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Crystal Engineering with Angstrom Precision: Nanoporous Graphene Membranes

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The single-layer graphene is the thinnest molecular barrier, impermeable to the smallest of molecules and ions.[1-4] To apply graphene as an ultrahigh-flux, molecular-sieving membrane, an idea that has fascinated many in the last decade, one needs to engineer graphene lattice, incorporating molecular-sized nanopores. For the separation of gases (for example, H_2 from CH_4), this entails a controlled etching of the graphene lattice such that the resulting pore-size is between 0.30 to 0.38 nm, and such that percentage of pores larger than 0.38 nm is less than a few ppm to obtain an attractive separation selectivity. This is one of the biggest bottlenecks in the realization of nanoporous graphene membrane. The state-of-the-art nanofabrication techniques are restricted to the resolution of a few nm. Etching methods relying on electron and ion-beams are neither scalable nor easy to control. In this context, I will share the development of a controlled carbon etching chemistry in our laboratory, leading to a pore-expansion rate of 1-3 angstrom/s, and a mean pore-size with a resolution of 1 angstrom [5,6]. I will discuss a novel method to fabricate large-area graphene membranes while completely avoiding a single crack or a tear. As a result, a record performance in the separation of H_2/CH_4 mixture was achieved. Overall, our approach opens the possibility to modulate the pore-size in graphene to tackle a wide-range of molecular separations.

Brief Biography Kumar is the GAZNAT Chair of Advanced Separations and a tenure-track Assistant Professor at the Institute of Chemical Sciences and Engineering (ISIC) at the École Polytechnique Fédérale de Lausanne (EPFL). His research group is developing novel routes to realize the nanoporous two-dimensional membranes with a precise control on the nanopore size and functionality. Kumar received his undergraduate degree in Chemical Engineering from the Indian Institute of Technology Bombay in 2005. Following this, he joined the global R&D division of Procter & Gamble in Kobe, Japan, where he worked on product design. Kumar joined the group of Michael Tsapatsis at the University of Minnesota in 2008 pursuing a PhD degree in chemical engineering, where he synthesized highly crystalline zeolite nanosheets (Science 2011). He joined the Strano group at the Massachusetts Institute of Technology (MIT) as a postdoctoral researcher in 2014 where he studied the effect of nanoconfinement on the phase transition of fluids (Nature Nanotechnology 2017).