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PRESS RELEASE (2025/8/8)

Dual-Function Organic Molecule May Advance Display Technologies and Medical Imaging

Researchers overcome a long-standing molecular design challenge by realizing efficient light emission and photon absorption in the same compound.

Fukuoka, Japan—Researchers at Kyushu University have developed a novel organic molecule that simultaneously exhibits two highly sought-after properties: efficient light emission suitable for advanced displays and strong light absorption for deep-tissue bioimaging. This breakthrough addresses a long-standing challenge in molecular design, paving the way for next-generation multifunctional materials. Their study, published online in the journal *Advanced Materials* on July 29, 2025, was conducted in collaboration with the National Taipei University of Technology and the National Central University.

Organic light-emitting diodes (OLEDs) are at the forefront of modern display and lighting technologies, powering nearly everything from smartphone screens to large televisions and monitors. A key phenomenon that is actively being researched to enhance OLED efficiency is thermally activated delayed fluorescence (TADF). This process occurs when absorbed energy trapped in a non-light-emitting state (triplet state) is shifted into a light-emitting state (singlet state) using heat from the surroundings. In simple terms, materials exhibiting TADF can efficiently produce light from energy that would normally be lost, leading to brighter and more energy-efficient devices.

Beyond displays, the ability to capture sharp images of biological tissues while causing minimal harm is crucial for medical diagnostics and research. To this end, techniques leveraging two-photon absorption (2PA) have proven useful. In 2PA, instead of absorbing a single high-energy photon, a molecule absorbs two lower-energy photons simultaneously from a high-intensity laser to reach an excited state capable of emitting fluorescence. Light with lower-energy photons and longer wavelengths, like near infrared, is ideal for biomedical imaging, since it can penetrate much deeper into tissues without scattering. As a bonus, 2PA means that only a small portion of tissue at the laser's focal point is excited, causing less damage to living cells.

Although TADF and 2PA are both desirable properties in organic materials—one for efficient light emission, and the other for superior imaging—combining both in a single molecule has been extremely challenging. This is because these mechanisms impose conflicting design requirements. Strong TADF calls for a twisted molecular structure that physically separates electron orbitals to facilitate energy conversion. In contrast, 2PA typically requires a more planar structure with significant orbital overlap to enable effective light absorption.

"Recognizing that these two functions have complementary advantages but conflicting molecular requirements, I was motivated to design a material that could harmonize both, ultimately aiming to create new multifunctional materials that could link the fields of electronics and life sciences," says Dr. Youhei Chitose, Assistant Professor of the Graduate School of

Engineering at Kyushu University, Japan, and the lead author of the study.

To fill this knowledge gap, the research team employed a clever molecular design strategy. They created a molecule called CzTRZCN that acts as a molecular switch, changing its structure and properties depending on whether it's absorbing or emitting light. Their approach involved combining an electron-rich carbazole (Cz) compound with an electron-deficient triazine (TRZ) core. The researchers were able to finetune how the electrons grouped into orbitals within the structure by also adding cyano (CN) groups, which exert a strong pull onto electrons.

The end result meant that during light absorption, CzTRZCN maintains enough orbital overlap between its components to efficiently absorb two photons simultaneously. After excitation, the molecule undergoes structural changes that separate these components, enabling TADF.

Through a combination of theoretical calculations and experimental validation, the team demonstrated that their newly designed material achieved remarkable dual functionality. When integrated into an OLED device, CzTRZCN achieved an external quantum efficiency of 13.5%, establishing a new benchmark among triazine-based TADF materials. Moreover, it exhibited a high 2PA cross-section (a measure of 2PA efficiency) and high brightness, signifying its potential for medical imaging.

"The proposed molecule is a metal-free organic compound with low toxicity to cells and high biocompatibility. This makes it ideal for use in medical probes for precise cancer and neurological diagnostics, especially through time-resolved fluorescence microscopy," highlights Chitose.

Overall, this study represents an important step toward developing versatile organic materials that bridge the fields of photoelectronics and bioimaging. Beyond medical use, the proposed molecular design strategy for achieving different orbital characteristics for absorption and emission can be widely applied to other multifunctional materials.

"Moving forward, we aim to expand this molecular design approach to cover a broader range of emission wavelengths. We also plan to collaborate with researchers in biomedical and device engineering fields to explore the implementation of these materials in practical applications such as in vivo imaging, wearable sensors, and OLEDs," concludes Chitose.

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For more information about this research, see "Unlocking Dual Functionality in Triazine-Based Emitters: Synergistic Enhancement of Two-Photon Absorption and TADF-OLED Performance with Electron-Withdrawing Substituents," Youhei Chitose, Gomathi Vinayakam Mageswari, Ryota Zenke, Toshiharu Ide, Shintaro Kohata, Ja-Hon Lin, Tzu-Chau Lin, Youichi Tsuchiya, and Chihaya Adachi, *Advanced Materials*, https://doi.org/10.1002/adma.202509857

About Kyushu University

Founded in 1911, Kyushu University is one of Japan's leading research-oriented institutes of higher education, consistently ranking as one of the top ten Japanese universities in the Times Higher Education World University Rankings and the QS World Rankings. The university is one of the seven national universities in Japan, located in Fukuoka, on the island of Kyushu—the most southwestern of Japan's four main islands with a population and land size slightly larger than Belgium. Kyushu U's multiple campuses—home to around 19,000 students and 8000 faculty and staff—are located around Fukuoka City, a coastal metropolis that is frequently ranked among the world's most livable cities and historically known as Japan's gateway to Asia. Through its VISION 2030, Kyushu U will "drive social change with integrative knowledge." By fusing the spectrum of knowledge, from the humanities and arts to engineering and medical sciences, Kyushu U will strengthen its research in the key areas of decarbonization, medicine and health, and environment and food, to tackle society's most pressing issues.

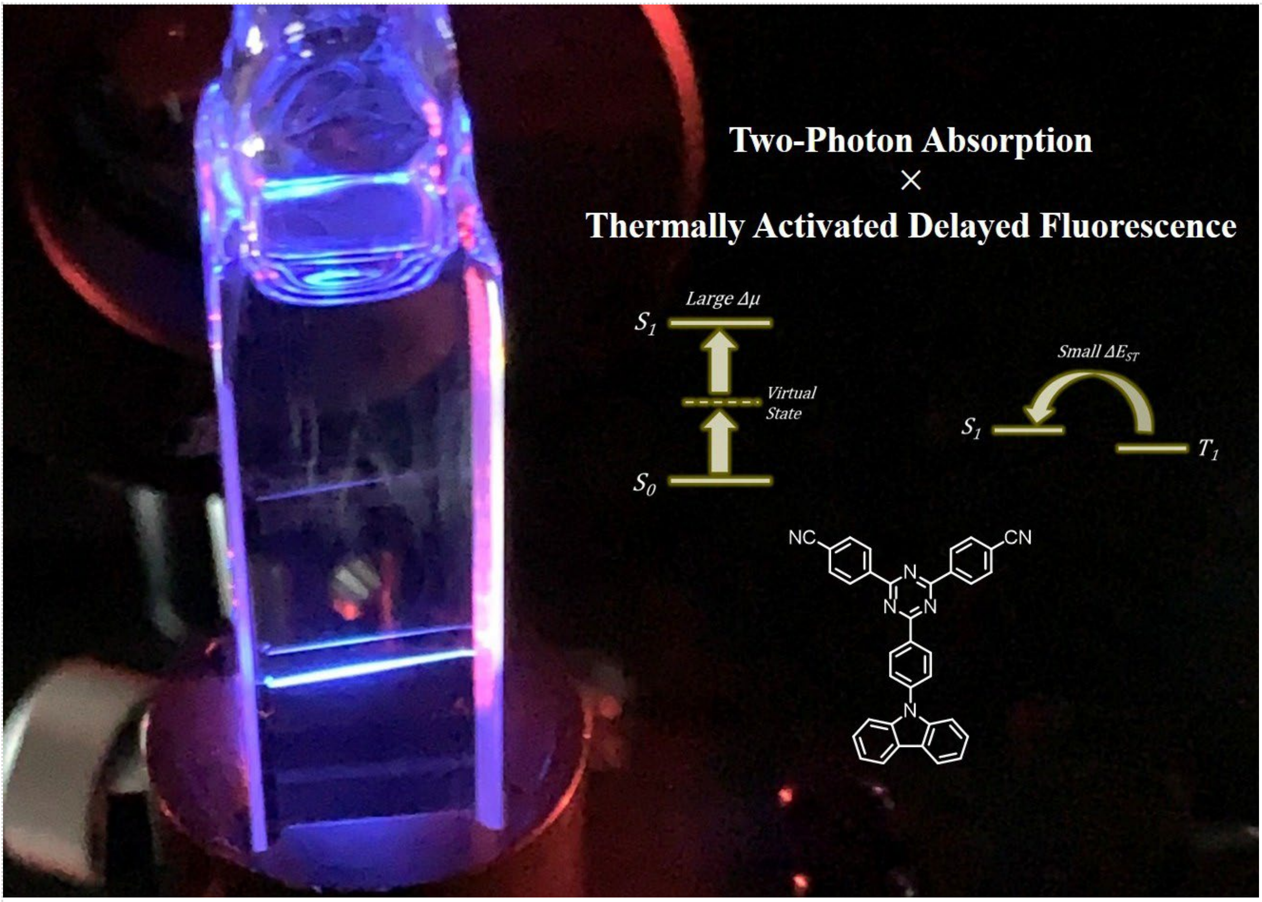

Fig. 1. This image depicts the structure of the proposed organic molecule, alongside the energy level diagrams of two-photon absorption (left side) and thermally activated delayed fluorescence (right side).
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