Core technology developed for ultra-high-resolution quantum dot displays

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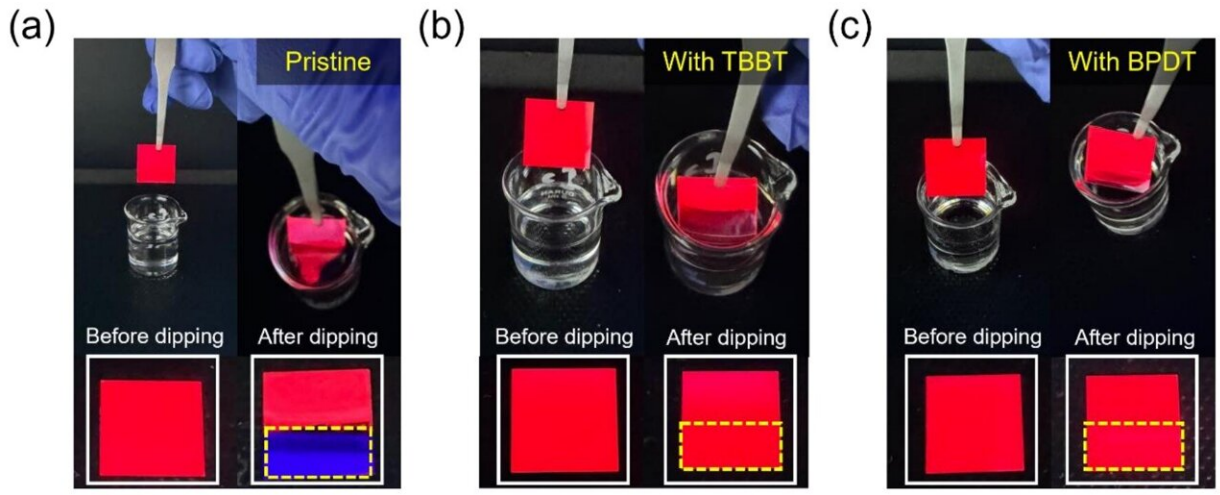

Ligand-crosslinking and solvent immersion test. Photographs of the QD films on silicon substrates for the solvent immersion test: a) Pristine QD film, b) TBBT crosslinked QD film and c) BPDT crosslinked QD film. Credit: *Nano Letters* (2025). DOI: 10.1021/acs.nanolett.5c01926

A research team has developed a direct optical lithography (DOL) technology that patterns quantum dots (QDs) at ultra-high resolution using only light, without photoresist. Through this, they also provided guidelines for selecting cross-linkers essential for fabricating high-performance QLEDs. This achievement is regarded as a core fundamental technology that can be applied to a wide range of optoelectronic devices, including micro-QLEDs, ultra-high-resolution

displays, transparent electronic devices, and next-generation image sensors.

The paper is published in the journal *Nano Letters*. The study was led by Professor Jong-Soo Lee in the Department of Energy Science and Engineering at DGIST.

QDs are ultra-fine semiconductor particles about one hundred-thousandth the thickness of a human hair. Their emission color can be freely tuned by size, thereby making them a next-generation display material with outstanding color reproduction. However, conventional photoresist-based patterning processes face limitations such as complex procedures, reduced emission performance, and pattern deformation. In addition, inkjet printing and micro-contact printing are also constrained in terms of resolution and precision.

To address these limitations, the research team introduced a diazirine-based crosslinker, TDBA, which reacts to ultraviolet light (i-line, 365 nm). TDBA possesses both a "carboxylic acid functional group" that can directly bind to the surface of QDs and a diazirine structure that responds to light.

With a single light exposure, it chemically bonds to the QDs to form ultra-fine patterns. Using this approach, the team successfully achieved ultra-high-resolution patterning at about 2 μm (6,350 DPI), while also ensuring excellent precision and stability.

In addition, following the patterning process, the team applied post-treatment using a thiol-based compound called "PETMP," which passivated surface defects on the QDs, thereby further improving their photoluminescence quantum yield (PLQY).

QLED devices incorporating these post-treated QDs as the emitting layer

achieved a maximum external efficiency of 10.3% and a maximum luminance of 99,369 cd/m^2, thereby demonstrating outstanding device performance. In addition, in semitransparent QLEDs utilizing R/G/B QDs, they verified the feasibility of double-sided emission, thus opening up possibilities for transparent display applications.

In addition to developing the fabrication technology, the team conducted an in-depth analysis of how the molecular structure of cross-linkers affects the optical and electrical properties of QDs.

By using density functional theory (DFT), a quantum mechanical calculation method, the team compared TBBT, which contains sulfur (S) atoms, with BPDT, which does not, and discovered that BPDT exhibits higher conductivity, making it more advantageous for improving QLED performance. This finding is expected to serve as an important guideline for selecting optimal materials in the fabrication of high-resolution, high-performance QD displays.

Professor Lee stated, "This research not only increases resolution, but also proposes a method for stable fabrication that preserves the intrinsic optical and electrical properties of QDs, along with clear criteria for material selection. We expect it will greatly accelerate the commercialization of next-generation displays such as AR and VR."

More information: Jung-Min Kim et al, Role of Conjugated Structure of Cross-linkers in Patterned QLEDs, *Nano Letters* (2025). DOI: 10.1021/acs.nanolett.5c01926

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