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PHOTOVOLTAICS

Solar cells take the strain

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There are two main types of photovoltaic (PV) effect: the p–n junction-based PV effect, which underpins existing solar cell technology but is constrained by the Shockley–Queisser limit, and the less well-known bulk PV effect, which is observed only in non-centrosymmetric materials. Reporting in *Science*, Marin Alexe and colleagues now introduce a new type of PV effect: the 'flexo-PV effect' — an artificial bulk PV effect that can be induced in any semiconductor by simply applying a point force. In the future, it may be possible to engineer both the flexo-PV effect and a p–n junction in the same material, providing a new approach to high-efficiency solar cells.

The bulk PV effect can give rise to photovoltages that are much larger than the bandgap of a material, and because this effect is not dependent on a p–n junction for charge separation, it is not subject to the Shockley–Queisser limit. Unfortunately, other factors usually result in bulk PV-based devices having low efficiency. However, Alexe's team propose that a bulk PV effect can be induced in any semiconductor, irrespective of its symmetry, by using a point force to introduce a strain gradient in a material, which breaks the local symmetry. "We have added the strain gradient to the very short list of parameters — chemical potential gradient and electric field — that are able to split photocarriers to generate current," says Alexe.

"We initially tested our proposal on the nanoscale because we knew that the induced strain and the associated gradients would be massive," explains Alexe. The team used the tip of an atomic force microscope to exert a point force on the surface of single crystals of different centrosymmetric materials and simultaneously measured the photocurrent under illumination. For TiO_2, a large negative current is induced when a force of 15 μN is exerted on the (100) facet of a single crystal. The magnitude of the current increases with increasing force, and the sign of the current is dependent on the facet of the crystal; for example, a large positive current is observed when the force is exerted on the (001) facet. Perhaps more important for solar cell applications, a strain gradient is also shown to induce a photocurrent in a Si(100) single crystal.

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Similar experiments were performed using a microscale needle to exert the point force. The observation of strain-induced photocurrent in both $SrTiO_3$ and TiO_2 indicates that the flexo-PV effect can also manifest when the force is exerted over a larger area.

Through use of a strain gradient, it is possible, in principle, to combine the two main PV effects in a single material and to design devices that can take advantage of both effects to increase the efficiency. Moreover, the flexo-PV effect is relevant to many materials, including perovskites. However, the team must first study the flexo-PV effect at the macroscale. "We are keen to learn if our flexo-PV effect is going to additively overlap with the p–n junction-based PV effect and boost the efficiency of existing solar cells," explains Alexe.

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