Synthesis, Pelletization, and Characterization of Metal Ion Modified Zeolite Adsorbents for Hydrogen Uptake in Fusion Fuel Cycle Applications

Abstract

The removal of trace hydrogen isotopes from helium purge gas is critical for the efficient operation of systems in the fusion fuel cycle of a nuclear fusion reactor. The current state-of-the-art systems in the fusion fuel cycle primarily utilize cryogenic adsorption processes with zeolites, which are costly, operationally demanding, and often exhibit limited hydrogen isotope uptake capacity [1]. Metal-ion-modified zeolites [2-3] offer a promising alternative to conventional zeolites, as they combine tunable adsorption properties, better isotope selectivity, and the potential for operation at greater than liquid nitrogen temperatures. This project proposes the synthesis of transition ion modified zeolite beads for application in the adsorber bed of fusion fuel cycle for effective removal of trace levels of hydrogen from helium. In addition, dynamic modelling of flow through porous media will be performed. The work integrates material synthesis, pelletization, characterization, and dynamic modeling, creating a workflow from material development to process-level performance prediction. The student is expected to work on advanced laboratory equipment, including high-energy ball mills, granulation systems, muffle furnaces, and microscopy techniques.

Deliverables
1. Synthesize metal ion modified zeolite beads (~ 30 grams) via ion-exchange and impregnation methods.
2. Pelletize the modified zeolites using suitable binders to form beads of ~ 3 mm diameter and evaluation of their mechanical strength.
3. Characterization of the synthesized materials
5. To develop and validate a two - dimensional model for flow through porous media

References:

1. V. Gayathri Devi, et al., Microporous and Mesoporous Materials, 385 (2025),113464.
2. V. Gayathri Devi, et al. Fusion Science and Technology, 80 (2024), 1031–44.
3. Georgiev PA, et al. Chemical Physics Letters, 449 (2007), 182–5.

Name of course with branch/discipline: Chemical Engineering / CAPD

Academic Project Requirements:

1) Required No. of student(s) for academic project: 1

2) Name of course with branch/discipline: M.E./M.Tech Other

3) Academic Project duration:

(a) Total academic project duration: 38 Weeks
(b) Student's presence at IPR for academic project work: 4 Full working Days per week

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