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Introduction to Advances in nanoporous metal films: production methods and applications

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The ability to precisely control the spatial arrangement, connectivity, and geometric characteristics of pores – collectively known as pore topology – at the nanoscale has fascinated material scientists for decades. This interest intensified following the discovery of ordered mesoporous silica materials such as MCM-41 and SBA-15 in the 1990s. By definition, nanoporous materials exhibit pore sizes smaller than 100 nm, while mesoporous materials, according to the IUPAC classification, feature pores in the 2–50 nm range. Although the terms 'nanoporous' and 'mesoporous' are often used interchangeably, mesoporous materials are technically a subset of nanoporous materials.

Nanoporous materials offer a significantly higher surface-to-volume ratio compared to their dense counterparts, enhancing or enabling a wide range of applications where surface area is a key factor. Following the discovery of mesoporous silica powders, research interests quickly expanded to other materials beyond silica, including metals, transition metal oxides, and more recently, metal–organic frameworks and covalent organic frameworks. Among these, nanoporous materials composed of metals and semiconductors (*e.g.*, transition metal oxides) are particularly promising, since they can be synthesized in diverse geometries – such as particles, wires, and thin films – by selecting the appropriate fabrication methods. Compared to nanoparticulate powders, nanoporous thin films offer several advantages including ease of fabrication and integration, precise control over thickness and porosity, reduced agglomeration, enhanced mechanical stability, and improved processability.

Inspired by early developments in mesoporous silica materials, where surfactants were used to create ordered porous structures, the first mesoporous thin films of Au and Pt were synthesized using surfactants as structure-directing agents. Advancements in surfactant chemistry, including cationic, anionic, nonionic (block copolymers), and amphiphilic compounds, have played a crucial role in the successful fabrication of nanoporous thin films. Another pivotal milestone in the field came with the anodization of valve metals, which enabled the formation of highly ordered, self-assembled nanoporous structures. While the electrochemical anodization of aluminium to create nanoporous alumina had been known for some time, it was not until the 1990s that researchers recognized the potential of anodic aluminium oxide templates for the templated growth of nanomaterials. These self-assembled nanoporous structures are also interesting for optical and photonic applications (*e.g.*, waveguides), electrochemical energy storage, or as selective membranes.

These advancements illustrate the continuous evolution of synthesis pathways for nanoporous thin films. Since these foundational developments, a wide variety of materials – including TiO_2, Si, ZnO, SnO_2, indium tin oxide, and CdS – have been synthesized in nanoporous thin film form.

The themed collection gathers papers on nanoporous metallic compounds (*e.g.*, Pt, Ag, CuSn and Al) and oxides (*e.g.*, titania, tantalum oxide, zinc oxide and cobalt oxide), along with their thorough characterization. These materials demonstrate broad applicability, ranging from pollutant photodegradation and gas sensing to energy-related uses such as electrodes for supercapacitors and electrocatalytic water splitting. The synthesis methods featured in this collection are very diverse, underpinning the immense evolution of methodologies in the field, including anodization, colloidal crystal templating, galvanic displacement, plasma treatment of predeposited metal nanoparticles over a polymer layer, dealloying, evaporation-induced

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self-assembly (EISA) mechanism *via* dip-coating, and the use of self-assembled block copolymer template films.

Looking ahead, we anticipate that the field of nanoporous thin films will continue to expand, driven by emerging scientific trends and technological demands. Key areas of growth include electronics and optoelectronics (*e.g.*, flexible and wearable sensors), energy storage and conversion (*e.g.*, batteries, supercapacitors, fuel cells, and solar cells), environmental sustainability (*e.g.*, water purification, chemical sensors and carbon capture), and biomedical applications (*e.g.*, biosensors and implantable devices). Additionally, artificial intelligence and machine learning-driven material discovery are expected to accelerate the identification of novel nanoporous thin films, leading to new breakthroughs in the near future.