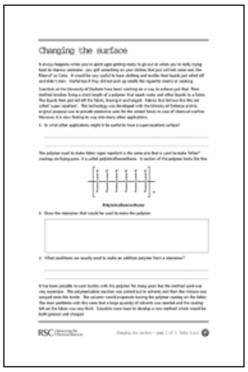
# Changing the surface


**Index 5.4.2**
1 sheet
**Index 5.4.3**
1 sheet
**Index 5.4.4**
3 sheets

This activity is based on the chemistry of functionalising the surface of a textile to make it water and stain resistant. The key idea is that a short length of $–(CF_2)n–$ polymer can be added to the surface of clothing to change its characteristics.

The polymer is polytetrafluoroethene (also known as a perfluoroalkyl) – the same polymer as that used to make Teflon® coatings. Teflon® and these textile coatings work in the same way. The tightly-bound, non-bonding electron pairs surrounding each fluorine atom are not easily polarised. This prevents the atoms both from hydrogen bonding with water, and from forming dispersion interactions with nonpolar liquids such as oils.

The technology for these coatings was developed by Prof J P Badyal at the University of Durham during the 1990s. The work was done in collaboration with the Ministry of Defence. Staff at the Ministry were interested in producing suits for armed forces personnel that would repel toxic chemicals such as mustard gas (a dispersion that consists of very tiny particles of liquid).

The mechanism of reaction is more complex than that of normal addition polymerisation. The details of the mechanism are still not fully understood and there are a number of different possibilities for how it might occur. This is not covered in the student material.

## Prior knowledge required by students

Students will need to have studied addition polymerisation or at least be aware of what polymers are. They should also know something about surfaces – at a minimum, they should be aware that the surface behaves differently from the bulk of a substance. They could perhaps have done the practical activity **The surfaces of substances**.

## Suggested lesson plan

- Begin by showing students the slide entitled **What's the connection?** This could be displayed as students are coming into the room. It shows pictures of four seemingly disparate items. The connection between these items is that the properties of each are governed not by what the bulk of the item is made of, but by its surface.
- Demonstrate super-repellant surface properties, either by dropping water onto a super-repellant surface (such as waterproof trousers for hikers), by showing the slide **Water-repellant surfaces**, or by showing the video clip **An electrifying way to stay dry** available at **http://www.research-tv.co.uk/stories/science/plasma/** (accessed November 2005).

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Alternatively, students could try dropping water onto a variety of surfaces themselves and looking at the shape of the drop formed on the surface. They could try cotton and other fabrics, Teflon® sheets, glass slides and waterproof trousers. (Note that the waterproof trousers on the market are generally not made using the technology featured in this activity and often do not have such convincing water-repellant properties as the fabrics shown on the slide and in the video clip.)

- Students do the first few questions on the student sheet.
- Show the video clip from **http://www.research-tv.co.uk/stories/science/plasma/**
- If possible do a demonstration with a plasma ball: As the electricity passes through the gas in the ball it excites the gas. You can see this happening because light is produced. By putting your finger on the outside of the ball you can localise the glow on your finger. If a textile is used instead of your finger on the glass surface, then it is possible to coat the textile with the excited gas, which forms a polymer coating.
- Students complete the rest of the student sheet.
- You could conclude with a discussion of surfaces that may be in use in the future (see question 9 on the student sheet).

## Answers

**1.** There are a number of possibilities here: aprons for chefs/cooks; babies' changing mats; tents; chairs and other surfaces in restaurants and bars etc. Get students to use their imaginations.

**2.**

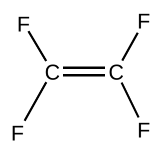


**Figure 1 Monomer used to make PTFE**

**3.** High temperature, pressure and a catalyst are usually used to make a polymer from a monomer in addition polymerisation.

**4.** Using a large number of solvents is expensive, especially if they are not recycled. Solvents escaping into the atmosphere can cause a number of environmental problems (*eg* chlorinated solvents destroying the ozone layer). A company may be fined if they are caught releasing a large quantity of pollutants into the environment and local residents may well complain. In addition, many solvents are flammable and can be a major hazard if a high concentration is present in a factory. Some solvents are hazardous to human health.

**5.** If the fabric were coated with a thick layer when only a thin one was needed it would cost a lot more to coat the fabric than necessary. A thick coating may well change the 'feel' of the fabric and make it less pleasant to wear.

**6.** The process has minimal environmental impact because so few resources are used. Since only a small amount of electricity is required, less $CO_2$ must be released during electricity generation than for a process that uses more electricity. Very little waste chemical material is produced, which reduces the need for waste disposal (often a cause of environmental damage).

**7.** If you can coat a wide range of materials then the process will find a wide variety of applications. Also, you do not need to put such careful controls in place to restrict which material is put through the process.

**8.** A shirt made of normal waterproof material is unlikely to be able to breathe and will feel very 'sweaty' and unpleasant next to the skin. An ordinary shirt with the polymer coating described will feel like an ordinary shirt and be far more pleasant to wear.

**9.** An open question aimed at encouraging students to think about some potential applications of fuctionalised surfaces. They may consider fragranced surfaces, other types of repellancy, clothing that could sense if you were sick, surfaces that kill bacteria or almost anything else. You could set them the challenge of searching the internet to find out if their idea is already being researched somewhere (depending on what they have thought of).

## References

J.P.S. Badyal, *Chemistry in Britain*, 2001, 37, 45.

S.R Coulson, J.P.S. Badyal et al, *Langmuir*, 2000, 16, 6287.

**http://www.research-tv.co.uk/stories/science/plasma/** (accessed November 2005)

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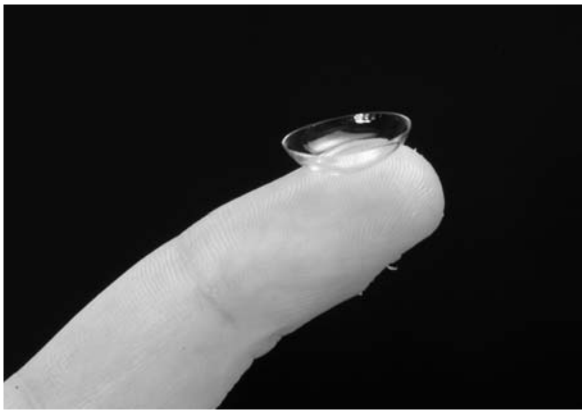
# What's the connection?

This is available as a projectable image on the CD-ROM – index 5.4.2

**Wear of car brake pads**



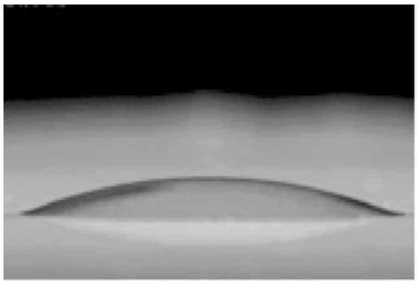
**Cleanliness of optical lenses**

**Resistance of medical devices to bacteria**

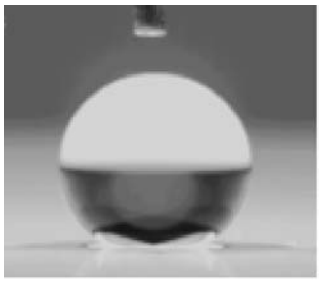
**Speed of computer hard disks**

# Water-repellant surfaces

**Image of a surface treated for superrepellancy kindly supplied by Professor JP Badyal, University of Durham see http://www.dur.ac.uk/chemistry/Staff/jpsb/jpsb.htm**



**Before surface treatment**

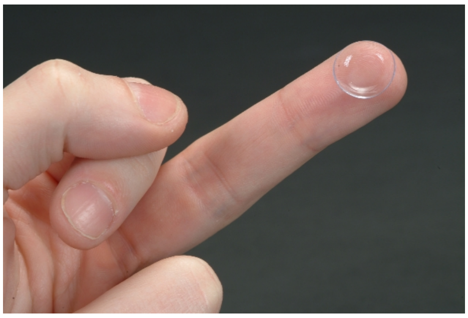


**The same surface after surface treatment**

# What's the connection?

Wear of car brake pads

Resistance of medical devices to bacteria



Cleanliness of optical lenses

Speed of computer hard disks

# Water-repellant surfaces

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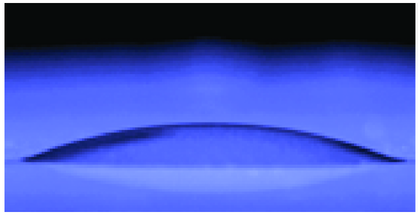

Before surface treatment

The same surface after surface treatment

# Changing the surface

It always happens when you've spent ages getting ready to go out or when you're really trying hard to impress someone:  you spill something on your clothes that just will not come out, like Ribena® or Coke.  It would be very useful to have clothing and textiles that liquids just rolled off and didn't stain.  Useful too if they did not pick up smells like cigarette smoke or cooking.

Scientists at the University of Durham have been working on a way to achieve just that. Their method involves fixing a short length of a polymer that repels water and other liquids to a fabric. The liquids then just roll off the fabric, leaving it unchanged.  Fabrics that behave like this are called 'super repellant'.  The technology was developed with the Ministry of Defence and its original purpose was to provide protective suits for the armed forces in case of chemical warfare. However, it is now finding its way into many other applications.

**1.** In what other applications might it be useful to have a super-repellant surface?

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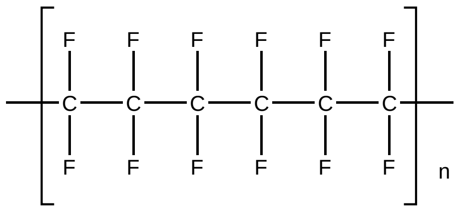
The polymer used to make fabric super repellant is the same one that is used to make Teflon® coatings on frying pans. It is called polytetrafluoroethene.  A section of the polymer looks like this:



**Polytetrafluoroethene**

**2.** Draw the monomer that would be used to make this polymer.

**3.** What conditions are usually used to make an addition polymer from a monomer?

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It has been possible to coat textiles with this polymer for many years but the method used was very expensive.  The polymerisation reaction was carried out in solvents and then the mixture was sprayed onto the textile.  The solvents would evaporate leaving the polymer coating on the fabric. The main problems with this were that a large quantity of solvents was needed and the coating left on the fabric was very thick.  Scientists were keen to develop a new method which would be both greener and cheaper.

Chemists who work in the field of Green Chemistry try to reduce the damage done to the environment when a product is made. Solvents can cause a number of environmental problems, so reducing the quantity of solvents used is a key part of making a process greener. If the solvents contain chlorine (eg CFCs) then they can damage the ozone layer. Other solvents cause a variety of problems when they are released into the environment and can contribute to either air or water pollution. Some are carcinogenic (cancer causing) and can be harmful to those using them. Many solvents are also flammable and can be a hazard if there is a high concentration in the air in the factory.

**4.** Why would using a large number of solvents be a problem for this industrial process?

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**5.** It is the surface of the coating that is important for making a fabric water repellant. Why would it be a disadvantage if the fabric was coated with a thick layer of polymer?

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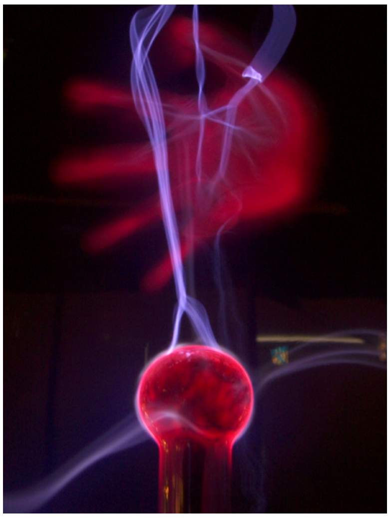
The team of scientists at Durham have been trying to solve this problem. They use a plasma to make the polymer coat the surface. Plasma is sometimes known as the fourth state of matter and makes up most of the universe. It is a mixture of electrons, ions, neutral particles and photons (particles of light). Although many of these particles are charged, plasma is neutral overall. Plasmas often have to be made at thousands of degrees Celsius, but they can also be produced at room temperature by passing electricity through a gas at low pressure as in plasma balls like the one shown below.



**A plasma ball**
**(Photograph by courtesy of Techniquest http://www.techniquest.org)**

As the electricity passes through the gas in the ball it excites the gas molecules. You can see this happening because light is produced. By putting your finger on the outside of the ball you can localise the glow on your finger. If instead of putting your finger on the outside of the ball, you put a textile on the inside, then you could coat it with the excited gas. This would form a polymer coating on the textile.

The main advantages of this method are that it can be used to coat almost any material, it is fast, does not use much electricity and produces hardly any waste chemicals so has minimal environmental impact.

**6.** Explain why this process has 'minimal environmental impact'.

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**7.** Why is it an advantage to be able to coat a wide variety of materials?

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These coatings are extremely thin – only nanometres thick – so this is an example of nanotechnology. A nanometre is 0.000000001 m. Think of how much bigger a kilometre is than an ant – a nanometre is that many times smaller than an ant. A nanometre is even smaller than a bacterium. You would not be able to feel such a thin coating on the surface of an item of clothing.

The coating does not change the properties of the majority of the fabric. When something made of cotton is coated in this way, it can still 'breathe', which it would not be able to do if it had an ordinary coating of plastic on it.

**8.** Why would it be better to have an ordinary shirt with a super-repellant coating than a shirt made of a normal waterproof material? (Hint: think about what the shirt would be like to wear.)

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## The future

There are many surfaces that are are already treated in some way to give them special properties, or that could benefit from this in the future. Some examples of applications where surfaces are important are:

- Anti-fouling coatings on ships (to stop barnacles and other marine life growing on them) or on walls (to prevent graffiti)
- Catalysts for many industrial processes
- Medical applications including new ways to deliver drugs or grow replacement body tissues
- New ways to release perfume from a textile surface.

The team of scientists at the University of Durham are also working on a smart 'multiplex' surface that responds differently in different situations. It might repel oil to prevent clothing from getting dirty, but then become hydrophilic (water attracting) once it is exposed to water. This would make clothes easier to launder and keep clean.

As it becomes easier to change the properties of the surface of an item by using nanotechnology, many different applications could become possible.

**9.** What special surface properties do you think it would be useful for scientists to develop?

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