LIGHT

British Science Week Seminar on Thursday 19th March

Professor Sir Colin Humphreys
Department of Materials Science and Metallurgy
University of Cambridge

Gallium nitride for saving lives, energy, carbon emissions and money!

SUMMARY

Gallium nitride and its alloys make up an amazing family of new materials which could save 25% of all the electricity we use and 25% of carbon emissions from power stations. This is not scientific hype: it is already starting to happen. Gallium nitride also has the potential to provide clean water, saving millions of lives in the developing world, and to enable totally secure communications. In addition, optimized gallium nitride Light Emitting Diodes (LEDs) will increase productivity at work and performance in schools, and improve the health of us all. Finally, our gallium nitride research is already being exploited in the UK where Plessey is manufacturing LEDs and creating jobs in Plymouth, an unemployment black spot. The UK is at the forefront of this outstanding developing technology.

WHAT IS GALLIUM NITRIDE?

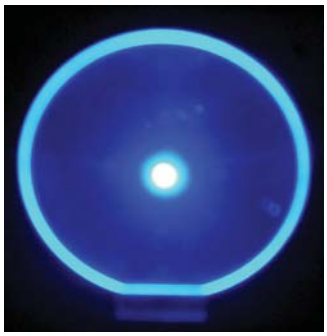
Gallium nitride and its alloys can emit light over a wide range of colours – from the infra-red (IR) to the ultra-violet (UV), including all the colours of visible light. Already these materials are widely used in LEDs that are part of our everyday lives: from blu-ray DVD players through to bicycle lights, from replacement LED light bulbs to back-lighting of our computer and TV screens. Cambridge and Manchester have been collaborating on gallium nitride research for over ten years. Our research has led to lower-cost LEDs that are now being manufactured in the UK. Plessey sold 2 million LEDs based on our research in 2014 and plans to sell many more in 2015.

ENERGY SAVINGS FROM GALLIUM NITRIDE LEDS

The Department of Energy (DoE) in the US has stated that by 2025 gallium nitride LEDs could reduce the global amount of electricity used for lighting by 50%. In the UK, lighting uses about one-fifth of all electricity. LEDs are poised to reduce this figure by 50%. Lighting will then

use 10% of all electricity, thus saving 10% of electricity. This amounts to an annual saving of over £2 billion per year in electricity costs. If this electricity comes from fossil-fueled power stations, as most does, LED lighting will save 10% of carbon emissions from these.

Commercially available replacement LED light bulbs are already six times more efficient than incandescent light bulbs and 50% more efficient than so-called low-energy compact fluorescent lamps (CFLs). In the laboratory there are LEDs which are even more efficient, and these will become commercially



available in the next few years. If we replaced all our lighting in the UK with LEDs we could close (or not build) eight large (1 GW) power stations.

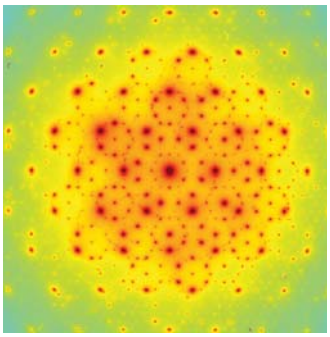
WHAT IS PREVENTING THE WIDESPREAD USE OF LED LIGHTING IN OUR HOMES AND OFFICES?

The main problem is cost. Low-power LEDs, for example used in toys, are very cheap; but high-power LEDs for lighting a room are expensive. I recently paid £15 for a replacement 60W equivalent LED light bulb. Not many people will pay this, even though the LED bulb rapidly repays for its cost in lower electricity bills. All commercial gallium nitride LEDs are grown on sapphire or silicon carbide wafers, both very expensive. My research group

has pioneered the growth of gallium nitride LEDs on silicon wafers, which are much cheaper. We patented our technology and set up two companies in 2010 and 2011 to exploit it. The UK company Plessey acquired both companies in 2012, hired post-docs from my research group to transfer the technology and are now manufacturing low-cost gallium nitride LEDs on silicon at their factory in Plymouth, Devon. This is the first manufacture of LEDs in the UK and the first commercially available LEDs on silicon in the world. Plessey are selling the LED chips to other companies to put into lightbulbs and other products. So this will enable cost reductions in LED lighting and accelerate its widespread adoption, thus saving the UK over £2 billion per year in electricity costs.

THE IMPORTANCE OF PEAK ELECTRICITY

Peak UK electricity demand in 2014 was on 3 January at 6pm. In general, electricity demand is highest on winter evenings. The



... close eight large (1 GW) power stations ...

electricity supply must match this peak demand or else the lights go out (and governments risk not being re-elected!).

There is often high pressure weather in winter, which results in weak winds, and so wind turbines often make a tiny supply to peak demand. By definition, solar power makes zero contribution to peak energy demand, because the sun is not shining on a winter's evening. So wind and solar energy cannot be relied upon to contribute to our peak electricity demands. On the other hand, LED lighting makes a major contribution to reducing peak electricity demand on winter evenings, when lights are switched on, so it is a much more effective way of making this peak demand than wind and solar power.

A COMPARISON OF LEDS, WIND AND SOLAR

The US Department of Energy has recently made an interesting forecast comparing electricity savings from LEDs, wind and solar. The DoE predicts that if LED costs continue to come down and the efficiency continues to increase, LEDs will have 90% of the US lighting market by 2030. LEDs will then save twice the electricity generated by wind and twenty times the electricity generated by solar. The annual US electricity savings due to LEDs in 2030 is estimated to be $40 billion. And there are no subsidies for LEDs.

TUNABLE WHITE LEDS

Nearly all the LED replacement light bulbs sold today are gallium nitride blue LEDs coated with phosphor materials, the combination producing white light. If we could eliminate the phosphors and produce white light by mixing blue, green and red LEDs within a single light bulb we would save another 5% of electricity, so that LEDs would save a total of 15% of all electricity, equivalent to saving the UK over £3 billion per year. We would also have colour tunable white lighting, so that you could choose to have reddish white light for a romantic dinner, for example. More of this later!

ENERGY SAVINGS FROM GALLIUM NITRIDE POWER ELECTRONICS

Gallium nitride not only has a low electricity consumption for lighting, it also has for electronics. Power electronic devices are very widely used, for example in chargers for mobile phones and laptops, in electric cars and in IT server farms. All these power electronic devices are made from silicon. However, gallium nitride power electronic devices are 40% more efficient than those made from silicon. If we replaced the silicon devices by gallium nitride ones we would save 10% of all the electricity we use.

... save up to 25% of carbon emissions from power stations ...

ENERGY SAVINGS FROM GALLIUM NITRIDE

Gallium nitride devices can save us 10% of electricity using existing LEDs. If we eliminate

the phosphors we can save a further 5% of electricity. If we replace silicon power electronic devices with gallium nitride ones we could save another 10%. So an astonishing 25% of the total electricity we consume can potentially be saved using gallium nitride devices. In addition, we could save up to 25% of carbon emissions from power stations. Unlike solar and wind power, these savings will be made at times of peak electricity demand.

LIGHT AND OUR HEALTH

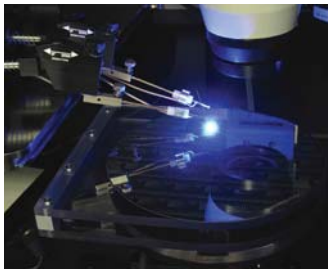
Life has developed over millions of years in natural lighting: sunlight. There is increasing evidence that sunlight is good for our health (if over-exposure is avoided). For example 90% of the vitamin D in our bodies comes from sunlight on our skin and only 10% comes from food. Two-thirds of the UK are "severely lacking" in vitamin D, leading to a weak immune system (enabling colds, coughs and worse), fatigue, broken bones, headaches, etc. Vitamin D is also believed to protect against certain cancers (eg breast, prostate) by preventing the overproduction of cells. With tunable LED lighting we will be able to mimic sunlight indoors and hence produce vitamin D indoors. We will also be able to minimize or eliminate Seasonal Affective Disorder (SAD), which affects over 3 million people in the UK.

IMPROVING PRODUCTIVITY AT WORK AND IN SCHOOLS

There is clear evidence that good quality lighting reduces absences due to illness from schools and improves exam performance. It also increases productivity at work. Optimised LED lighting in schools and workplaces should be a government priority to improve productivity and performance.

WATER PURIFICATION

The earth's atmosphere prevents deep ultra-violet radiation from reaching us, so life on earth has developed in the absence of deep-UV light, and it has no defence against it. Deep-UV light damages the nucleic acid in both DNA and



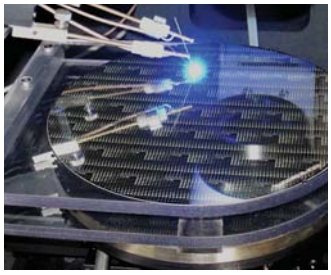
RNA and stops all bacteria and viruses from reproducing: effectively killing them. By adding aluminium to gallium nitride we can produce LEDs emitting deep-UV light. At present the intensity of the light is not sufficient to purify flowing water, so more research is needed. However, there is the clear potential to save literally millions of lives in the developing world by using this gallium nitride technology, which

... Optimised LED lighting in schools ...

could be powered by solar cells. It would also be more efficient than chlorination in the developed world.

SECURE COMMUNICATIONS AND LIFI

We are researching gallium nitride single photon sources to create pairs of entangled photons for totally secure communications. For example, mobile phone conversations could then be totally secure. In addition, in about five years time WiFi radio frequency bands will become saturated. We are



researching transmitting the same information using light from LEDs, thus overcoming the potential WiFi crisis.

CONCLUSIONS

Gallium nitride is a key material for saving 25% of electricity and carbon emissions. It can also save millions of lives, provide secure communications and augment WiFi. It can improve productivity at work and in schools. It can help UK

... stops all bacteria and viruses from reproducing ...

manufacturing and job creation. Optimised LED lighting can improve the health of us all. The UK is at the forefront of this amazing new material.

NANOTECHNOLOGY

Meeting of the Parliamentary and Scientific Committee on Tuesday 14th July

NANOTECHNOLOGY – what is it and what is it for?

Professor Andrew Fisher
University College London

Professor Milo Shaffer
Imperial College London

Co-Directors, London Centre for Nanotechnology

Nanotechnology is driven by a collision of science and techniques drawn from different disciplines, which has uncovered new fundamental behaviours of matter and new opportunities for practical applications. Modern semiconductor integrated circuits are carved, "top-down", at increasingly short length scales, underpinning the continuous improvement in electronics over recent decades ('Moore's law'). At the same time, chemists have learnt how to build increasingly large, well-defined structures from "the bottom up". These worlds intersect at the nanoscale, where dimensions are measured in nanometres (billionths of a metre); it is the same lengthscale on which much of the complex machinery of living systems operates. Within this range, the physical laws governing the behaviour of matter begin to switch from classical to quantum mechanical, and become subtly dependent on size. The concepts, knowledge, and tools from different disciplines, including electronic engineering, materials science, chemistry, physics, biochemistry, and medicine are being exchanged and developed, creating new opportunities in which science and technology are synergistic: new science leads to new technologies, which in turn enable further scientific developments.

THE LONDON CENTRE FOR NANOTECHNOLOGY

Almost ten years ago UCL and Imperial College London decided to create a joint London Centre for Nanotechnology (LCN) using funding from the HEFCE Science Research Infrastructure Fund, recognizing the very widespread importance that now attaches to the ability to control matter in the nanometre range. The LCN concept involves making available to the widest possible range of researchers a full set of tools for making and characterizing nanostructures, enabling them to carry out leading fundamental research and to target applications in