The sky's the limit for solar power

Solar power has the potential to meet humanity's energy needs many times over. To make full use of this resource requires solar cells that are highly efficient yet cheap to make and install. We talked to Ravi Silva, director of the Advanced Technology Institute at the University of Surrey, UK, to find out why we cannot rely simply on the cost of silicon continuing to fall. Read the interview after the introduction below.

Ravi Silva

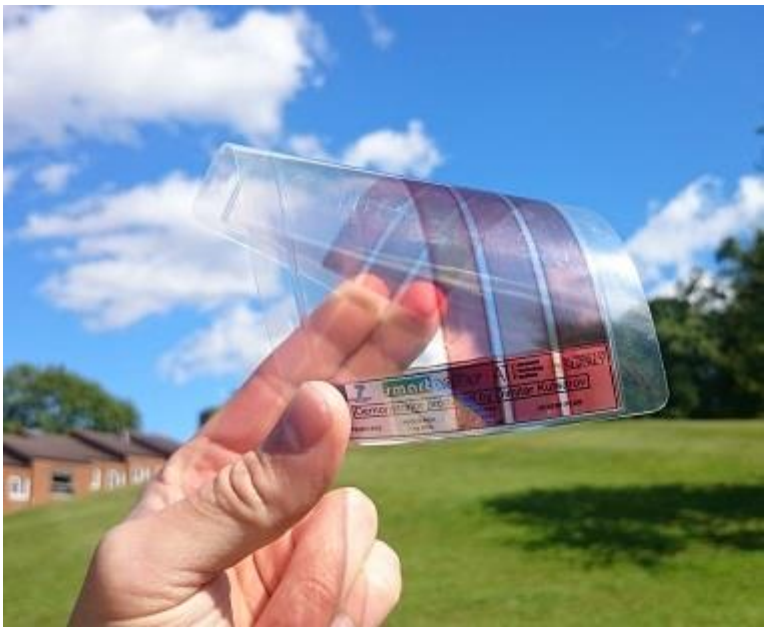
Solar photovoltaic (PV) systems contribute increasingly to global energy production, with generating capacity dominated by panels made from wafers of crystalline silicon. Refinements to this approach have yielded solar cells that are highly efficient, and decreasing costs have allowed their widespread adoption even at the relatively high latitudes of northern Europe.

But there are drawbacks to this first-generation technology that limit the size of the solar economy. The thickness and complex fabrication processes associated with silicon-wafer solar cells mean that material, production and installation costs are still too high for them to displace fossil fuels.

Second-generation solar cells, in which crystalline wafers are replaced by thin films of silicon or other semiconductors, have led to cheaper PV systems, but this has been at the cost of energy conversion efficiency. A third generation of devices employs organic materials and nanostructures to improve performance, but has still failed to match the reliability and cost per Watt of first-generation cells.

Silva hopes that a fourth generation of solar cells will achieve the balance of efficiency and cost needed to incite a solar-power revolution. His approach synthesizes all that researchers have learned from previous iterations, resulting in composite cells that combine the efficiency benefits of inorganic nanostructures with the convenience and low cost of solution-processable organic polymers.

We caught up with Silva at the 2nd International Conference on Advanced Energy Materials at the University of Surrey, and asked him about his work and the factors that motivate it.



This changes everything

What are the reasons for the decreasing cost of solar power?
Solar-cell prices have followed a Moore's law-like trend seen in electronic circuits, with module prices halving every year or so in the last few years. Although the cost of solar power will achieve grid parity within the next decade, a step change will be needed for national agendas to be impacted. The primary driver behind the trend has been the decreasing cost of the silicon feedstock. However, PV applications compete for high-quality silicon with the integrated circuit industry, and this competition keeps prices higher than they otherwise might be.

In the most recent energy auctions in India, large solar farms above 50 MW offered solar energy at about 2.5 rupees per kWh, which is competitive with that provided by fossil fuels. But you have to remember that to make use of solar energy you need a very stable grid, and at the moment the grid might not be able to take a large intermittent source like solar or wind. This is a problem for all grids, and more so in developing countries.

This means that for now we still need fossil fuels or nuclear to provide baseload power. It's interesting to realise that the current cost of solar is about a quarter of the price that the UK government has committed to the nuclear industry for the next 35 years. One might justify this by saying that it's to ensure that baseload is available beyond 2030, but with the decreasing cost of energy storage, there is a question about whether customers are getting value for money. I think there is a very good chance that we will soon have the batteries necessary to tolerate the intermittency of wind and solar power without the need for fossil fuel or nuclear baseload provision.

Bear in mind that the Earth receives solar energy at a rate of about 165,000 TW daily and humanity uses 10–15 TW daily, so there is a greater than 10,000-fold oversupply of solar power: the Earth receives enough energy in an hour to power civilization for a year. Putting aside enough space for solar farms on rooftops and in extra-urban environments should allow us to meet our needs with solar power, but although space is not really an issue, it is still desirable to increase the efficiency of solar cells.

Is it the aim of your research to increase this efficiency?
Only partially, and the reason I say that is because the main goal is to get more value for money, more Watts per dollar. Although silicon power is cheap, it’s not yet cheap enough to entice everybody to adopt the technology. We hope that the new technologies that we are investigating represent the step change that I mentioned as being necessary before widespread adoption of solar PV.

If you think of a typical solar energy system, you first have to consider the module cost, which is the cost of the panel itself. On top of that there’s the balance of system cost, which comprises the inverters, the installation, etc. If the total cost is a dollar, 50 cents will go to the module cost and 50 cents to the balance of system cost. Of the module cost, roughly a third goes into processing the wafers, a third into making the electrodes and back planes, etc, and only a third goes into the feedstock costs. That’s why, even though the cost of silicon might come down further, it’s still just a marginal, albeit important, activity. What we are trying to do is to reduce the cost of the material not just a hundredfold, but a thousandfold. And we can reduce the balance of system costs, too, based on the systems we are proposing. Instead of a system producing energy at 20 cents per Watt, say, we are trying to reduce it to 2 cents, so that there can be no financial basis for sticking with the current fossil fuels.

How will your research help to achieve this?
The key principle is the fact that solution-processed materials can have thicknesses a thousandth of that of a typical solar cell – more like paint that can be put on a building. If your processing needs are only a spray-gun instead of vacuum coaters and other high-tech systems, and if all you need to size your modules to fit

is a pair of scissors, then you start affecting not just the feedstock costs but the production of the modules, the balance of systems and all of that. It allows a payback time as low as 6 months rather than the 20 years for current silicon-based PV.

How close are you to this goal?
At present, we have prototype systems that work, but to be useful they must have suitable lifetimes and be scaled up economically. In terms of scale-up, we have EU funding for about €12 million through two programmes: SMARTONICS and CORNET, which will allow us to create an open innovation forum for organic electronics. Within that process we aim to bring in major companies and universities to work on a single open innovation platform. Led by the Aristotle University of Thessaloniki, Greece, CORNET initially includes the University of Surrey and National Physical Laboratory in the UK, the University of Ioannina and the Hellenic Organic & Printed Electronics Association in Greece, the Centre National de la Recherche Scientifique (CNRS) in France, and various SMEs and end users of organic PV
including Fluxim (Switzerland), AIXTRON (Germany), OET (Greece), Granta Design (UK) and Centro Ricerche Fiat (Italy).

If the capital can be repaid in as little as six months, then presumably the durability of the devices does not need to be anything like that of current silicon systems.
That is exactly one of the key selling points associated with the technology. In my view, you could potentially be able to replace your solar cells within two to four years, and if you have made back your costs within the first six months, then anything beyond that is just a bonus. And if installation is as simple as taking a sheet and just covering your rooftop with it, so much the better.

In order to bring these innovations to market, we are working with companies such as Tata Steel, who are closely involved in assessing the potential of the technology. Chris Mills, one of our researchers at the Advanced Technology Institute, is employed by Tata Steel UK, and has an interest in developing steel products with added value. One way to achieve this is to integrate steel surfaces with systems such as solar cells. Large-area solar panels in external steel facades are an obvious application, but any powered steel or steel-faced product – like vehicle panelling or white goods, for example – could benefit.
Presently the biggest problem we have is that steel facias and roofs are bespoke, and solar cells have to be installed separately on top. If they can both be incorporated into a single unit, installation is much more economical. Typically,

when installing solar energy systems, if you can integrate the solar cells into the structural materials, you can drop your overall system costs by 30–40% in building-integrated photovoltaics (BIPV).

Where do you expect the field to be in five years' time?
I hope that five years from now a number of companies will have adopted this technology. Already in Europe some companies are entering the field – particularly in Germany, where they are taking a lead in promoting organic solar cells. I hope that in the UK, too, we will see solar-cell manufacturers using organic materials.

Do you think that a single technology will come to dominate as crystalline silicon cells do now?
It will be horses for courses. There is always the risk that you back one horse and then you find that other technologies are better for certain applications. The classic example today is gallium arsenide. When you use solar cells in space, you use gallium arsenide because it is the most efficient type available for a given mass. But a single such chip with concentrators could be as much as a few thousand dollars as opposed to the dollar that we are trying to reach for terrestrial PV.

We are also looking at solution-processed indoor solar PV. Actually, although we call it solar, that's not quite right, because it does not rely on sunlight. There is no name given to indoor PV applications, so we tend to talk about solar cells that work in low-light conditions like inside buildings. In the future, devices should be powered by the energy scavenged from the environment. This does not necessarily need to be at visible wavelengths, but could be infrared energy. There is a lot of energy in the electromagnetic spectrum that is not being used at present simply because we have not chosen to harness it. Therefore you can see in the case of solar PV that the sky is the limit: energy is everywhere, we just need to find efficient means of harnessing it.

About the author
Marric Stephens is editor of *nanotechweb.org*

Further reading
K D G I Jayawardena *et al* 2013 'Inorganics-in-Organics': recent developments and outlook for 4G polymer solar cells *Nanoscale* **5** 8411-27 DOI: 10.1039/C3NR02733C