

Mesoporous thin films: exploiting physics and chemistry in nanoconfinement

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The integration of sol-gel synthesis, self-assembly, and orthogonal functionalization provides a versatile platform for designing mesoporous thin films (MTFs) with tunable structural and surface properties. These films can be readily integrated into optical, electrochemical or microfluidic devices and can incorporate molecular, bioactive, or nanostructured functionalities, making them highly adaptable for diverse applications. In addition, the highly controlled mesopore size permits to communicate with vapor or liquid media, permitting exchange of physical or chemical signals through capillary condensation, perm-selective diffusion or electron transfer at interfaces.

MTF-based electrode platforms exploit nanoconfinement and chemical functionalization to achieve molecular sieving, selective exclusion, and preconcentration, thus enhancing signal modulation. MTF-based electrodes present perm-selective tunable behavior by exploiting electrostatic or steric effects. Electroactive MTFs also enable electro- and photo-assisted catalytic processes for the generation of solar fuels or organic synthesis, leveraging controlled transport, interfacial phenomena, and adjustable optoelectronic properties. The use of ultrafast spectroscopy permits us to understand the roles of the inorganic matrix and co-catalysts in the ultimate performance of the photoelectrodes, revealing complex behaviors.

In addition, MTF can stand as novel platforms to develop novel information transfer processes such as hypersound responsiveness or liquid-liquid communication. We will show how capillary effects, osmotic gradients and surface complexation lead to novel nanofluidic and signal transfer effects. By controlling local chemical and physical processes, new emergent phenomena can be achieved, such as inter-liquid communication or reaction-fueled macroscopic movement.

We will show that that by combining synthesis, advanced characterization, and modeling, we can indeed “program” properties from the molecular to the mesoscopic scale. This approach opens pathways to selective sensors, photoelectrocatalysts, biofunctional matrices, and intelligent materials capable of performing vectorial processes.

Recent references:

- Alvarez-Fernandez et al. *Acc. Mater. Res.* **2026**, 7, 88–99.
Cardozo de Oliveira et al. *Nano Letters* **2026**, 26, 1004-1010.
Pizarro et al. *Nano Letters* **2025**, 25, 5193–5199.
P. Vensaus et al. *ACS Appl. Eng. Mater.* **2024**, 2, 224–235
F. C. Herrera et al. *Chem. Mater.* **2023**, 35, 8009–8019