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‘Near-pefect’ solar absorber highlights bright outlook for UAE’s sun-powered future

A team of researchers led by a Masdar Institute professor have developed a solar absorber that has tiny nanoparticles of silver embedded in silicon dioxide, making it capable of absorbing nearly all light in the ultraviolet to visible range.

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One thing the UAE definitely does not lack is sunshine.

During even the least sunny month, January, there is an average of 8.1 hours of sunshine per day in Dubai, while the blazing heat of June sees an extraordinary 11.5 hours per day.

As a result, the country is one of the best places in the world for solar power plants, and authorities have capitalised on this by making huge investments.

It is four years since the Shams 1 concentrating solar power plant near Madinat Zayed, in Al Gharbia, became operational in a large-scale demonstration of the commitment of Abu Dhabi emirate to renewable energy.

Similarly, the Mohammed bin Rashid Al Maktoum Solar Park in Dubai started producing power in 2013, and by 2030 it is set to have a mammoth 5,000MW generating capacity.

As well as investing billions of dirhams in power plants, the UAE is also positioning itself at the cutting edge of the technology that underpins solar power.

Nothing illustrates this better than a recent project led by Professor TieJun Zhang, from the Department of Mechanical and Materials Engineering at the Masdar Institute, a part of Khalifa University of Science and Technology in Abu Dhabi.

He and his co-researchers have designed, fabricated and characterised an ultrathin nanocomposite solar absorber that has tiny nanoparticles of silver embedded in silicon dioxide, sitting on top of other layers.

What is especially notable is that, despite being very thin, the nanocomposite material can absorb nearly all light in the ultraviolet to visible range.

As the researchers themselves describe it in a scientific paper, recently published in the journal Advanced Optical Materials, the absorber is “near-perfect”.

“Almost all the sunlight will be absorbed by this device, so we can maximise the solar thermal energy conversion through this design,” said Dr Zhang, who co-authored the paper with four other Masdar Institute researchers and two professors from the Massachusetts Institute of Technology.

“It’s different from a classical thick coating. We fabricated an ultrathin nanocomposite film that is a high-performance solar absorber but that requires less material.”

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Using smaller quantities of material leads to significant cost savings, especially when scaled up in an industrial setting.

It is the particular nanocomposite structure on the top of the absorber that gives it such an extraordinary ability to absorb sunlight.

The absorber was characterised in detail by the researchers using equipment such as transmission and scanning electron microscopes and atomic force microscopes. These high-tech devices offer much more detailed information than optical (light-based) microscopes are able to.

The absorber has a substrate, or base layer, on top of which sits a 100 nanometres (0.1μm) layer of silver. Then comes a 20nm layer of silicon dioxide and, above this, a 30nm layer of the nanocomposite in which nanoparticles of silver are embedded in the silicon dioxide. On top of this layer sit larger silver nanoparticles - they can be about 40nm in height - that form of their own accord after the fabrication of the nanocomposite film using a process of “co-sputtering”, which involves simultaneously evaporating, or sputtering, two substances - in this case silicon dioxide and silver - onto the absorber’s surface.

When tested, the performance of the absorber was found to be better than forecast by theoretical predictions: an unusual, but very welcome, situation.

“We’re looking at maybe some mechanisms we didn’t understand before. We’re looking into the mechanisms, at what’s enhancing the light absorbing,” said Dr Zhang.

Through systematic characterisation and modelling of the absorber, the researchers have been able to reveal the mechanisms behind its superior ability to absorb sunlight.

The nanocomposite film allows for a process called impedance matching, which is similar to a concept involved in electrical power transmission, to reduce reflection from the multi-layered structure. Also, the larger silver particles on the uppermost layer act as “antennae” to concentrate and guide light into the absorber, further boosting light absorption over the solar irradiance spectrum.

Many other researchers around the world are looking at ways to make photovoltaic cells more efficient. For example, as reported in The National in 2014, a British company called Oxford Photovoltaics found that adding a layer made from calcium titanium oxide minerals called perovskites significantly improved performance.

Dr Zhang’s research was funded through a collaboration between the Masdar Institute and MIT, and received additional support from the UAE National Research Foundation. A key aim of the funds from this last organisation is to help develop advanced technologies that can be used by industry.

This aim - of seeing the UAE push forward the boundaries of solar technology, as well as using it in its vast power plants - is one shared by Dr Zhang.

“Through this project we develop our own research and development capability and also foster human capital development in this region. This is a big breakthrough,” he said.

“I think it’s very, very critical for the UAE because we’re driving the knowledge-based industry … We’re moving forward to more advanced technology, so hopefully we can contribute to the next-generation solar technology.”

This has been possible, Dr Zhang said, because of investments made in the research infrastructure in the UAE over the past decade. He has a laboratory of his own at the Masdar Institute and also used the institute’s core lab facilities to complete the work detailed in the recent paper.

The paper’s other authors are Masdar Institute postdoctoral researchers Dr Jin-You Lu and Dr Aikifa Raza, Emirati MSc students Sumaya Noorulla and Afra Alketbi, and two MIT scientists, Professor Nicholas Fang and Professor Gang Chen.

After completing this project, Dr Zhang and his research group are continuing to work on solar power absorbers. In particular, they are researching materials that can absorb sunlight at extremely high temperatures of about 700 Celsius.

So in the years to come we can expect the UAE - as well as remaining a key centre for solar power generation - to come up with further technological innovations for the sector.

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