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LED lighting

A bright future

Jeremy Walker/SPL

Electric light bulbs have been in use for over a century. They work, but they waste most of the energy they receive. At Cambridge University, Professor Colin Humphreys and his team are working to produce a new type of energy-efficient lighting, based on light-emitting diodes.

GCSE key words
Energy efficiency
Energy transfers
Diodes

Look at the lighting around you — room lights, street lights, car lights. We use a lot of electric light. Much of it comes from tungsten filament lamps, in which a thin filament of tungsten wire heats up when an electric current passes through it. Over 90% of the energy transferred by the current is wasted as heat energy. That's very inefficient. Roughly 20% of the UK's electricity is used for lighting, so we're generating large amounts of carbon dioxide and other polluting gases for little benefit.

Colin Humphreys of the Department of Materials at Cambridge University thinks we can do much better. He's developing a new generation of light-emitting diodes (LEDs) which he thinks will replace filament lamps before too long. And already he has had some success, with traffic lights.

BOX 1 DON'T WE ALREADY HAVE ENERGY-EFFICIENT LIGHTS?

You are probably aware of another type of energy-efficient lamp, the compact fluorescent tube. These save both money and energy over their lifetimes, compared to filament lamps (see Table 1). However, they haven't made a great impact on domestic or commercial users. This may be because of their high initial cost, or because they are bulkier than a filament lamp and take a few minutes to reach full brightness. They have another problem: they contain mercury, which is a hazard when they are disposed of.

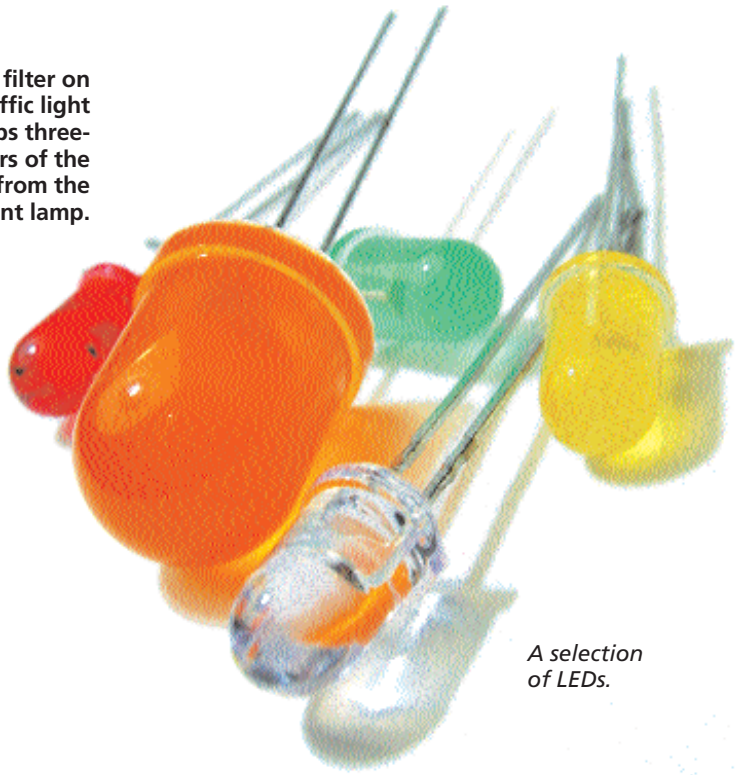
LEDs are those small lamps which glow red to show that your stereo system is switched on, or which flicker when your modem is transferring data to and from the internet. The first LED was invented in 1960, and since then their design has greatly

Use Table 1 to show that a compact lamp saves money in the long run, compared to a filament lamp. Assume that it costs 0.7p to run a 100 W device for 1 hour.

Table 1 *Comparing compact and filament lamps*

	Initial cost (£)	Lifetime (hours)	Power rating (W)
Filament lamp	0.50	1000	100
Compact fluorescent lamp	5.00	10 000	12

The red filter on a red traffic light absorbs three-quarters of the light from the filament lamp.



A selection of LEDs.

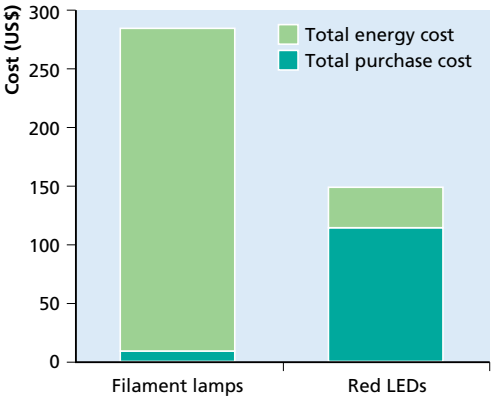


Figure 1 *Comparison of lifecycle costs for red traffic lights.*

● **Read the interview with Professor Humphreys at: http://www.admin.cam.ac.uk/univ/science/working/humphreys.html**

improved. By altering the material from which they are made, it is possible to have yellow, green and blue LEDs.

Modern LEDs are much more energy-efficient than light bulbs. Because a much smaller fraction of the energy supplied to them is lost as heat, they are noticeably cooler than equivalent filament lamps. Red LEDs have a valuable use in the rear lights of bicycles. Their batteries last 20 times longer than those in old-fashioned rear lights.

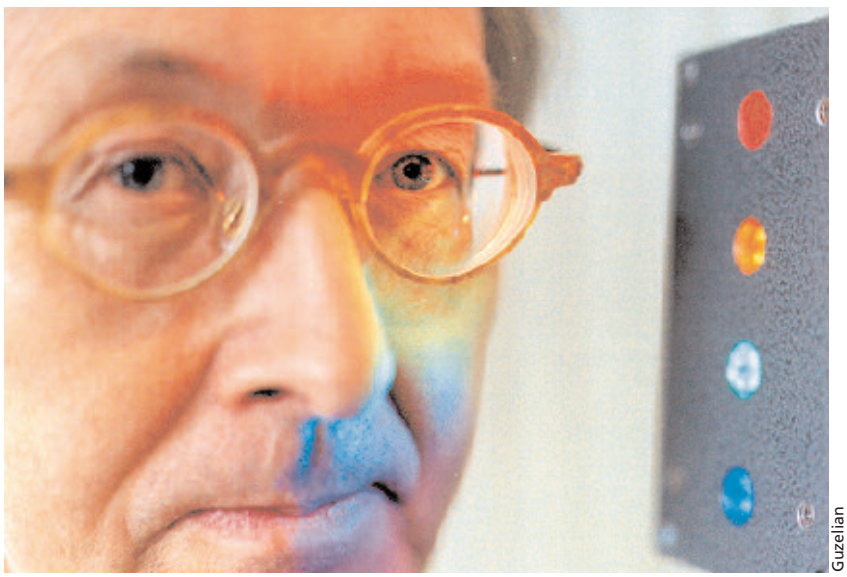
RED, AMBER, GREEN

Most traffic lights use filament lamps. These are replaced every 6 months, before they can fail and cause traffic chaos. LED traffic lights have a lifetime of 10 years or more, representing a saving in maintenance costs. A 12 W LED replaces a 150 W bulb, so there are also great savings in electricity costs (see Figure 1).

The UK's first set of LED traffic lights has been installed in London, near the headquarters of the Department of Transport. The American city of Denver in Colorado is switching entirely to LED traffic lights and its power bill has decreased from $330 000 to $26 000 per year. Even though LEDs have a higher initial capital cost, the reduced electricity costs represent a saving of $5 million over 10 years. The environment will benefit too, with almost 10 000 tonnes less carbon dioxide pumped into the atmosphere. This is equivalent to planting an 800 ha forest, or removing over 1000 cars from the roads.

The UK Department of Transport tells us that this technology is becoming increasingly well-known, and Highways Authorities across the country are installing LED traffic lights wherever possible.

Below: *Professor Humphreys with some different coloured LEDs.*



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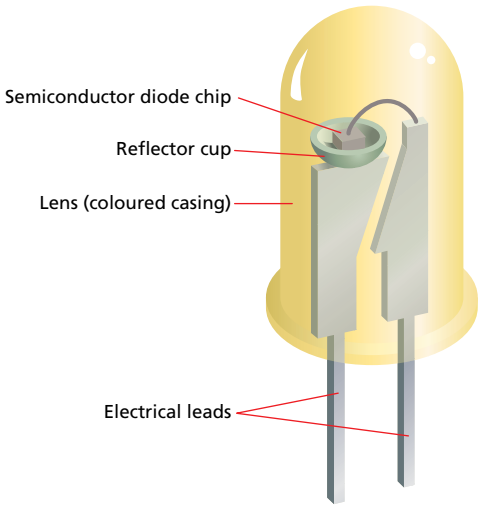

Figure 2 *At the heart of an LED is a tiny sliver of semiconducting material. As a current flows, light emerges, and the reflector and lens are designed to ensure that as much as possible of this light is directed where it is wanted.*

ONE WAY TRAFFIC

All diodes allow electric current to flow in one direction only. An LED is unusual in that it emits light as a current flows through it. You can think of a diode as a waterfall in a circuit. Current flowing over the fall loses energy; current cannot flow up the fall (Figure 3).

In an LED, some of the energy lost is converted to light, represented by the arrows in the circuit symbol. The height of the waterfall determines the colour of the light emitted — the smallest drop gives red, the greatest drop gives blue or ultraviolet.

An LED is a semiconductor device. Semiconductors are materials which allow an electric current to flow, but their resistance is much greater than that of metals. Silicon, the basis of many computer chips, is an example of a semiconductor.

Professor Humphreys and his team are working with a different material, gallium nitride (GaN). He describes it as 'probably the most important semiconductor material since silicon', and it will find many new applications, such as in transistors which can operate at high temperatures.

The problem with GaN is that, during its manufacture, large numbers of defects appear in its crystal structure. These limit the mobility of electrons — a major problem which must be overcome if it is to achieve its potential.

LET THERE BE WHITE LIGHT

To replace filament lamps, we need white LEDs, and these are tricky to produce. One solution might be a combination of red, green and blue (as in a television screen), but this has proved difficult. The combined colour tends to alter as the LEDs age.

Colin Humphreys' approach is different. He hopes to make an LED which emits ultraviolet light. It will be coated in a phosphor, a substance which absorbs the ultraviolet light and re-emits it as visible light.

He is also working on a violet LED which will be used in detecting cancerous tumours at an early stage of their development. This, and the environmental aspect of his work on LEDs, gives him great satisfaction. He says, 'This is very motivating and I really think our research can save many lives.'

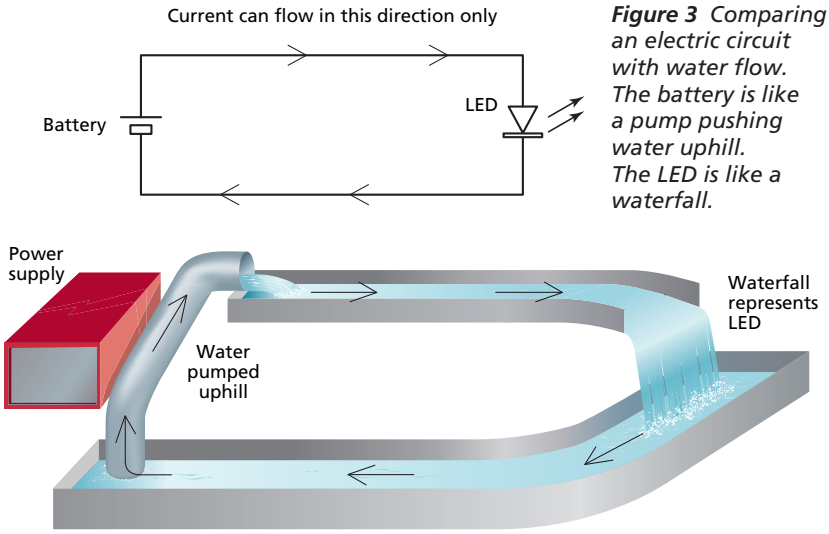

Figure 3 *Comparing an electric circuit with water flow. The battery is like a pump pushing water uphill. The LED is like a waterfall.*

David Sang writes textbooks and is an editor of CATALYST.

BOX 2 SAVING LIVES ON THE ROAD

LED brake lights come on almost instantaneously — within a millionth of a second of the driver pressing the brakes. Conventional filament lamps, as fitted in most cars, take 0.25 s to warm up enough to glow. In that time, a car moving at 70 mph will travel 8 m, the length of two small cars.

So the new LED brake lights give following drivers extra warning in case of a sudden halt, and in that way can save lives.

Element wordsearch

There are names of 48 different elements here — can you find them all? Words can run in any direction.

Answers on page 15.

A	F	E	R	M	I	U	M	E	S	E	N	A	G	N	A	M
M	M	U	O	N	E	N	I	R	O	L	H	C	O	P	U	M
O	A	U	N	Z	C	A	R	B	O	N	N	A	T	I	U	E
L	R	I	I	I	R	A	C	I	X	E	N	O	N	I	R	N
Y	E	T	C	N	E	O	N	U	E	O	T	I	S	Z	A	D
B	I	A	A	C	I	A	F	M	A	M	M	E	M	L	N	E
D	M	M	D	L	O	T	E	R	N	U	N	U	I	V	I	L
E	U	U	M	E	D	S	C	E	L	G	I	T	O	A	U	E
N	N	I	I	K	L	I	T	A	A	M	H	P	D	N	M	V
U	A	B	U	C	O	S	H	M	L	I	A	N	I	A	R	I
M	H	R	M	I	G	P	E	O	U	C	M	W	N	D	E	U
A	T	E	E	N	L	R	H	M	X	L	I	U	E	I	V	M
M	N	T	U	U	I	C	E	E	U	Y	T	U	I	U	L	U
U	A	T	S	C	I	N	M	R	L	I	G	I	M	M	I	I
L	L	Y	I	N	I	U	T	C	H	I	N	E	N	S	S	D
A	P	U	E	M	I	N	I	U	R	A	D	O	N	S	N	O
T	M	S	O	N	O	B	O	R	O	N	V	E	C	R	O	H
N	R	R	F	G	Y	N	E	Y	M	U	I	D	A	R	R	R
A	B	A	R	X	C	I	Y	T	T	R	I	U	M	T	I	A
T	H	A	L	L	I	U	M	U	I	D	A	L	L	A	P	Z