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Designing Macroporous-Mesoporous Adsorbents for Sustainability

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Nanoporous materials offer significant advantages for application as selective sorbents, catalysts or nanocarriers for biomedical technologies, owing to their high specific surface area and well-calibrated pores large enough to perform reactions or processes involving adsorption and diffusion of bulky species. Here, we discuss synthesis concepts for the design of functional nanoporous materials containing both mesopores and macropores, that could offer interesting prospects for separation technologies. Emphasis is placed on hierarchically-porous monolith and powder sorbents for critical materials recovery and pollutant removal.
Monolithic macroporous-mesoporous silica generally exhibits high surface area for adsorption, and silica monoliths display exceptional adaptability, due to the range of options for functionalization and excellent tunability in terms of pore size, pore volume, and framework structure. Furthermore, hierarchically-porous monoliths have superior mass transport properties compared to traditional particulate adsorbents.[1] This attribute permits large volumes of feedstock to be rapidly processed through the sorbent, greatly elevating the potential scalability of the system, circumventing issues such as pressure buildup and column clogging. Recently, we described a way to use designed (powdered) hierarchically porous monoliths in practical, scalable metal extraction systems. We apply the sorbents in continuous flow columns for Scandium extraction at conditions realistic for industrial use (Fig 1).[2]
Covalent organic frameworks (COFs) are also of great potential as adsorbents owing to their tailorable functionalities, low density, and high porosity. However, their intrinsically stacked 2D structure limits the full use of their surface for sorption, especially the internal pores. The construction of ultrathin COFs could increase the exposure of active sites to the targeted molecules in a pollutant environment. We show that an ultrathin COF can be prepared with uniform thickness of ca. 2 nm employing graphene as the surface template [3]. The resulting hybrid aerogel with ultralow density (7.1 mg cm-3) has the ability to remove organic dyes of different sizes with high efficiency (Fig. 2). The 3D macroporous structure and well-exposed adsorption sites permit rapid diffusion and efficient adsorption of organic pollutants, greatly contributing to an enhanced uptake capacity.

References:
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