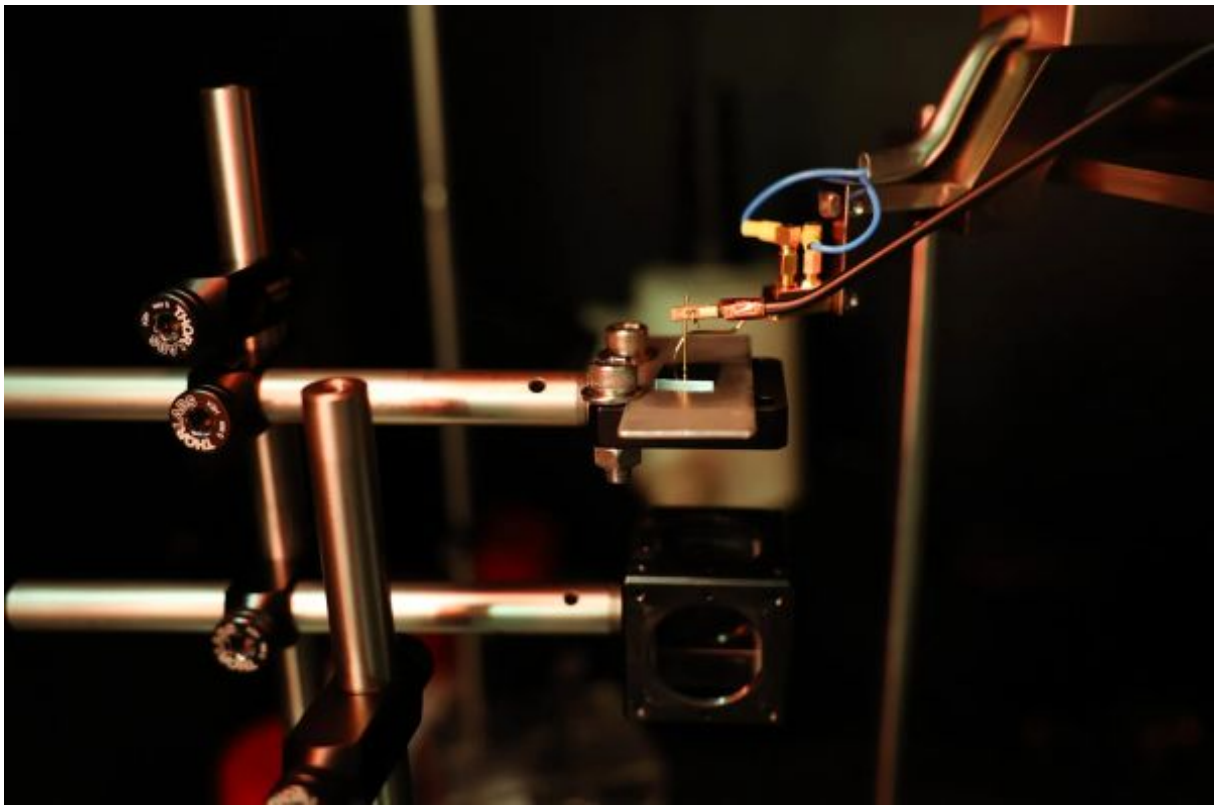


New surface chemistry brings quantum-dot infrared detectors close to commercial performance

ICFO researchers have developed a new chemical strategy to overcome a long-standing limitation of colloidal quantum-dots: electronic defects associated with their surfaces. With the treated dots, they have built photodiodes achieving sensitivity comparable to commercially available photodetectors, opening opportunities for a broader range of optoelectronic technologies. The study is published in Nature Communications.

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Colloidal quantum dots are tiny semiconductor crystals whose optical and electronic properties can be precisely tuned by controlling their size. Unlike conventional crystalline semiconductors, they can be synthesized in solution and deposited onto different substrates using comparatively simple processing methods, and can be easily integrated with CMOS readout electronics. Their versatility, scalability and low cost makes them attractive building

blocks for a wide range of technologies, from solar cells and light-emitting devices to infrared photodetectors and imaging systems.
However, despite decades of progress, quantum-dot semiconductors have struggled to match the electronic quality of their single-crystalline counterparts, such as indium gallium arsenide (InGaAs). One of the main reasons lies at their surfaces, where imperfect chemical bonding creates electronic defects that limit the final device performance.
The challenge becomes particularly pronounced in larger lead sulfide (PbS) quantum dots, which are needed to absorb light at longer infrared wavelengths. As quantum dots grow, they expose different facets, including non-polar surfaces (that is, surfaces without a net electrical charge), which are difficult to protect using conventional chemical treatments.
Now, ICFO researchers **Dr. Debranjan Mandal**, **Dr. Yongjie Wang**, **Dr. Carmelita Roda**, **Dr. Miguel Dosil**, **Dr. Gaurav Kumar** and **Dr. Lucheng Peng**, led by **ICREA Prof. Gerasimos Konstantatos**, have developed a new passivation strategy to neutralize surface defects that, instead of relying on traditional halide-based treatments, is based on metal-thiolate chemistry. As demonstrated in a recently published Nature Communications study, thiolates enable **more effective passivation of the non-polar facets of large PbS quantum dots**, while also addressing their polar surfaces. Consequently, quantum dots exhibit **substantially improved electronic quality and thermal stability** compared with conventionally treated materials.
"For years, a central challenge in colloidal quantum-dot technology has been understanding why these materials, despite their attractive properties, still suffer from electronic losses that are much larger than those of conventional semiconductors," explains ICREA Prof. Gerasimos Konstantatos, senior researcher of the article. "We have now identified that incomplete passivation of non-polar quantum-dot surfaces is an important source of these losses."

From improved materials to high-performance infrared photodetectors and beyond
To demonstrate the technological impact of their approach, the researchers incorporated the treated PbS quantum dots into **short-wave infrared (SWIR) photodiodes**. The devices exhibited exceptionally low dark currents and electrical noise, with performance substantially improved over previously reported SWIR quantum-dot photodetectors. Most notably, they **reached sensitivity levels comparable to those of commercially available InGaAs photodiodes**.
At the same time, this achievement has implications extending well beyond infrared detection. In particular, the new passivation strategy could improve the performance of quantum-dot photovoltaic technologies, where voltage losses remain a major limitation.
"What makes this result particularly important is that we are addressing a fundamental limitation of the semiconductor material, rather than simply optimizing a particular device," explains Dr. Debranjan Mandal, first author of the study. "The improvements in electronic quality and stability could thus benefit several quantum-dot technologies, including

photovoltaics and infrared optoelectronics," he stresses.

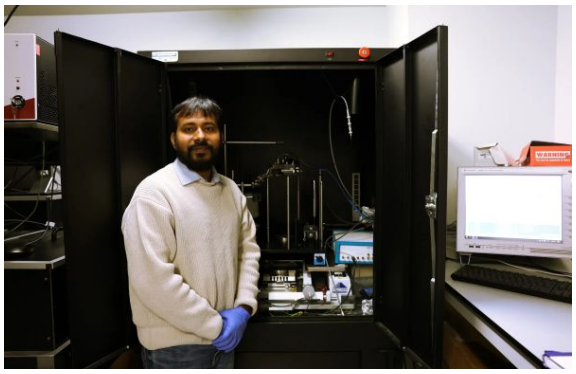
Overall, the study illustrates how advances in chemical control at the nanoscale can translate into improvements in semiconductor performance, bringing solution-processed quantum-dot technologies closer to the standards established by conventional crystalline materials. This could ultimately make SWIR photodectectors and other optoelectronic devices more widely available for industrial and commercial use.

Reference

Mandal, D., Wang, Y., Roda, C. et al. "Non-polar surface passivation of PbS Quantum Dots using metal thiolates enables photodiodes rivaling InGaAs performance." Nature Communications (2026).
DOI: https://doi.org/10.1038/s41467-026-78740-1

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Dr. Debranjan Mandal at the laboratory at ICFO. Credit: ICFO.