Docket #: S18-205

Intrinsically microporous ladder-type Tröger's base polymers

For the first time, researchers in Prof. Yan Xia's laboratory have synthesized a new ladder type microporous polymide (PIM) by linking an arene-norbornene building block to a Tröger's base which can be used for high-performance gas separation membranes.

These PIMs are extremely rigid, solution processible with large Brunauer- Emmett-Teller (BET) surface areas (up to ~1000 m^2 g^{-1}), among the highest reported. The ladder polymer membranes exhibit outstanding thermal properties and gas separation performance and are easy to synthesize. Additionally, the ladder polymers are soluble in organic solvents such as chloroform, dichloromethane, etc., thereby making them amenable for fabrication into thin-film composite or integral-asymmetric membranes in flat-sheet or hollow fiber geometry. They are excellent candidate materials in a variety of industrial applications such as fluid separations for gas and liquid mixtures and sensors.

Stage of Development
Completed synthesis, characterization and gas transport properties of two prototype ladder polymers

Related Technologies from Xia Lab
Stanford docket S14-325 "Versatile synthesis of microporous, rigid, soluble, easily processed ladder polymers"

Applications

- **Membrane-based gas separation processes** such as:
  - Hydrogen recovery from petrochemical process streams
  - On-site nitrogen generation (O_2/N_2)
  - Acid gas removal from natural gas (CO_2, H_2S)

- **Fluid separation**
- **Sensors**

Advantages

- **Novel** - first report of arene-norbornene-Tröger's base-derived ladder polymers
- **Facile Synthesis**
- **Large BET surface areas** (up to ~1000 m^2 g^{-1}), among the largest reported.
- **Excellent mechanical properties**
- **High O_2/N_2 separation performance**
- **Strong molecular sieving properties** due to their highly contorted and rigid W-shaped dibenzocyclobutanorbornane and V-shaped Torger's base building blocks
- **Soluble in organic solvents** such as chloroform, dichloromeuthane, etc.,

Publications

- Abdulhamid, Mahmoud A., Holden WH Lai, Yingge Wang, Zexin Jin, Yew Chin Teo, Xiaohua Ma, Ingo Pinnau, and Yan Xia. "Microporous Polyimides from Ladder Diamines Synthesized by Facile Catalytic Arene–Norbornene Annulation as High-Performance Membranes for Gas Separation."*Chemistry of Materials* 31, no. 5 (2019): 1767-1774
- Ma, Xiaohua, Holden WH Lai, Yingge Wang, Abdulrahman Alhazmi, Yan Xia, and Ingo Pinnau. "Facile Synthesis and Study of Microporous Catalytic Arene-Norbornene Annulation–Tröger's Base Ladder Polymers for Membrane Air Separation." *ACS Macro Letters* 9, no. 5 (2020): 680-685.
- Ma, X., Pinnau, I., Holden, W.H. and Xia, Y., King Abdullah University of Science and Technology KAUST, 2022. *Intrinsically microporous ladder-type tröger's base polymers.* U.S. Patent Application 17/273,950.

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