3D-PRINTED ZEOLITE X GYROID MONOLITH ADSORBENTS FOR CO_2 CAPTURE

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ABSTRACT

The global challenge of climate change, driven predominantly by the rise in atmospheric carbon dioxide (CO_2) levels owing to human activities, requires effective CO_2 mitigation strategies such as carbon capture and storage (CCS) [1,2]. In this work, a cylindrical monolith featuring triply periodic minimum surface (TPMS) based gyroid sheet geometry with high surface area to volume ratio was 3D-printed using slurry composed of water washable photopolymer resin and zeolite X powder. The 3D-printing technique employed was digital light processing (DLP) because of its ability to print complex geometries with high resolution such as the gyroid sheet. Printed samples were calcined at three different temperatures (550, 700, and 800 ^oC) to remove the polymer, leaving behind zeolite X monoliths with minimal binder (3DPZX-550, 3DPZX-700, 3DPZX-800). 3DPZX-550 showed comparative CO_2 adsorption performance to zeolite X beads. It also demonstrated faster CO_2 adsorption kinetics than zeolite X powder and beads due to its structured continuous features of gyroid geometry and high density of smooth and continuous flow channels allowing for faster gas transport and low diffusional resistance. The time taken to reach a CO_2 adsorption capacity of 3.5 mmol/g was 77 min for 3DPZX-550, which was significantly lower than that for zeolite X powder (100 min) and beads (96 min). While showing sufficient mechanical strength of 0.24 MPa, 3DPZX-550 sample showed specific breakthrough time of 730 s/g under CO_2/N_2 mixture (15/85) in breakthrough test at flow rate of 20 ml/min, in contrast to powder (763 s/g) and beads (1059 s/g), thus showing faster kinetics till breakthrough. The equilibrium CO_2/N_2 selectivity for the zeolite monolith (3DPZX-550) varied from 328 (at 50 mbar) to 51 (at 1 bar) whereas, the powder sample exhibited selectivity values in the range of 294 (at 50 mbar) to 33 (at 1 bar). 3DPZX-550 also showed pressure drop of 14.5 Pa/m and 267 Pa/m at gas flow rates of 20 ml/min and 50 ml/min, respectively, which was significantly lower than the commercial beads (134 Pa/m and 446 Pa/m, respectively). This study showed a facile approach to 3D-printing monolith adsorbents with complex high porous topology for application in CO_2 capture.

KEYWORDS: 3D-printing, Zeolite, Gyroid, Adsorption, Carbon Capture

REFERENCES

[1] Gebremariam S, Varghese A, Kuppireddy S, AlWahedi Y, Dumée L, Karanikolos G. (2023). *Chem. Eng. J.*, 473, p. 145286.

[2] Varghese A, Kuppireddy S, Bhoria N, Singh S, Pokhrel J, Karanikolos G. (2021). *Chem. Eng. J.*, 420, p. 129677.