Characterization of Organic Porous Thin Films Fabricated at the Air/Liquid Interface Using Atomic Force Microscopy and Nano-FTIR Spectroscopy

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Abstract

Thin films of metal–organic frameworks (MOFs) and related materials are promising for applications in catalysis, sensing, separation, and electronics. For these implementations, precise control over crystallinity, orientation, and thickness is crucial. Although various films have been fabricated and investigated, the detailed structural characterization of pore regularity, defect types, and their distributions remains a challenge.
In this talk, I will present our recent efforts to investigate hydrogen-bonded organic framework (HOF) and MOF thin films fabricated at air/liquid interfaces. We employ atomic force microscopy (AFM) and infrared scattering-type scanning near-field optical microscopy (IR s-SNOM) with nano-FTIR capability. Molecular dynamics (MD) simulations have also been performed to corroborate the experimental findings and to gain insight into the self-assembly processes.
AFM imaging of HOF films revealed well-ordered honeycomb networks in multilayer structures (10–20 layers), indicating the presence of one-dimensional pore channels arising from the vertical alignment of building-block molecules [1]. MD simulations demonstrated that intermolecular hydrogen bonding and Coulomb interactions drive the formation of the horizontal network and vertical stacking, consistent with our experimental observations [2].
In MOF thin films, we resolved domain structures with lateral dimensions on the order of tens of nanometers. Nano-FTIR spectra suggest the presence of uncoordinated carboxylic acid groups, i.e., incomplete metal–ligand coordination, across the films. Slight variations in the fabrication process altered the types of defects or produced thicker domains with fewer uncoordinated groups [3].
These combined studies highlight how nanoscale imaging, vibrational spectroscopy, and simulation together provide deep insights into the structure and formation mechanisms of organic porous thin films.

References

[1] K. Yamanami *et al*., Langmuir 38 (2022) 1910.
[2] K. Matsui et al., AIP Advances 12 (2022) 105109.
[3] Y. Matsumoto et al., in preparation.

Figures

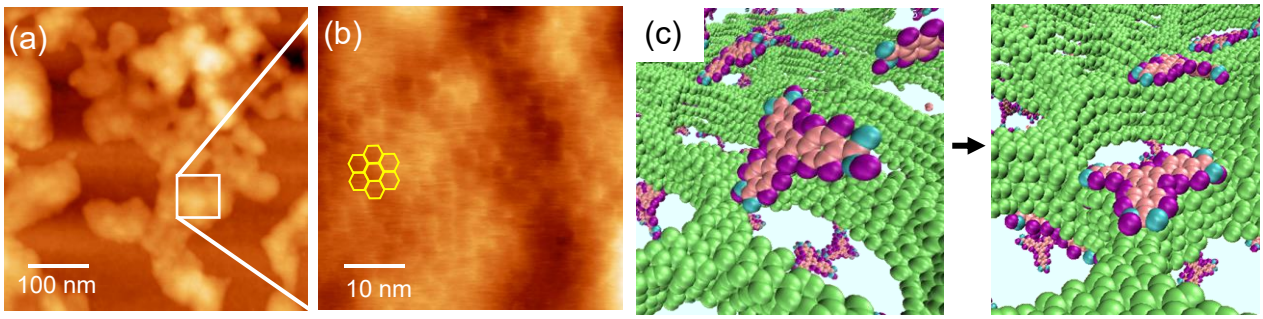

Figure 1: (a) AFM image of HOF film islands. (b) Enlarged image of the squared region in (a). (c) Snapshots from MD simulation.