# Confined single-molecule imaging by low-dose electron microscopy

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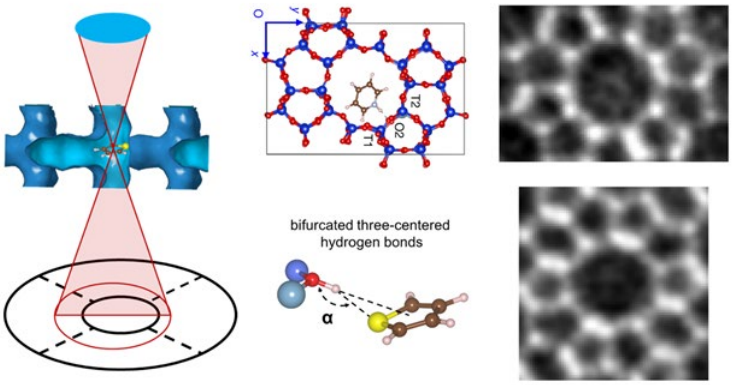
Single-molecule imaging with atomic resolution is a notable method to study various molecular behaviors and interactions. Although low-dose electron microscopy has been proven effective in observing small molecules., it has not yet helped us achieve an atomic understanding of the basic physics and chemistry of single molecules in porous materials, such as zeolites. The configurations of small molecules interacting with acid sites determine the wide applications of zeolites in catalysis, adsorption, gas separation, and energy storage. Here we report the atomic imaging of single pyridine and thiophene confined in the channel of zeolite ZSM-5. Based on integrated differential phase contrast scanning transmission electron microscopy (iDPC-STEM), we directly observe pyridines or thiophenes' adsorption and desorption behaviors in ZSM-5 under the in situ atmosphere. The adsorption configuration of a single pyridine or thiophene is atomically resolved and the S atoms in thiophenes are located after comparing imaging results with calculations. The strong interactions between molecules and acid sites can be visually studied in real-space images.

**Graphic:**




**Keywords:**

Single-molecule imaging, iDPC-STEM, zeolites

**Reference:**

[1] Wang HQ, et al. Atomic imaging of zeolite-confined single molecules by electron microscopy. Nature 607, 703-707 (2022).
[2] Wang HQ, et al. Imaging of Single Molecular Behaviors Under Bifurcated Three-Centered Hydrogen Bonding. Angew. Chem. Int. Ed. e202308675, (2023).

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