processing could form supramolecular physical attractions with the fullerene derivatives, thereby suppressing fullerene aggregation. Consequently, the BF7-incorporated PCBM-based solar cells exhibited improved efficiency and greatly improved thermal stability. If BF7 is introduced as a nonvolatile additive to the representative NFA-based OSC of a PM6:Y6 active layer, the perfluorophenyl C6F5 moieties in BF7 would induce F-F, F-H, and F-π interactions with the difluorophenyl-based FIC-end-groups of Y6, thereby modulating the phase segregation and crystallization of Y6 and PM6 for improved PCE and thermal stability. With 0.5- wt% BF7 in the active layer, the efficiency of the PM6:Y6-based device was enhanced dramatically to 17.01% from 15.16% of that without BF7. Moreover, 97% of the best efficiency could be maintained after isothermal heating at 100 °C for 72 h.

The evolution of PM6:Y6 thin-film morphology with and without BF7 additive was highly correlated with device performance, and the stability was thoroughly investigated by U-Ser Jeng (NSRRC) and his coworkers including Chun-Jen Su at TLS 23A1; these researchers used grazing-incidence time-resolved wide-angle X-ray scattering (GIWAXS) measurements with in situ annealing and grazing-incidence small-angle X-ray scattering measurements (GISAXS), as shown in Fig. 2. The experimental results demonstrated that the underlying mechanism of the double-effects of BF7 was associated with delicately controlled phase segregation and crystallization of the acceptor Y6 from the weakly ordered networks of the polymer donor PM6 through the selective supramolecular interactions of BF7 with Y6 to form a Y6-BF7 ordered complex of higher thermal stability than that of neat Y6 crystallites. The theoretical calculations consistently revealed preferred F-π noncovalent supramolecular interactions between the perfluorophenyl moieties of the nonvolatile additive BF7 and the difluorophenyl-based FIC end groups of Y6. In addition, they found that BF7 could have similar bifunctional effects of improving PCE and thermal stability on another well-known OSC system of PM6:IT-4F with the small-molecule acceptor IT-4F of similarly featured FIC end-groups.

In summary, the improvement of OSCs is primarily dependent on the rapid development of superior NFA n-type materials. The control and optimization of the morphology of the NFA:polymer blends through supramolecular interactions can further improve the efficiency and impart morphological stability against thermal heating. The study of morphological evolution plays a crucial role in understanding the mechanism of molecular packing under the influence of an additive. The GIWAXS and GISAXS techniques at TLS 23A1 used by Jeng and his coworkers offer insightful information on the nanostructures of the organic thin films. (Reported by Yen-Ju Cheng, National Yang Ming Chiao Tung University)


**TLS 23A1 Small/Wide Angle X-ray Scattering**
- GIWAXS, GISAXS
- Materials Science, Thin-film Chemistry.

**References**

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**Orientalional Control of Artificial Water Channels by Water-Induced Self-Assembly**

*Water-induced self-assembly (WISA) is a smart approach to control the dual-axis alignment of soft water channels.*

Transport of water in cell membrane systems is well known to occur along Aquaporin channels. Thus, channels with a diameter of ~0.25 nm only allow the transport of water while simultaneously preventing the passage of other solutes. This selectivity mechanism is based on size exclusion, electrostatic repulsion, and water-molecule dipole reorientation.

Currently, most studies on biomimetic membrane technology are based on this concept. Artificial water channels are typically composed of a water-permeable central pore surrounded by an external hydrophobic shell.
To prepare bioinspired artificial water channels, Chien-Lung Wang (National Yang Ming Chiao Tung University), Kuan-Yi Wu (Chinese Culture University), and Wei-Tsung Chuang (NSRRC) cooperatively developed an amphiphilic discotic molecule (AD) with a hydrophilic core and a hydrophobic shell (Fig. 1). Disk-like AD molecules can form a liquid crystalline (LC) phase of hexagonally packed columns. As water can interact with the hydrophilic pore of the AD molecules via hydrogen bonding, artificial water channels can be formed in the columnar arrays. However, the orientational control of the highly ordered LC phase remains challenging, especially in a large area. They proposed that the dynamic interaction between water and the hydrophilic core of AD enables water to not only act as a morphological modulator that manipulates the phase stability and morphology but also as an orientational director that controls the growth direction and orientational order of the amphiphilic LC. This phenomenon is the so-called water-induced self-assembly (WISA).

To confirm the orientational control of artificial water channels by WISA, they designed a cell and then inserted water on the left side of the supercooling melt sample at 57 °C (Fig. 2(a)). In Fig. 2(b), the polarized optical microscopy (POM) image reveals that the LC growth direction is along the normal of the AD–water interface, indicating a guiding field to direct the orientation of LC nucleation and growth. The 2D grazing-incidence X-ray diffraction (GIXRD) patterns (Fig. 2(c)) reveal that the hexagonally packed columnar LC phase in the hydrated sample exhibits single-crystal-like orientation and that the column axis is parallel to the substrate according to this method. To change the aligned direction of the artificial water channels, the AD sample was inserted into the grid and then water was allowed to cover the surface (Fig. 2(d)). Water induces the column axis to be perpendicular to the substrate, as demonstrated by micro-beam small-angle X-ray scattering (SAXS) at the TPS 25A beamline.

Fig. 2: (a) Illustration of the planar growth of the hydrated LC structure of the AD via directional WISA and (b) the corresponding POM image. (c) Illustration of GIXRD measurement. (d) Illustration of the vertical growth of the artificial water channel array of the AD via the directional WISA and the corresponding microbeam SAXS pattern. (e) Probing depths of photoelectrons from C 1s and O 1s of the LC columnar structure of the AD and relative intensity areas of the hydrophobic (green) and hydrophilic (blue) segments of the AD in C 1s spectra and H2O (red) in O 1s spectra as functions of the probing depth. [Reproduced from Ref. 1]
In addition, depth-profiling X-ray photoelectron spectroscopy (XPS) analysis at the TLS 24A1 beamline was employed to prove whether water exists in the channels. By changing the photon energy of the incident X-ray, this XPS method can probe the chemical compositions of the surface at different depths (Fig. 2(e)). The C 1s and O 1s spectra can be decomposed into a C–C bond and a C=C bond, corresponding to the hydrophobic shell and a series of peaks from C–C–O, C=C=O, O–C=O, and O=C=C segments, which are attributed to the hydrophilic core. Furthermore, in the O 1s spectrum, the O–H signal of water is directly observed. The relative intensity areas corresponding to the hydrophilic cores and water increase with the increase in the depth, while the intensity areas corresponding to the hydrophobic shell decrease. This finding demonstrated that the hydrophilic core of the column can incorporate water molecules; hence, it may be used as artificial water channels to transport water molecules. The artificial water channel array of AD exhibits a salt rejection ratio of > 99.9% and a water permeability of 7.7 × 10^6 H_2O·channel−1·s−1, which is comparable to those of commercial thin-film composite membranes. ( Reported by Wei-Tsung Chuang)


**TPS 25A Coherent X-ray Scattering**

**TLS 24A1 XPS, UPS, XAS, APXPS**

- SAXS, WAXS, GIXRD, **In-situ** SAXS

- Supramolecular Chemistry, Artificial Water Channels, Amphiphilic Liquid Crystals

**Reference**


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**Stabilization of Lead-Reduced Metal Halide Perovskite Nanocrystals Through High-Entropy Alloying**

_A novel perovskite alloy doped with various metals is developed for environmentally friendly materials._

With the emergence of ambient intelligence in the 21st century, mobile devices and home automation have become ubiquitous. Technological innovations have enabled display technology to evolve beyond providing only display functions. Currently, humans can directly issue instructions to display systems through logic semiconductor technology, overcoming the binary nature of computers. Displays no longer provide only display functions. In addition, the production of commercial inorganic fluorescent materials requires an evaporation process that consumes considerable energy and exhibits a rigid structure. Colloidal metal halide perovskite (MHP) materials exhibit excellent optic properties and solution processability,

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_Scheme: The stacking-controlled colloidal synthesis of two-dimensional perovskites was achieved through a collaboration between the research team of Shih and Chiu. [Reproduced from Ref. 1]_