

RESEARCH NEWS STORY

20 April, 2026

Chiba University

The University of Osaka

Institute of Science Tokyo

Kitasato University

Self-Assembling Luminophores Form Nanotubes with Multidirectional Exciton Transport

Folding-mediated self-assembly of luminescent molecules reveals a new design principle for efficient light-energy transport

For many years, designing synthetic polymer systems has been inspired by the hierarchical self-assembly of folded proteins into functional nanostructures. However, extending folding-based design principles to small synthetic molecules has remained elusive. In particular, luminescent molecules with complex three-dimensional structures were considered difficult to assemble. Now, researchers from Japan demonstrate that such molecules can undergo folding-mediated self-assembly to form highly ordered nanotubes. These structures exhibit unique multidirectional energy transport, highlighting their potential for advanced optoelectronic applications.

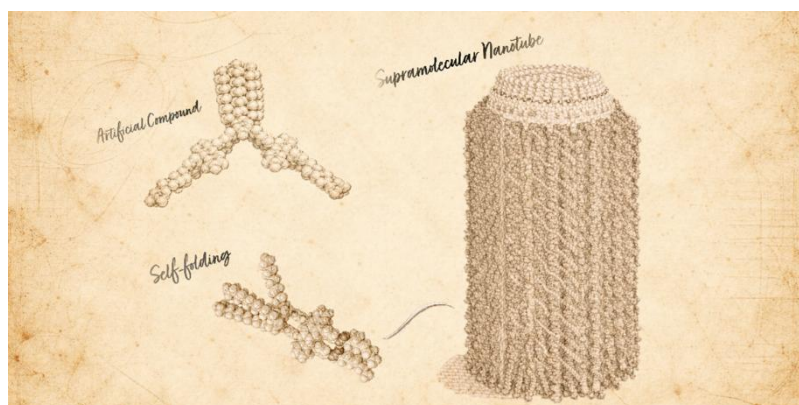


Image title: Self-Folding π -Luminophores Form Supramolecular Nanotubes with Multidirectional Exciton Transport

Image caption: A recent study shows that sterically demanding diphenylanthracene-based artificial π -luminophores can be programmed to self-fold and preorganize into highly ordered supramolecular nanotubes. This folding-mediated assembly guides directional π - π stacking and cooperative interactions, enabling the formation of stable curved architectures. Notably, the resulting nanotubes exhibit multidirectional exciton migration—both along the tube axis and around its circumference—revealing a new molecular design strategy for advanced optoelectronic materials.

Image credit & source link: Professor Shiki Yagai from Chiba University, Japan

Image license: Original content

Usage Restrictions: Credit must be given to the creator.

In biological systems, especially for protein molecules, the formation of nanotubular structures is often guided by molecular folding. The folding process organizes interaction sites and enables the formation of complex architectures with high structural precision. However, translating that principle to synthetic small-molecule systems has remained challenging.

In a recent study, a team of scientists led by Professor Shiki Yagai from the Graduate School of Engineering, Chiba University, Japan, reported that π -luminophore dyads can overcome this limitation and assemble into well-defined supramolecular nanotubes with unusual excitonic properties. The team included Dr. Takumi Aizawa (currently an Assistant Professor at Aoyama Gakuin University; who conducted this work as a Ph.D. student at the Graduate School of Science and Engineering, Chiba University); Dr. Hikaru Sotome from the Graduate School of Engineering Science, The University of Osaka, Japan; Professor Martin Vacha from the Department of Materials Science and Engineering, Institute of Science Tokyo, Japan; and Dr. Go Watanabe from the School of Frontier Engineering, Kitasato University, Japan. Their research findings were published online in the [*Journal of the American Chemical Society*](#) on April 01, 2026. *“Diphenylanthracene (DPA) derivatives are sterically demanding and were previously considered to be aggregation-incompetent. We wanted to see if they can be programmed to form highly ordered supramolecular nanotubes through folding-mediated self-assembly,”* mentioned Prof. Yagai.

The team synthesized a series of artificial molecules capable of adopting folded conformations. The central aromatic unit was systematically expanded from terphenylene to diphenyl-naphthalene and finally to DPA. They examined how these structural variations influenced molecular folding, as well as the resulting assembly structures and properties. X-ray and neutron scattering techniques were used to analyze how folded molecules assemble into nanotubes, while polarized UV-vis and infrared spectroscopy provided detailed insights into their internal organization.

The study showed that the terphenylene-based system formed twisted ribbon-like structures, the diphenyl-naphthalene derivative generated curved assemblies including helical coils and toroids, and the DPA analog produced hollow cylindrical nanotubes. The researchers attributed this structural progression to folding-assisted directional π - π stacking combined with cooperative hydrogen bonding. These together directed the curved supramolecular assembly, enabling the emergence of complex nanotubular structures. The study also confirmed that in concentrated solutions, the nanotubes can be arranged to form luminescent fibers that reach several centimeters in length.

Molecular simulation results showed that a stable nanotube is achieved when DPA units adopt alternating tilts within stacked toroidal layers. This arrangement generates a herringbone-like chromophore wall, relieving stacking frustration and stabilizing the curved tubular architecture. The alternating molecular tilt thus proves to be a key structural principle underlying nanotube stability.

The research team also investigated energy transfer within these spontaneously assembled, intricate tubes. While it was previously known that energy is transferred along the length of such tubular structures, directional energy transfer has not been well evaluated. In this case, the nanotubes displayed multidirectional exciton migration. Unlike many one-dimensional

supramolecular assemblies, where energy transport is mainly expected along the longitudinal axis, these nanotubes enabled exciton motion both along the tube axis and around its circumference. Time-resolved fluorescence anisotropy measurements indicated exciton migration lengths of about 55 nm in the axial direction and about 11 nm circumferentially. This behavior links supramolecular topology directly to energy-transport function and suggests that closed tubular chromophore packing can support more complex excitonic dynamics than conventional linear stacks.

This study revealed a fundamental design principle for constructing curved microstructures, such as rings, helices, and tubes, that have been difficult to achieve by conventional approaches. This can be achieved by controlling the interaction sites and orientations during molecular assembly through folding.

Molecular design based on such folding is expected to provide new guidelines for creating artificial nanostructures that mimic the sophisticated organization seen in proteins. The nanotubes obtained in this work exhibited three-dimensional energy transport within their interiors. *“Molecular assemblies with such energy-transfer capabilities can be developed for applications in organic materials that utilize light energy, including artificial photosynthesis and highly efficient luminescent systems,”* concluded Prof. Yagai.

To see more news from Chiba University, click [here](#).

About Professor Shiki Yagai from Chiba University

Dr. Shiki Yagai is currently a Professor at the Graduate School of Engineering, Chiba University, Japan. He received his PhD from Ritsumeikan University, Japan, in 2002. His research focuses on supramolecular materials based on functional dyes and π -conjugated systems, supramolecular polymers, supramolecular gels and liquid crystals, photoresponsive molecular assemblies, organic solar cells, and luminescent mechanochromic materials. He has published more than 200 papers that have been cited more than 9,804 times. He leads the “Materials Science of Meso-Hierarchy” project (<https://mesohierarchy.jp/en/>), supported by a Grant-in-Aid for Transformative Research Areas from the Japan Society for the Promotion of Science (JSPS) KAKENHI program.

Funding:

SasView contains code developed with funding from the European Union’s Horizon 2020 research and innovation programme under the SINE2020 project (grant agreement No. 654000), and the MD simulations were implemented using the supercomputers of the Research Center for Computational Science in Okazaki (24-IMS-C038 and 25-IMS-C039) and Grand Chariot at Hokkaido University through the HPCI System Research Project (hp240115 and hp250108), while the work was supported by the Japan Society for the Promotion of Science (JSPS) KAKENHI grants (JP22H00331, JP23H04873, JP23H04875, JP23H04877, JP24H01727) under the Grant-in-Aid for Transformative Research Areas “Materials Science of Meso-Hierarchy,” as well as by Japan Science and Technology (JST) ACT-X (JPMJAX23D3), JST CREST (JPMJCR24S1 and JPMJCR23O1), and the IAAR Research Support Program at Chiba University, with Takumi Aizawa acknowledging JSPS for a research fellowship for young scientists (21J21037) and Takuho Saito and Hiroki Itabashi acknowledging JSPS fellowships

(21J20988, 24KJ0529). STFC is acknowledged for the allocation of SANS beam time at ISIS, RAL plus consumables and travel via experiment numbers RB2220130 and RB2320271.

Reference:

Title of original paper: Folding-mediated self-assembly of sterically demanding π -luminophore dyads into nanotubes exhibiting multidirectional exciton transport

Authors: Takumi Aizawa^a, Hironari Arima^a, Sota Mihara^a, Takahiro Ueno^a, Shotaroh Yoshii^a, Takuho Saito^a, Hiroki Itabashi^a, Sougata Datta^b, Hiroki Hanayama^c, Akira Sakamoto^d, Rintaro Shimada^d, Sarah E. Rogers^e, Martin J. Hollamby^f, Takashi Kajitani^g, Yoshiki Ishii^h, Go Watanabe^h, Koji Harano^{i,j}, Takuma Matsumoto^k, Nithin Pathoor^k, Martin Vacha^k, Hikaru Sotome^l, and Shiki Yagai^{b,c}

Affiliations: ^aDivision of Advanced Science and Engineering, Graduate School of Science and Engineering, Chiba University, Japan

^bInstitute for Advanced Academic Research (IAAR), Chiba University, Japan

^cDepartment of Applied Chemistry and Biotechnology, Graduate School of Engineering, Chiba University, Japan

^dDepartment of Chemistry and Biological Science, College of Science and Engineering, Aoyama Gakuin University, Japan

^eISIS Pulsed Neutron Source, Rutherford Appleton Laboratory, UK

^fDepartment of Chemistry, School of Chemical and Physical Sciences, Keele University, UK

^gCore Facility Center, Research Infrastructure Management Center, Institute of Science Tokyo, Japan

^hDepartment of Data Science, School of Frontier Engineering, Kitasato University, Japan

ⁱCenter for Basic Research on Materials, National Institute for Materials Science, Japan

^jResearch Center for Autonomous Systems Materialogy (ASMat), Institute of Integrated Research, Institute of Science, Japan

^kDepartment of Materials Science and Engineering, Institute of Science Tokyo, Japan

^lDivision of Frontier Materials Science, Graduate School of Engineering Science, The University of Osaka, Japan

Journal: *Journal of the American Chemical Society*

DOI: [10.1021/jacs.6c00854](https://doi.org/10.1021/jacs.6c00854)

Contact: Shiki Yagai

Graduate School of Engineering, Chiba University

Email: yagai@faculty.chiba-u.jp

Academic Research & Innovation Management Organization (IMO), Chiba University

Address: 1-33 Yayoi, Inage, Chiba 263-8522, Japan

Email: cn-info@chiba-u.jp

Hikaru Sotome

Graduate School of Engineering Science, The University of Osaka

Email: hikaru.sotome.es@osaka-u.ac.jp

Public Relations Division, Institute of Science Tokyo

Address: 2-12-1 Ōokayama, Meguro, Tokyo 152-8550, Japan
Email: Media@adm.isct.ac.jp

Office of Public Relations, Kitasato University
Address: 5-9-1 Shirokane, Minato, Tokyo 108-8641, Japan
Email: kohoh@kitasato-u.ac.jp