PRESS RELEASE

Toyama, July 17, 2026

Large-Scale Crystals Could Revolutionize Future OLED Displays

Crystalline rubrene thin films integrated into OLEDs achieve 1,000-fold higher current density than conventional amorphous devices

Crystalline organic semiconductors offer excellent charge transport but have been difficult to incorporate into practical OLEDs. Researchers from the University of Toyama developed the first OLED using a non-epitaxial crystalline rubrene thin film. Using a two-step annealing process, they achieved 1,000-fold higher current density and a turn-on voltage of just 1.33 V. This breakthrough demonstrates that crystalline organic semiconductors can be integrated into practical OLEDs, paving the way for a "crystalline generation" of displays.

Since the first practical organic light-emitting diode (OLED) was developed in 1987 by Ching W. Tang and Steven A. VanSlyke at Eastman Kodak Company in the USA, OLED technology has come a long way. The original device used two thin organic layers to produce green light when electricity was applied, demonstrating that organic materials could be used to create practical light-emitting devices. Today, OLEDs are widely used in smartphone and television displays as well as lighting, with continuous improvements in efficiency and lifespan.

Now, researchers from the University of Toyama, Japan, led by Professor Masahiro Morimoto of the Academic Assembly Faculty of Engineering, along with Mr. Yuya Honda and Prof. Shigeki Naka from the same university, have advanced the technology further by developing an OLED that incorporates a crystalline rubrene thin film as its light-emitting layer. This paper was made available online on July 1, 2026, and will be published in Volume 320 of the journal *Synthetic Metals* on August 01, 2026.

Rubrene is an organic semiconductor that can transport electrical charges much more efficiently in its crystalline form. However, when deposited as a thin film using the conventional vacuum evaporation process used to manufacture OLEDs, it forms a disordered (amorphous) structure in which electrical charges move much less efficiently.

To overcome this limitation, the researchers first fabricated the OLED by depositing several ultrathin layers, including a 50 nm-thick rubrene layer, onto an indium tin oxide substrate. They then used a two-step heat treatment to transform the rubrene layer into a crystalline film. During the first heating step, tiny crystal seeds formed within the rubrene layer. After the remaining layers were deposited, a second heating step allowed these crystals to grow into large crystalline domains.

Using polarized optical microscopy, the researchers observed large crystalline regions measuring about 1 mm throughout the rubrene film. Similar crystal structures were found across the entire substrate, indicating that the crystals had grown uniformly. X-ray diffraction revealed that the rubrene had formed an orthorhombic crystal structure.

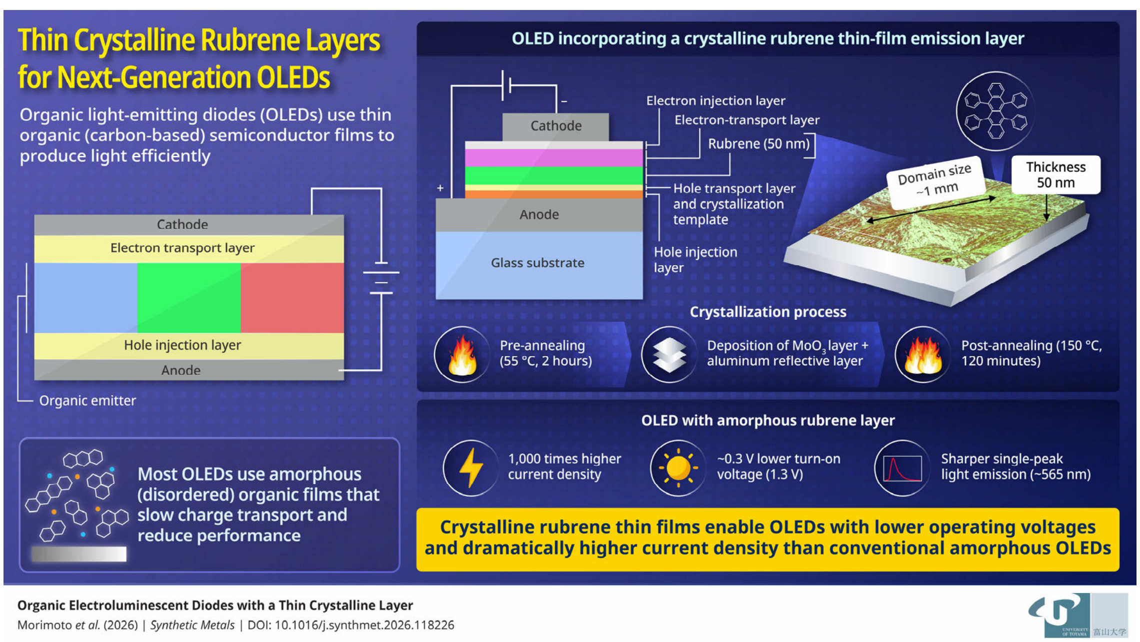
“We have extended the concept of Tang's organic electroluminescent diodes to rubrene crystalline thin films and fabricated OLEDs with superior characteristics. This represents the first application of non-epitaxial crystalline thin films to OLEDs,” says Prof. Morimoto

Compared with OLEDs containing amorphous rubrene, the crystalline devices exhibited current densities up to 1,000 times higher and reduced the luminance turn-on voltage by 0.30 V to just 1.33 V. Moreover, the electroluminescence spectrum changed from the broad, two-peak emission characteristic of amorphous rubrene to a sharp single peak near 565 nm, a distinctive signature of the crystalline structure.

The study demonstrates that organic crystals with high charge-transport properties can be successfully integrated into practical thin-film OLEDs using standard vacuum-deposition techniques. Building on nearly four decades of OLED innovation since Tang and VanSlyke's pioneering work, the findings suggest that crystalline organic materials could provide a new path toward more efficient OLED devices.

“Just as the semiconductor industry has driven historical breakthroughs by precisely controlling the structural order of materials, we believe the OLED field is now at a similar turning point. While current commercial OLEDs remain amorphous, our findings clearly show that transitioning to 'crystalline' structures will define the next generation of OLED technology.” says Prof. Morimoto.

Image 1



Title: OLED with a non-epitaxial crystalline rubrene thin film
Caption: A two-step annealing process transformed amorphous rubrene into a crystalline thin film, enabling OLEDs with up to 1,000 times higher current density, lower turn-on voltage, and a sharp single emission peak.
Credit: Professor Masahiro Morimoto from the University of Toyama, Japan
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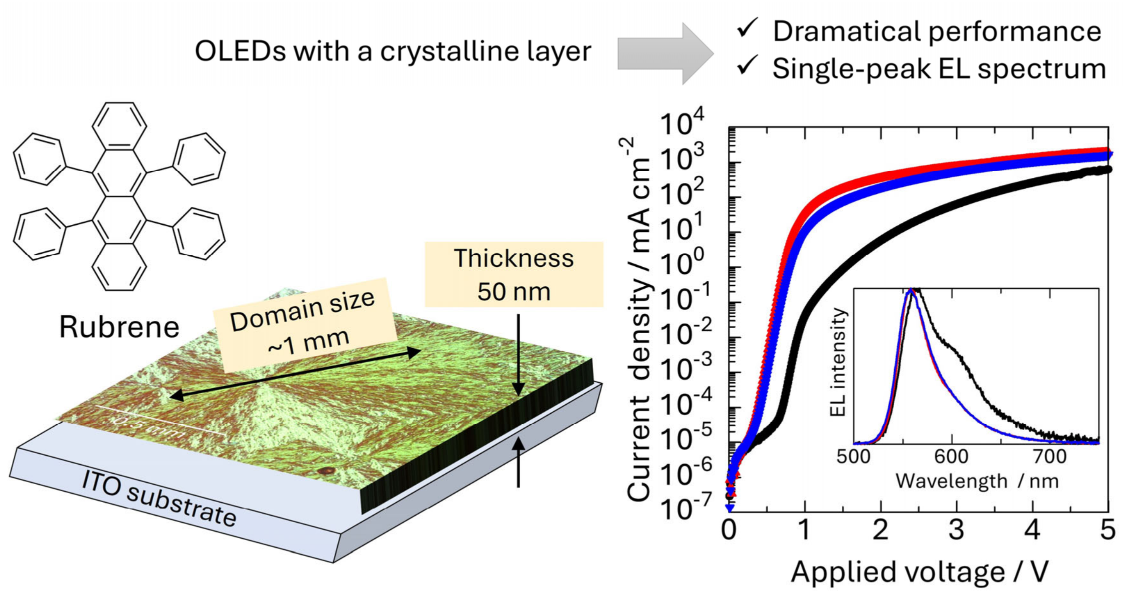
Image 2



Title: Crystalline rubrene thin films enable brighter, lower-voltage OLEDs
Caption: The crystalline rubrene thin film forms large orthorhombic crystal domains up to 1 mm across, providing efficient charge transport, high current density, low turn-on voltage, and a sharp single-emission peak.
Credit: Professor Masahiro Morimoto from the University of Toyama, Japan
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Reference

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About University of Toyama, Japan

University of Toyama is a leading national university located in Toyama Prefecture, Japan, with campuses in Toyama City and Takaoka City. Formed in 2005 through the integration of three former national institutions, the university brings together a broad spectrum of disciplines across its 9 undergraduate schools, 8 graduate schools, and a range of specialized institutes. With more than 9,000 students, including a growing international cohort, the university is dedicated to high-quality education, cutting-edge research, and meaningful social contribution. Guided by the mission to cultivate individuals with creativity, ethical awareness, and a strong sense of purpose, the University of Toyama fosters learning that integrates the humanities, social sciences, natural sciences, and life sciences. The university emphasizes a global standard of education while remaining deeply engaged with the local community.

Website: https://www.u-toyama.ac.jp/en/

About Professor Masahiro Morimoto from the University of Toyama, Japan
Masahiro Morimoto, Ph.D., is the Professor in the Academic Assembly Faculty of Engineering at the University of Toyama, Japan. His research focuses on the structural manipulation of organic thin films for next-generation electronic devices, with particular interests in organic electronics, OLEDs, photo-sensors, and thin-film growth. He also studies polarization and charge-carrier transfer at metal–organic semiconductor interfaces and explores the use of soft organic and plant-based materials to develop electronic devices that can better coexist with people and the environment.

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Media contact: Yumiko Kato
E-mail: ykato@ctg.u-toyama.ac.jp