Covalent organic frameworks demonstrate considerable potential for efficient energy transport

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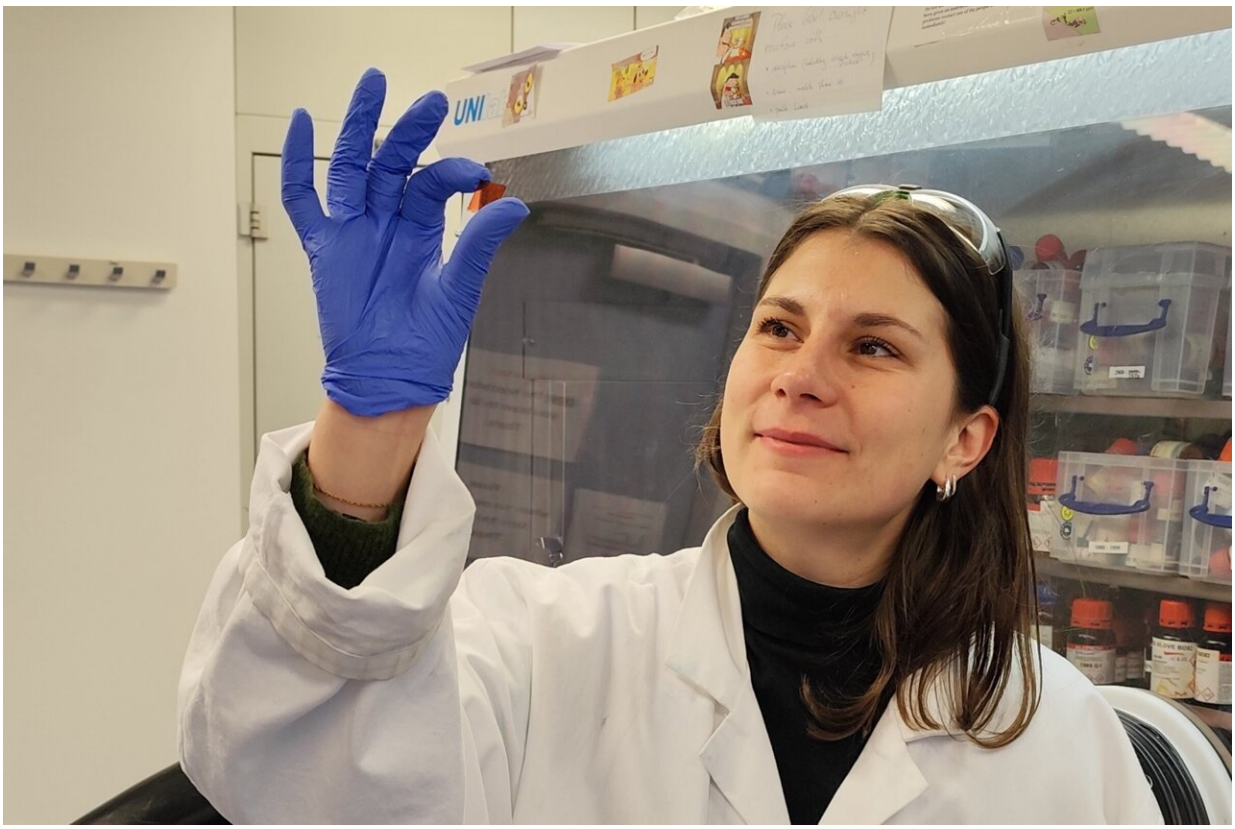

Laura Spies looks at one of the COF thin films examined in the study. Credit: Florian Wolf

An interdisciplinary research team from LMU, the Technical University

of Munich (TUM), and the University of Oxford has employed novel spectroscopic techniques to investigate the diffusion of excited states in covalent organic frameworks (COFs).

These modular materials can be adapted for desired properties through the targeted selection of their components, offering a broad range of applications. The study revealed how efficiently energy can be transported in these crystalline, semiconducting materials—a decisive advance for future optoelectronic applications such as sustainable photovoltaic systems and organic light-emitting diodes (OLEDs).

At the heart of the study, published in the *Journal of the American Chemical Society*, are COF thin films of highly crystalline, porous material. Through the use of state-of-the-art spatiotemporal techniques like photoluminescence microscopy and terahertz spectroscopy in conjunction with theoretical simulations, the team revealed remarkably high diffusion coefficients and diffusion lengths of several hundreds of nanometers.

"As such, these thin films significantly exceed the known energy transport capabilities of similar organic materials," says Laura Spies, doctoral candidate at the Chair of Physical Chemistry and Functional Nanomaterials at LMU and co-lead author.

"The energy transport works exceptionally well, even across structural defects such as grain boundaries," adds Dr. Alexander Biewald, former doctoral candidate in the Physical Chemistry and Nanooptics group and second co-lead author of the study.

New prospects for the development of sustainable organic materials

Temperature analyses yielded further insights into the underlying mechanisms. "The results indicate that both coherent and incoherent transport processes are at play," explains Professor Frank Ortmann, co-author of the study.

Coherence pertains when the waves of motion occur in an orderly fashion, undisturbed over long distances, allowing fast and low-loss energy transfer. Incoherent processes, by contrast, are characterized by disordered, random motions, which require thermal activation and are often less efficient.

These insights significantly contribute to our understanding of energy transport in COFs and show how the molecular structure and organization in the crystal can affect these processes.

"Our work highlights how vital the interdisciplinary and international cooperation of researchers with expertise in synthesis, experimental analysis, and theoretical modeling—made possible by e-conversion—is for the success of such studies," say the corresponding authors of the study, Professor Achim Hartschuh and Professor Thomas Bein.

The results open up new prospects for the development of sustainable organic materials in photocatalysis and optoelectronics, such as photovoltaics.

More information: Laura Spies et al, Spatiotemporal Spectroscopy of Fast Excited-State Diffusion in 2D Covalent Organic Framework Thin Films, *Journal of the American Chemical Society* (2025). DOI: 10.1021/jacs.4c13129

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