

Opening the Black Box: Operando Microscopy Transforms Nanofluidics

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Nanofluidics has long promised transformative applications in biosensing, energy, and information processing, but progress has been limited by the difficulty of observing molecular transport in confined geometries in real time. Operando microscopy is now transforming this landscape. By coupling high-speed, single-molecule-sensitive imaging with electrical, mechanical, and optical probes, we can directly watch how ions, biomolecules, and even quantum emitters behave inside nanofluidic devices. This ability to visualize transport and structural transitions as they occur is revealing unexpected mechanisms—such as electromechanical blistering in 2D channels, lumen-charge-controlled gating in protein pores, and liquid-activated emission in hBN that underpin new generations of robust sensors and ionic memristors. In this talk, I will show how operando microscopy is transforming nanofluidics from a “black box” discipline into a design-driven science, enabling reproducible device architectures, scalable iontronic circuits, and entirely new modes of quantum and molecular sensing.

References

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