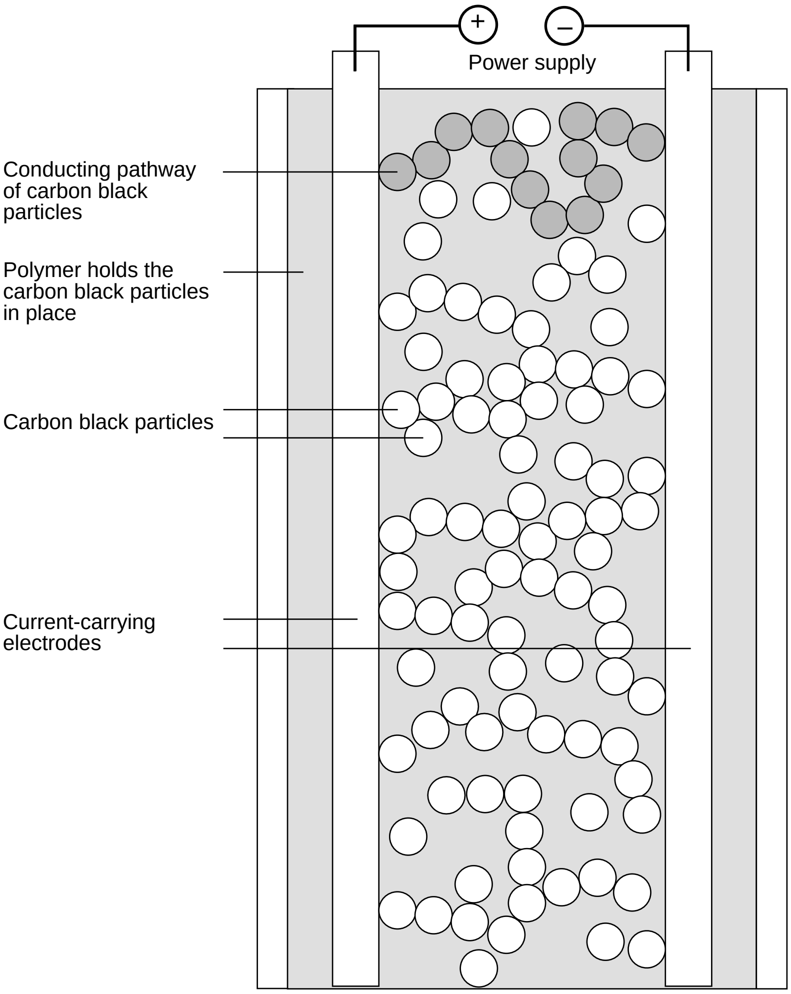
Usually plastics are excellent electrical insulators. They do not conduct electricity. However, they can be made to conduct electricity by mixing them with a material that is a good conductor. This material is called a **conducting filler**. The plastic polymer holds the filler in position so that it carries the electric current through the polymer. Changing the ratio of filler to polymer changes how well the material conducts. Many commercial products use carbon black – a form of carbon that conducts electricity – as the conducting filler.

Self-regulating heating cables

An electric current always has a heating effect. So, like all electrical components, conducting polymers warm up when an electric current flows through them. These polymers are used to make heaters with a built in temperature controller. The heaters are in the form of cables that, for example, can be attached to pipes to keep their contents at a particular temperature.

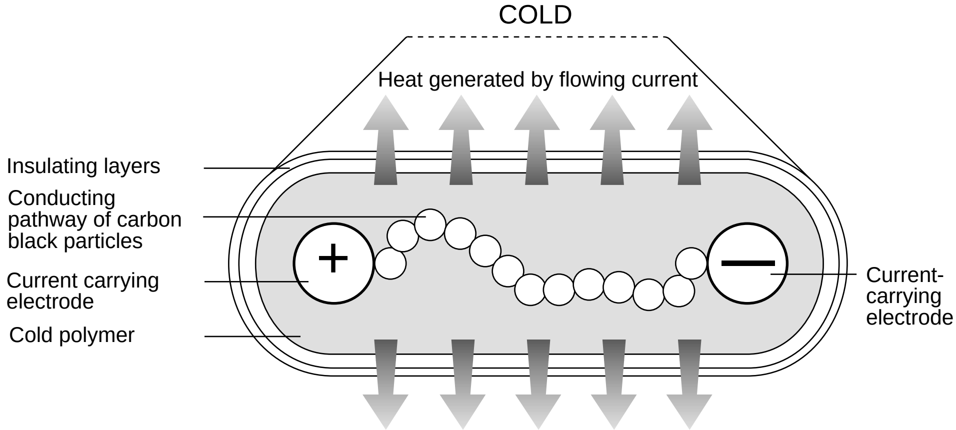
How they work

Two copper wire electrodes run along the whole length of cable. They are held apart, embedded in a conductive polymer which contains carbon black. The carbon black particles form tiny conducting paths between the two electrodes. This results in thousands of parallel circuits along the length of the cable, all acting independently of each other.

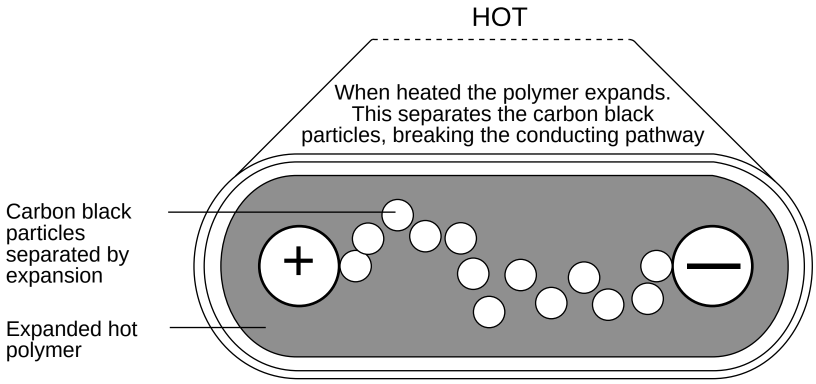


One complete conducting pathway of carbon black particles has been shaded in. Can you spot four others?

If we consider a section of the cable, we can see how it works (see below).



As electric current flows through the carbon black, heat is generated. This is the source of heat in the cable and this heat may be used, for example, to keep the contents of a pipe at the correct temperature. But, as the polymer itself warms up, it expands. As it expands, the carbon black particles inside it are pulled apart (see below). This breaks some of the conducting paths, less current flows, less heat is generated and the cable cools down.



As it cools, the polymer contracts, forcing the carbon black particles together again and reforming the conductive paths. The cable generates more heat again.

The self-regulating heating cable has many advantages over conventional electrical heaters:

- heat is only generated when required. This makes the heater energy efficient;
- the heat generated varies as the surrounding temperature varies;
- heat is only generated in the parts of the cable which are cold; the heating on the cable is localised. This is because the conductive carbon black pathways act independently as thousands of miniature parallel resistors;
- the cable is flexible, allowing the heating of awkward shapes such as pipes;
- as it is manufactured from a polymer, the cable is corrosion resistant;
- by altering the electrical properties of the polymer a variety of temperatures may be achieved making it suitable for a large range of applications;

- the cable can be cut to the required length up to a maximum of 250 m; and
- the cable cannot overheat, even when overlapped or sandwiched in thermal insulation, thus increasing safety.

Questions

1. What is a polymer?
2. Give two examples of where a plastic would be used because of its electrically insulating properties.
3. Give an example of a material that conducts electricity.
4. How could the conducting plastic be manufactured so that it becomes a better conductor of electricity?
5. What might happen to the plastic polymer if it overheats?
6. a) What happens to the runniness (viscosity) of a liquid such as treacle when it cools?

   b) What happens to a typical liquid if it is cooled to a low temperature?

   c) Give two examples of situations where it is important that the contents of a pipe do not cool down too much. Explain what might happen if they did.

   d) How could you use conducting polymers to keep the contents of a pipe warm?

Extension questions

7. Self-regulating heating cable is made of a **composite** material. This is a mixture of two or more materials and combines the properties of the materials in it. What two main materials are present in this composite and what property of each is necessary?
8. List any advantages in using a self-regulating heating cable to keep the contents of a pipe at the correct temperature, compared with using a conventional electric heater.
9. Expain in terms of the behaviour of their particles why materials expand when they are heated.
10. In self-regulating heating cables, *heat is only generated when and where it is required.* Explain why this is. You may wish to use diagrams in your answer.

Shape changing polymers (or molecules with a memory) information sheet

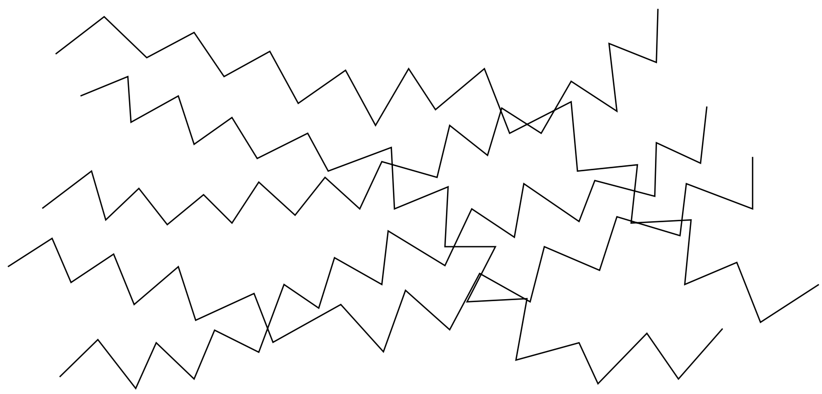
One way to classify polymers (plastics) is by their response to heat. All plastics can be moulded when they are made, and then set hard into shape as they cool. After this, **thermosoftening** (also called thermoplastic) plastics can be remelted, and then reshaped. **Thermosetting** plastics cannot be remelted and so cannot be reshaped once they have been made.

If we want a flexible plastic carrier bag, then a thermosoftening plastic is suitable. On the other hand, a saucepan handle must be made of a thermosetting plastic. This can withstand quite high temperatures. At very high temperatures it eventually burns or decomposes rather than melts.

There is now a type of polymer which makes a plastic that is midway between these two sorts. It has a very special property called **shape retention**. When this plastic has been heated it softens and becomes pliable. In this state it can be stretched. If it is cooled it will set hard in this stretched shape. But, the plastic remembers its original shape and will, if heated again, shrink back to this. It is called a **heat-shrinking polymer (or plastic)**.

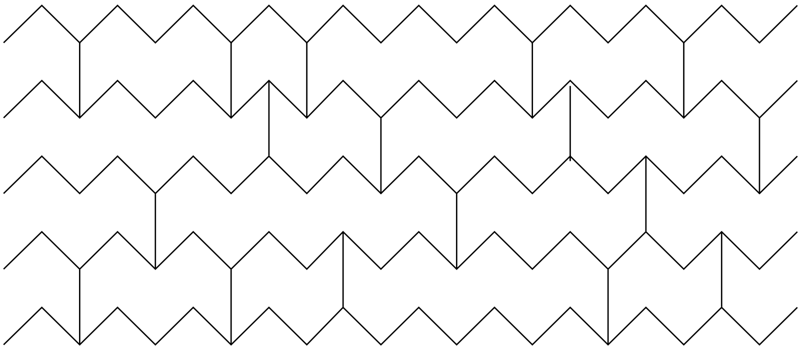
A question of structure

Thermosoftening plastics can be thought of as long chains of large molecules which have few or no crosslinking covalent bonds between the chains (see below). This sort of structure is easily melted as the chains will slide away from each other. If the material is stretched when it is hot the chains slide past each other and then stay in their new position, when the material is cooled.



A thermosoftening plastic

Thermosetting plastics have many covalent bonds linking the long chains. Not only is it impossible to melt the polymer if the material is stretched, the chains cannot slide past one another. The material is rigid and brittle.



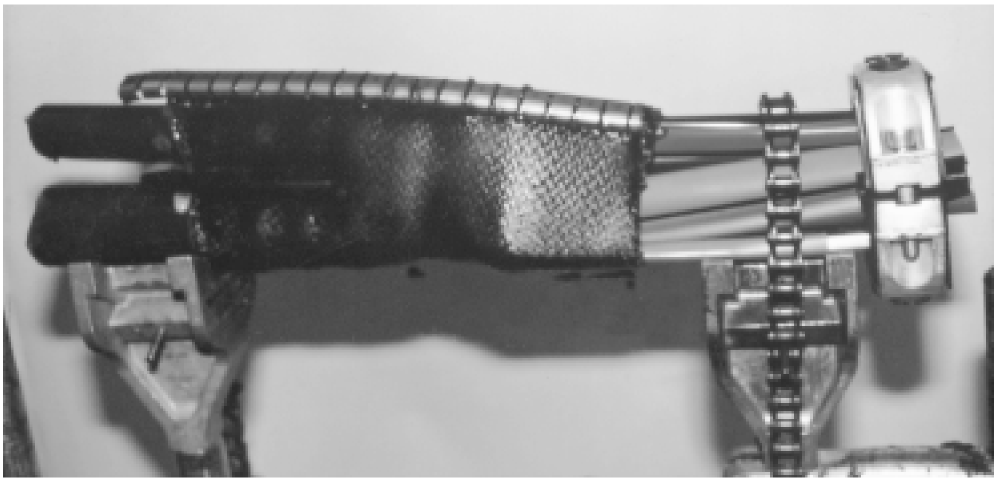
A thermosetting plastic

Heat-shrinking plastics have some crosslinking between the chains – more than thermosoftening plastics and fewer than thermosetting plastics.

They can be heated and softened enough to be reshaped. This stretches the cross-links. When they are cooled in the stretched state they stay stretched and retain the new shape. But, if they are now heated the chains are free to slide back to their original position, and the plastic returns to its original shape. The bonds are then behaving rather like stretched elastic bands that have been released.

Why are heat-shrinking plastics useful?

They can be used in awkward situations because when they shrink they can fit tightly over an object. A common example of this is heat shrink plastic sleeving for electrical wiring, for instance under the bonnet of a car. It is easy to fit a loose sleeve round a join and then seal it tightly by applying heat.



Heat shrink sleeving before being heated

Questions

1. Which sort of plastic, thermosoftening or themosetting, is suitable for recycling? Explain your answer.
2. What does *to melt easily* mean?
3. What are the properties of a *rigid, brittle* material?
4. From the list below pick out the properties of a typical plastic:

   good conductor of electricity/poor conductor of electricity

   water resistant/water absorbent

   high density/low density
5. Explain how a heat-shrinking plastic could be used to hold together a bunch of wires in a car engine.
6. Where else could a heat-shrinking plastic be used to provide a tight waterproof seal?

Extension questions

7. In what way does a heat-shrinkable plastic resemble:
   a) a thermosoftening plastic?
   b) a thermosetting plastic?
8. What is meant by *shape retention*?