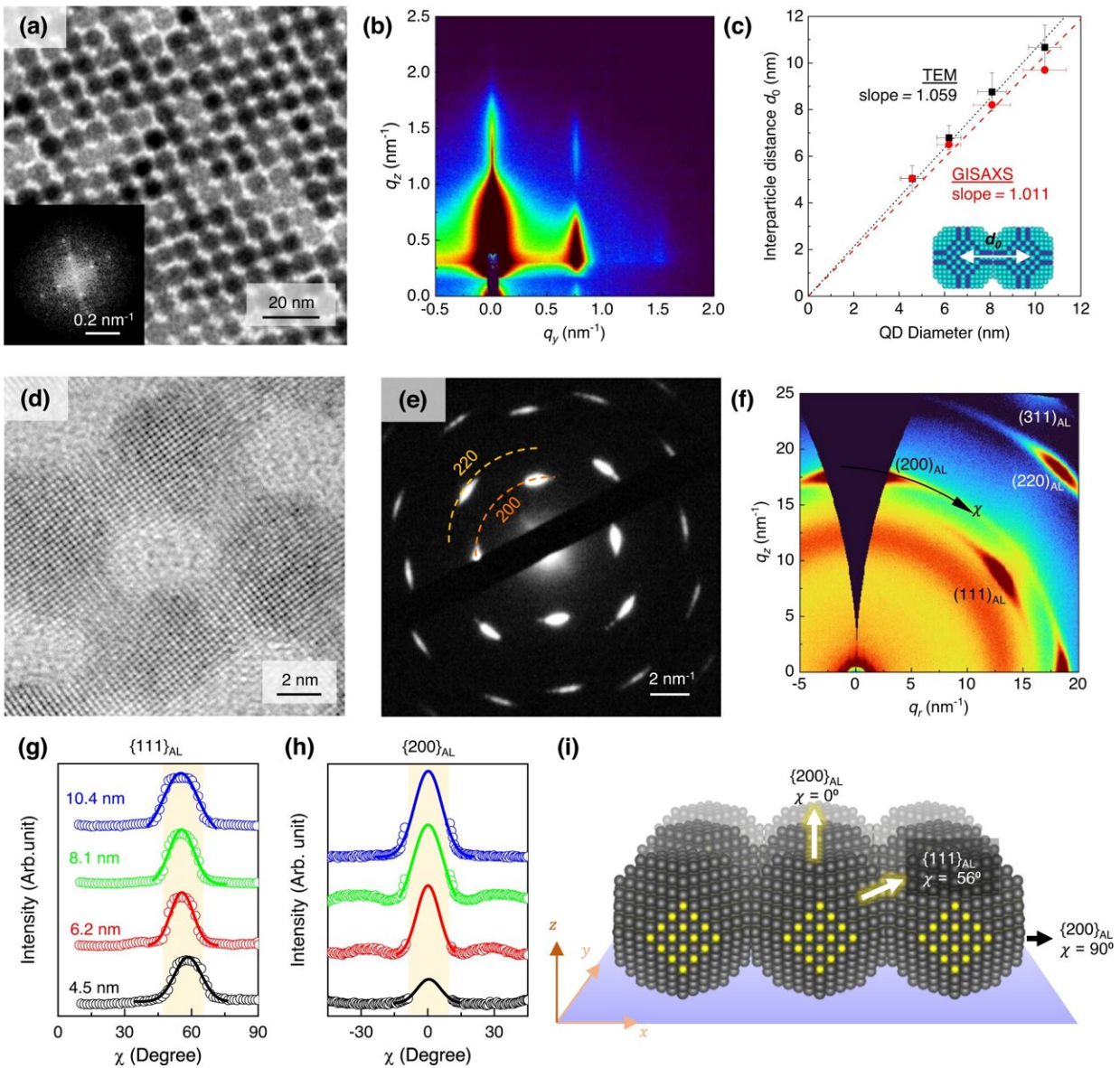


# Forging a dream material with semiconductor quantum dots

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Epitaxially-connected PbS quantum dot superlattices (QD-SL). a Transmission

electron micrograph (TEM) of the QD-SL containing 8.1 nm diameter PbS QD. (inset) Fast-Fourier transform (FFT) of the micrograph. **b** The grazing incident small-angle X-ray scattering (GISAXS) pattern of the corresponding sample indicates the two-dimensional ordering of the QD monolayer. **c** The plot compares the extracted average diameter of the QDs versus the center-to-center (inter-QD) distance from the TEM images (black squares), and GISAXS measurement (red dots) of QD-SLs fabricated from various diameters of QD building blocks. Error bars represent standard deviation. **d** High-resolution TEM shows the epitaxial connection of the QDs and **e** selected area electron diffraction (SAED), demonstrating the PbS atomic orientation in the QD-SLs. It is a conclusion supported by the **f** grazing incident wide-angle scattering (GIWAXS) pattern taken from a much larger sample cross-section. **g** Azimuthal line cut-off ( $\chi$ ) on scattered X-ray wavevector ( $q$ ) for  $\{111\}$ AL and **h**  $\{200\}$ AL of the GIWAXS patterns show the consistency of the ordering for all QD diameters. **i** An illustration reconstructing the PbS QD-SL alignment on the substrate showing the atomic lattice orientation relative to the normal surface. Credit: *Nature Communications* (2023). DOI: 10.1038/s41467-023-38216-y

Researchers from the RIKEN Center for Emergent Matter Science and collaborators have succeeded in creating a "superlattice" of semiconductor quantum dots that can behave like a metal, potentially imparting exciting new properties to this popular class of materials.

Semiconducting colloidal quantum dots have garnered tremendous research interest due to their special optical properties, which arise from the quantum confinement effect. They are used in [solar cells](#), where they can improve the efficiency of energy conversion, biological imaging, where they can be used as fluorescent probes, [electronic displays](#), and even [quantum computing](#), where their ability to trap and manipulate individual electrons can be exploited.

However, getting [semiconductor quantum dots](#) to efficiently conduct electricity has been a major challenge, impeding their full use. This is

primarily due to their lack of orientational order in assemblies. According to Satria Zulkarnaen Bisri, lead researcher on the project, "making them metallic would enable, for example, quantum dot displays that are brighter yet use less energy than current devices."

Now, the group has published a study in *Nature Communications* that could make a major contribution to reaching that goal. The group, led by Bisri and Yoshihiro Iwasa of RIKEN CEMS, has created a superlattice of lead sulfide semiconducting [colloidal quantum dots](#) that displays the electrical conducting properties of a metal.

The key to achieving this was to get the individual quantum dots in the lattice to attach to one another directly, "epitaxially," without ligands, and to do this with their facets oriented in a precise way.

The researchers tested the conductivity of the material they created, and as they increased the carrier density using a electric, double-layer transistor, they found that at a certain point it became a million times more conductive than what is currently available from quantum dot displays. Importantly, the quantum confinement of the individual quantum dots was still maintained, meaning that they don't lose their functionality despite the high conductivity.

"Semiconductor quantum dots have always shown promise for their [optical properties](#), but their electronic mobility has been a challenge," says Iwasa. "Our research has demonstrated that precise orientation control of the quantum dots in the assembly can lead to high electronic mobility and metallic behavior. This breakthrough could open up new avenues for using semiconductor quantum dots in emerging technologies."

According to Bisri, "We plan to carry out further studies with this class of materials, and believe it could lead to vast improvements in the

capabilities of quantum dot superlattices. In addition to improving current devices, it could lead to new applications such as true all-QD direct electroluminescence devices, electrically driven lasers, thermoelectric devices, and highly sensitive detectors and sensors, which previously were beyond the scope of quantum dot materials."

**More information:** Enabling Metallic Behaviour in Two-Dimensional Superlattice of Semiconductor Colloidal Quantum Dots, *Nature Communications* (2023). [DOI: 10.1038/s41467-023-38216-y](https://doi.org/10.1038/s41467-023-38216-y)

Provided by RIKEN

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