MARCELA BILEK

Improving the design of an important industrial instrument

Marcela Bilek is a physicist. This means that she is an expert in **physics**, a branch of science that aims to understand light, sound, electricity and other properties of matter and energy.

Marcela Bilek helped improve the design of a powerful electrical instrument, called a cathodic arc. It is often used to make coatings on the outsides of objects to protect or decorate them. Marcela's work meant that new and improved coatings could be made in the cathodic arc. In particular, her work led to better coatings for the parts inside computers, and coatings for medical implants, such as artificial heart pumps.

fact file

Born: 20 January 1968

Schooling: (Sydney) Engadine Public School, Heathcote High School

Selected achievements:

- Malcolm McIntosh Prize for Physical Scientist of the Year, 2002
- Edgeworth David Medal, Royal Society of New South Wales, 2002
- Pawsey Medal, Australian Academy of Science, 2004
- *The Australian* Innovation Challenge Award for Health, 2011

Encouraged to ask questions

Marcela Milena Marie Bilek was born in the Czech Republic. She came to Australia with her parents and brother, when she was four years old. Her father was an **engineer** who had travelled the world selling heavy machinery. He often invited Marcela to watch documentaries about science on television with him, and he encouraged Marcela to question what happened around her.

Marcela did well in all her subjects at school, but three teachers she had at secondary school particularly inspired her interest in maths, **chemistry** and especially **physics**. In her Year 12 exams, Marcela's marks were so high she was made 'dux' of the school.

Specialising in physics and computing

Marcela studied science at the University of Sydney from 1986 to 1990, specialising in physics and computing. Afterwards, she worked for Comalco, a company that produces the metal aluminium from bauxite rock. There she developed a 3D computer **model** that allowed users to compare the benefits of different ways of using electricity to extract aluminium. The model was so accurate it made expensive experiments unnecessary. It became useful to the whole aluminium industry, and Marcela was awarded an international prize for it.

> Physics underpins everything in a sense … I view it as the most basic of the sciences.
>
> – Marcela Bilek

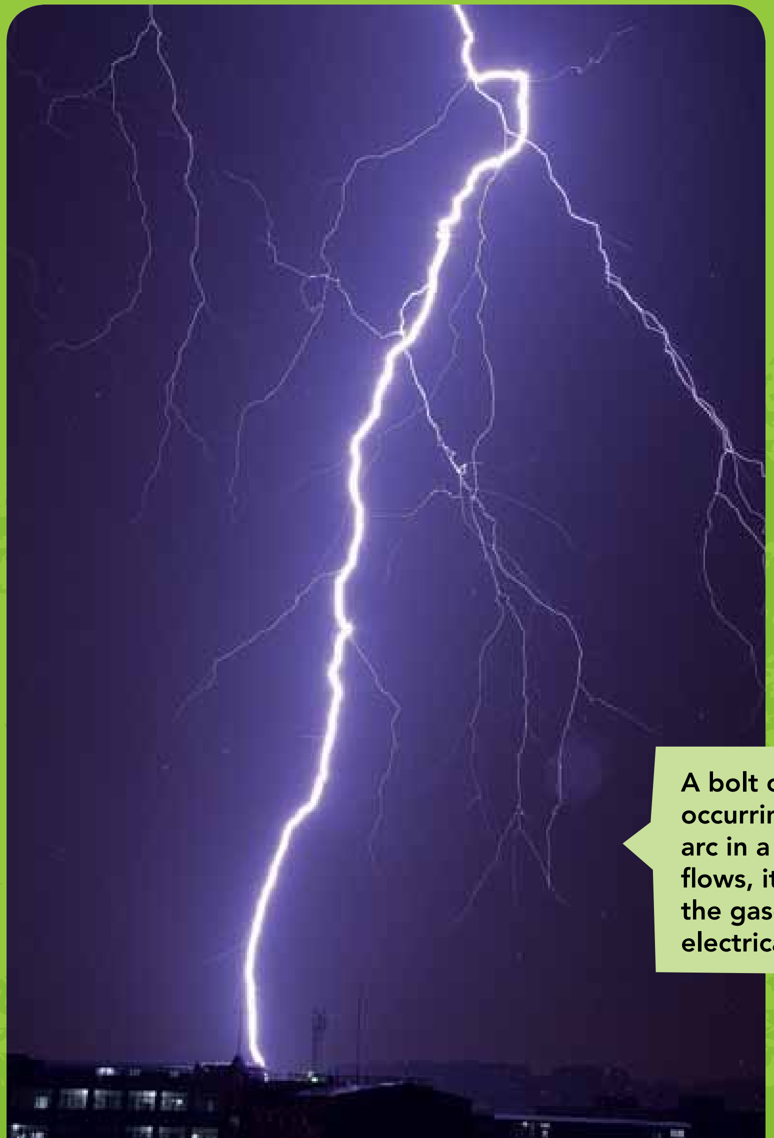
Introduced to the cathodic arc

Marcela moved to the United Kingdom in 1993, to complete her **PhD** at Cambridge University. She wanted to study at Cambridge because of the important discoveries about electricity that had been made there in the past, such as the discovery of **electrons**. In her laboratory, she began experimenting with an electrical instrument called the cathodic arc. Inside the cathodic arc, a powerful flow of electricity, called an electric arc, could turn a lump of solid material, such as a metal, into a type of **vapour**, called plasma.

more about...

PLASMA

Most substances on Earth occur in the forms of solids, liquids or gases. We think of these forms as the three main states of matter. However, in the universe, about 99 per cent of all matter, including our Sun, is in the state of plasma. Plasma is sometimes called the 'fourth state of matter'. It forms when gas is made very hot and **atoms** have their electrons ripped off, becoming electrically charged.



A bolt of lightning is a naturally occurring electric arc, like the electric arc in a cathodic arc. When lightning flows, its intense heat breaks down the gases in air, turning them into electrically charged plasma.

How industry used the cathodic arc

At the time, the cathodic arc was commonly used by different industries to make metal and other coatings, **micrometres** thick, for doorknobs, machine parts, tools, showerheads and jewellery. These coatings would protect an object from wearing away, or from rusting, or give it a more attractive finish.

Marcela realised the cathodic arc could be much more useful to industry if it could also make thinner coatings that were only **nanometres** thick. If these coatings became possible, the cathodic arc might become suitable for making computer parts, for instance, or other small, layered parts inside electronic devices. There would be many possible uses for smooth, nano-sized coatings and layers.

Science jargon

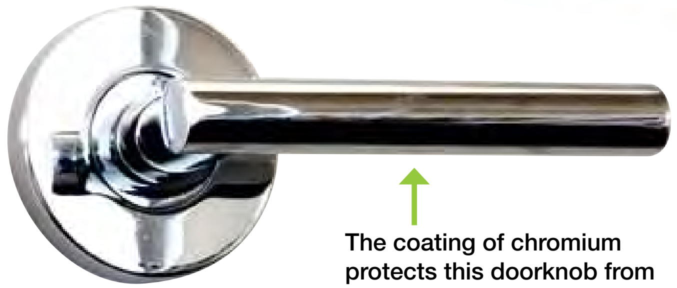
micrometre one thousandth of a millimetre; commonly called a micron

nanometre one millionth of a millimetre

Investigating a problem with the cathodic arc

However, it was not possible to make nano-sized coatings because of a certain problem in the cathodic arc, which Marcela began to investigate. The problem was that when the plasma formed in the cathodic arc, large (micrometre-sized), unwanted droplets would form in it, along with the small electrically charged **atoms** that were wanted to coat the base material. The large, unwanted droplets would form lumps in the coating on the base material. The lumps didn't matter for coatings that were micrometres thick, but they made thinner coatings too uneven.

The hardness of the coating of titanium nitride protects the sharp edges of steel drill bits from wearing away.



The coating of chromium protects this doorknob from scratching.

The coating of zirconium nitride protects the surface of this tap from rusting.

Since Marcela's work, cathodic arcs have many new uses, but they are still widely used to make outer coatings to protect or decorate an object.

The coating of zirconium carbo-nitride makes this watch look like gold but cost less.

the science behind it

THE CATHODIC ARC

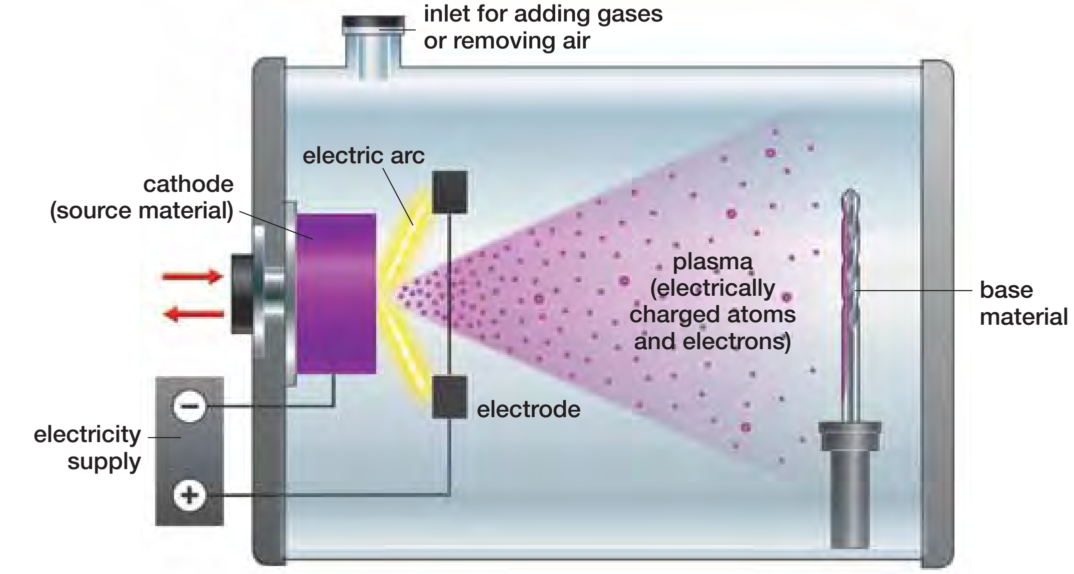
The cathodic arc is an instrument that adds a thin layer of one material (the source material) on top of another (the base material). Inside the cathodic arc, a solid block of the source material works as a type of **electrode** called a cathode. It and another electrode are connected to an electricity supply. After this is switched on, the cathode and other electrode are touched together, and electricity starts to flow through them. The two electrodes are then drawn slowly apart. The flow of electricity fills the gap between them, forming an electric arc.

The arc is like a continuous spark. It produces extreme heat, and raises the temperature at the cathode so it is hot like the Sun. This makes the source material explode out of the cathode, changing from a solid state to a gas. As the gas gets even hotter, the atoms it is made of have their **electrons** ripped off. The atoms are then electrically charged, becoming plasma.

The plasma drifts into a chamber where air is removed and different gases can be added, depending on what type of coating is wanted. When the plasma hits the base material, it cools, and changes state, back into a solid again. It forms a layer, or coating, on the base material.

Did you know?

About 100 trillion atoms would fit on a pinhead, depending on the size of the pinhead and type of atom.



In a cathodic arc, a solid source material is changed into plasma by a strong electrical force. The plasma is used to coat the base material.

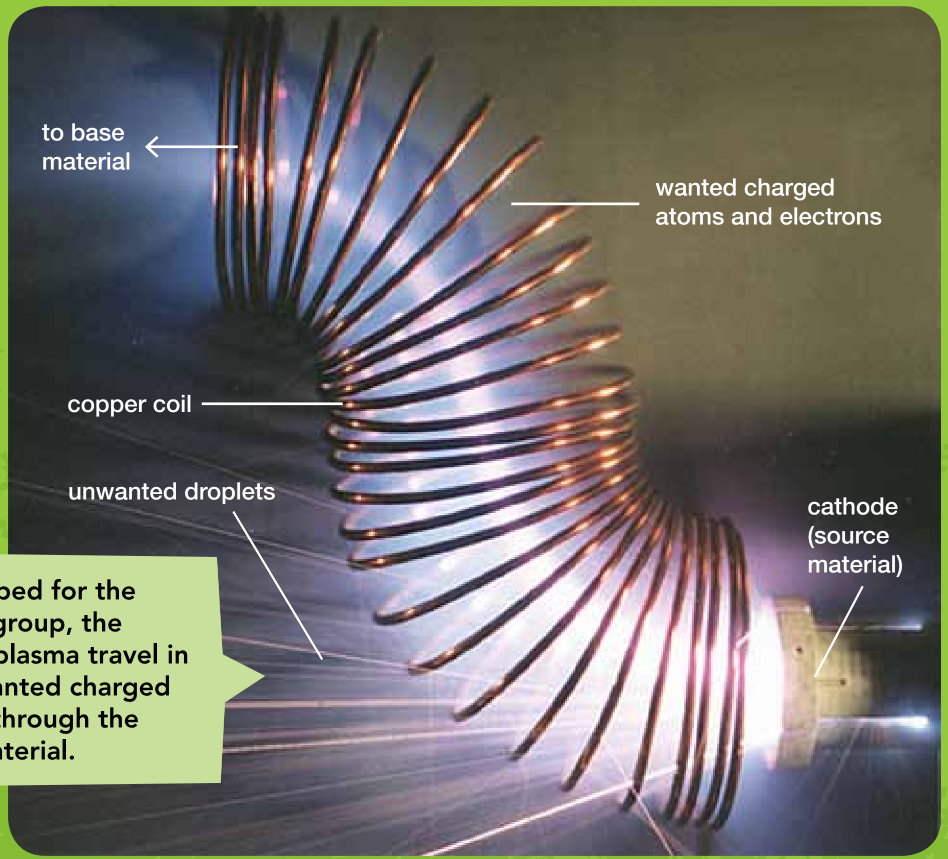
Marcela continues research on the cathodic arc

After completing her **PhD** in 1996, Marcela stayed in Cambridge, working as a scientist at Emmanuel College. She continued her study of the cathodic arc, and started visiting the Lawrence Berkeley National Laboratory in the United States, where other scientists were also working on the cathodic arc. In 1997, Marcela did some important research on the effect of adding extra gases into the cathodic arc to change the types of coatings that were made. However, her main focus was still the problem of the lumpy coatings.

Improving the filtering in the cathodic arc

Marcela was not the first scientist to be interested in solving the problem of the lumpy coatings. Ukrainian scientists in the 1970s had also studied the problem. They had found a basic way to filter out some of the unwanted droplets from the plasma, by using a copper coil inside the cathodic arc to create a **magnetic field**. This guided the wanted charged **atoms** and **electrons** of the plasma in a curved direction, towards the base material, leaving the heavier, unwanted droplets still travelling in straight lines.

Working with Ian Brown and André Anders in the United States, Marcela began improving this filtering process. Her team used computers and other advanced equipment to experiment with the copper coil and measure the effects at the scale of nanometres. By adding extra loops and wires to the coil, the scientists greatly increased the amount of wanted material that landed on the base material. This meant the cathodic arc could produce smoother, thinner coatings.



In the filter system developed for the cathodic arc by Marcela's group, the unwanted droplets in the plasma travel in straight lines, while the wanted charged atoms and electrons flow through the copper coil to the base material.

New uses for the cathodic arc

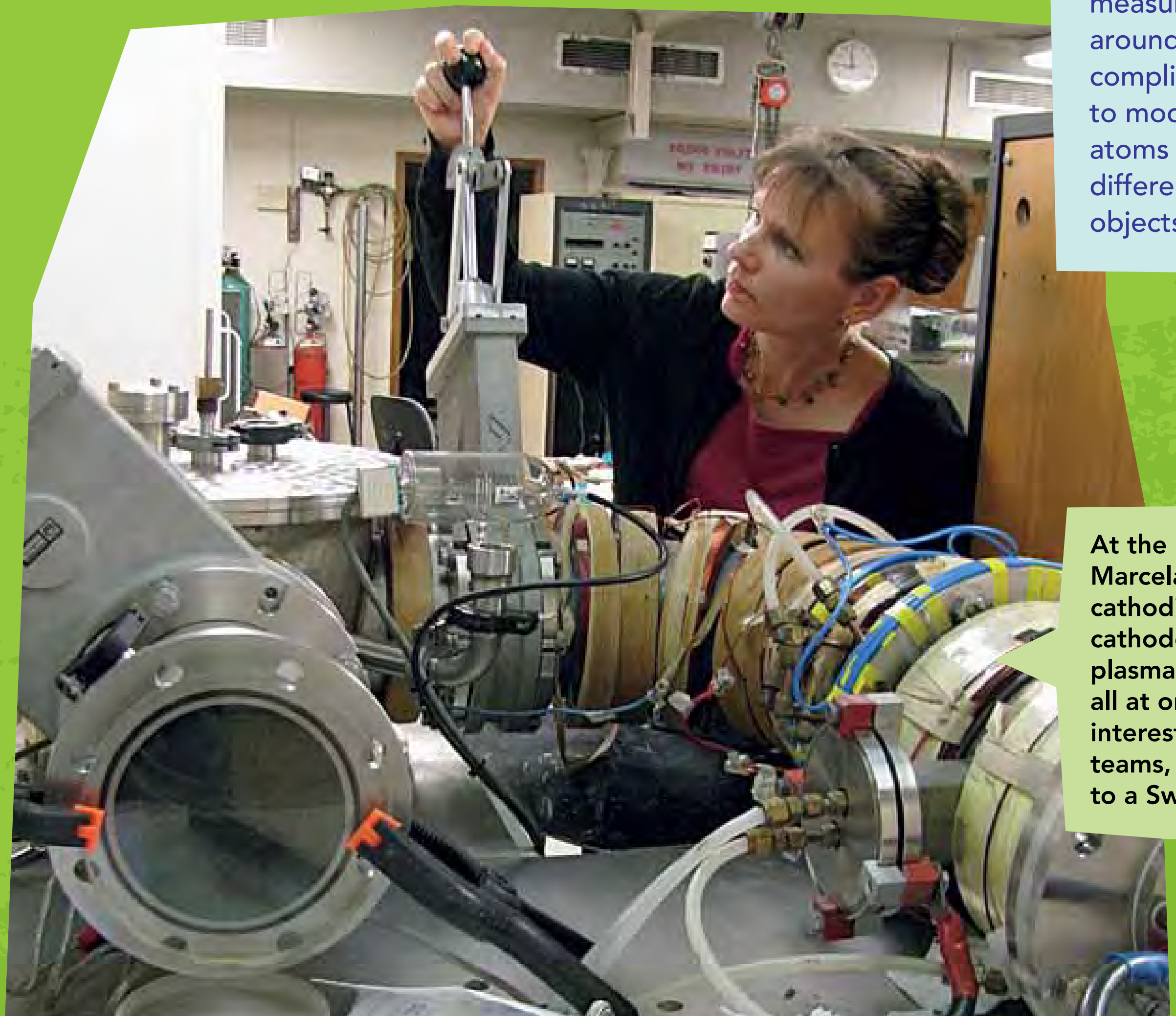
The improved filtering designs developed by Marcela's group made the cathodic arc even more useful to industry. All over the world manufacturers started to use the filtering designs in their cathodic arcs.

Thin films for computer parts

Marcela's work had made the cathodic arc more suitable for making thin fims, or layers only nanometres thick in electronic parts. In the computer parts industry, the cathodic arc became used to make thin films of a substance called carbon to coat **hard disks**. Cathodic arcs were also used to coat read/write heads, which 'read' the signals stored on hard disks and transfer them to the rest of the computer, or 'write' the signals from computer to disk. These developments, along with other scientific advances, contributed to the development of computers with more memory.

A professor at the University of Sydney

Marcela returned to Australia in 2000. She was appointed as the first ever female professor of **physics** at the University of Sydney. There she continued her research into cathodic arcs and other electrical processes that make plasma.



At the University of Sydney, Marcela's team built a special cathodic arc that had three cathodes so it could make plasma from three materials, all at once. It attracted the interest of other research teams, and a copy was sold to a Swedish team in 2008.

more about...

NANOTECHNOLOGY

Altering things on the scale of nanometres is called **nanotechnology**. A nanometre is about ten times as wide as an atom, so at this scale, scientists are working with atoms or layers of atoms. Nanotechnology is becoming more advanced as scientists develop better tools, such as powerful microscopes and computers. The microscopes help scientists observe, measure and move atoms around. The computers do the complicated maths necessary to model and predict how atoms will behave. Atoms obey different laws of physics to the objects we see around us.