Serendipitous observation may lead to more efficient solar cells and new gas sensors

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While investigating perovskite crystals, University of Groningen scientists made an observation that could make perovskite solar cells more efficient. It could also lead to new sensors for oxygen and water vapor. The results were published online by the journal *Science Advances* on 27 July.

Photovoltaic cells based on hybrid perovskites were first introduced in

2009, and they rapidly became as efficient as standard silicon solar cells. They now convert light into electricity at about 22 percent efficiency. 'And the theoretical limit is about 33 percent', says Maria Antonietta Loi, Professor of Photophysics and Optoelectronics at the University of Groningen.

However, part of the electric charge disappears into what are known as traps. This happens in both silicon and perovskite, and reduces the efficiency of photovoltaic cells. So it would be nice to know more about traps and how to avoid them. A serendipitous observation by University of Groningen scientists provided new insight into hybrid perovskite traps.

Charge eaters

While investigating perovskite crystals, postdoc Hong-Hua Fang placed a crystal in a vacuum chamber. 'The reason was to cool it down', Fang explains. While he pumped out the air, he left on a laser that excites the crystal. This laser light produces electronic charges in the crystal, which emit light when they recombine. In this instance the crystal should have emitted green light, but surprisingly, when the air was removed from around it, the green light disappeared too. Fang: 'But when we let the air in again, the light emission was restored.' So apparently, without air, most charges disappear into the traps.

Atmospheric gases somehow blocked the activity of the 'charge eaters' in the crystals, so Fang set out to investigate. He exposed crystals to different types of gas and discovered that oxygen and water vapor deactivated the traps, while gases such as nitrogen, carbon dioxide or argon had no effect. The next step was to localize the traps, which he did by using two different laser lights to excite either the surface or the interior of the crystals. He discovered that the traps were mainly on the surface.

Sensor

'We assume that there are positively charged groups of traps on the surface because of the crystal structure of the hybrid perovskites', explains Loi. The next step is to find a way to eliminate them. Water vapor or oxygen work well, but in the long run they can damage the material, so they are not an option. Fang is busy testing alternatives. If he succeeds, he will further enhance the efficiency of perovskite solar cells. 'The number of traps in the material that we used for these experiments was relatively low, but we estimate that by eliminating them, we could go from an efficiency of 22 percent to one equaling or surpassing that of crystalline silicon, which is 25 percent.'

There is another possible application for the findings. Loi: 'As the effect of oxygen and water vapor on perovskite is reversible, it would make a nice sensor.' Perovskite crystals inside sealed food packaging could detect the presence of harmful oxygen. 'Just shine a laser on the sensor, and if it lights up you know the seal has been broken.'

More information: H.H. Fang, S. Adjokatse, H. Wei, J. Yang, G. R. Blake, J. Huang, J. Even, M. A. Loi, Ultrahigh sensitivity of methylammonium lead tribromide perovskite single crystals to environmental gases. *Science Advances* 2, e1600534 (2016). DOI: 10.1126/sciadv.1600534