Optoelectronics gain spin control from chiral perovskites and III–V semiconductors

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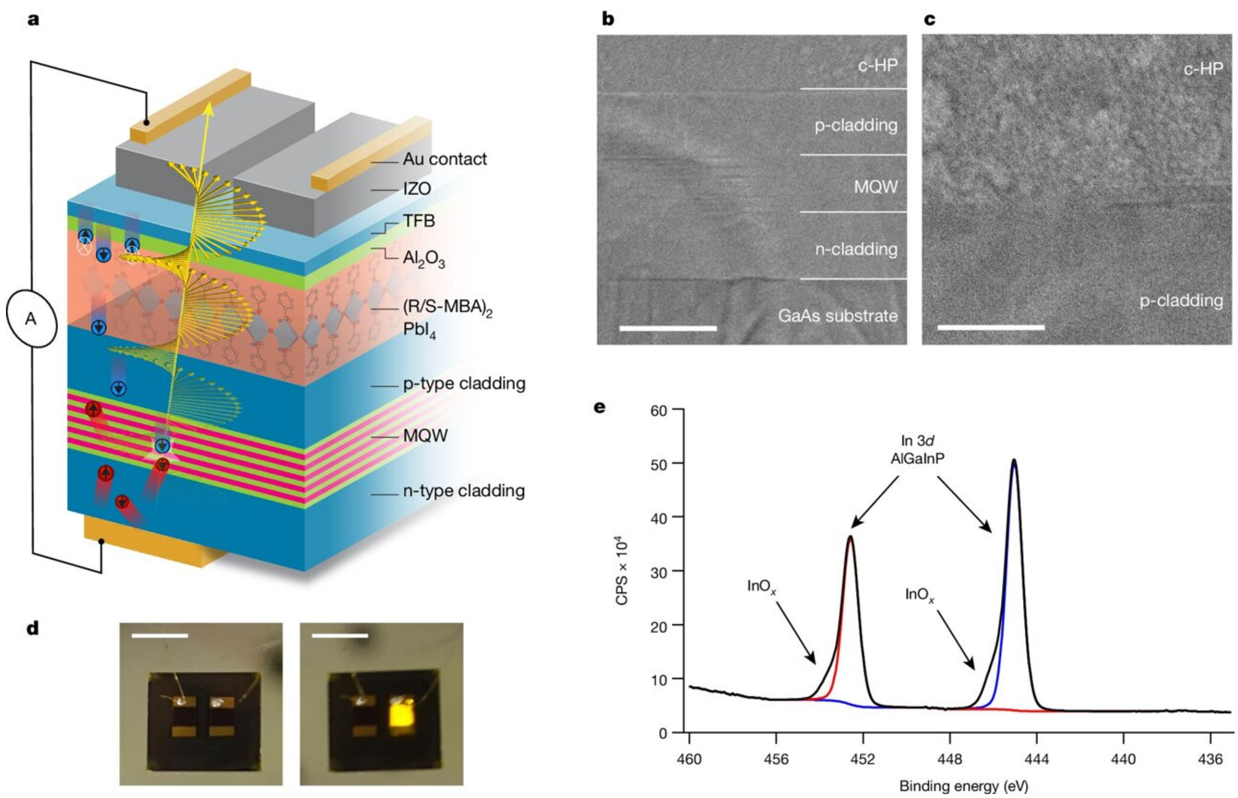

LED schematic and interface characterization. Credit: *Nature* (2024). DOI: 10.1038/s41586-024-07560-4

A research effort led by scientists at the U.S. Department of Energy's (DOE's) National Renewable Energy Laboratory (NREL) has made advances that could enable a broader range of currently unimagined optoelectronic devices.

The researchers, whose previous innovation included incorporating a perovskite layer that allowed the creation of a new type of polarized light-emitting diode (LED) that emits spin-controlled photons at room temperature without the use of magnetic fields or ferromagnetic contacts, now have gone a step further by integrating a III-V semiconductor optoelectronic structure with a chiral halide perovskite semiconductor.

That is, they transformed an existing commercialized LED into one that also controls the spin of electrons. The results provide a pathway toward transforming modern optoelectronics, a field that relies on the control of light and encompasses LEDs, solar cells, and telecommunications lasers, among other devices.

"It's up to one's imagination where this might go or where this might end up," said Matthew Beard, a senior research fellow at NREL and co-author of the *Nature* article titled "Room temperature spin injection across a chiral-perovskite/III-V interface."

Beard also serves as director of the Center for Hybrid Organic Inorganic Semiconductors for Energy (CHOISE). The research relied on a broad range of scientific expertise drawn from NREL, the Colorado School of Mines, University of Utah, University of Colorado Boulder, and the Universite de Lorraine in France.

The goal of CHOISE is to understand control over the interconversion of charge, spin, and light using carefully designed chemical systems. In particular, the work focuses on control over the electron spin that can be either "up" or "down."

Most current-day optoelectronic devices rely on the interconversion between charge and light. However, spin is another property of electrons, and control over the spin could enable a wide plethora of new effects and functionality. The researchers published a paper in 2021 in which they reported how by using two different perovskite layers they were able to control the spin by creating a filter that blocks electrons "spinning" in the wrong direction.

They hypothesized at the time that advancements could be made in optoelectronics if they could successfully incorporate the two semiconductors, and then went on to do just that. The breakthroughs made, which include eliminating the need for subzero Celsius temperatures, can be used to increase data processing speeds and decrease the amount of power needed.

"Most current-day technologies are all based on controlling charge," Beard said. "Most people just forget about the electron spin, but spin is very important, and it's also another parameter that one can control and utilize."

Manipulating the spin of electrons in a semiconductor has previously required the use of ferromagnetic contacts under an applied magnetic field. Using chiral perovskites, the researchers were able to transform an LED to one that emits polarized light at room temperature and without a magnetic field. Chirality refers to the material's structure that cannot be superimposed on its mirror image, such as a hand.

For example, a "left-handed" oriented chiral system may allow transport of electrons with "up" spins but block electrons with "down" spins, and vice versa. The spin of the electron is then converted to the "spin," or polarization, of the emitted light.

The degree of polarization, which measures the intensity of light that is polarized in one direction, reached about 2.6% in the previous research.

The addition of the III–V semiconductor—which is made of materials in the third and fifth columns of the periodic table—boosted the polarization to about 15%. The degree of polarization serves as a direct measure of spin accumulation in the LED.

"This work is particularly exciting to me, as it combines spin functionality with a traditional LED platform," said the first author of the work, Matthew Hautzinger.

"You can buy an LED analogous to what we used for 14 cents, but with the chiral perovskite incorporated, we've transformed an already robust (and well understood) technology into a futuristic spin-control device."

More information: Matthew P. Hautzinger et al, Room-temperature spin injection across a chiral perovskite/III–V interface, *Nature* (2024). DOI: 10.1038/s41586-024-07560-4

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