

# Tritium transport modeling at the pore scale in ceramic breeder materials using TMAP8

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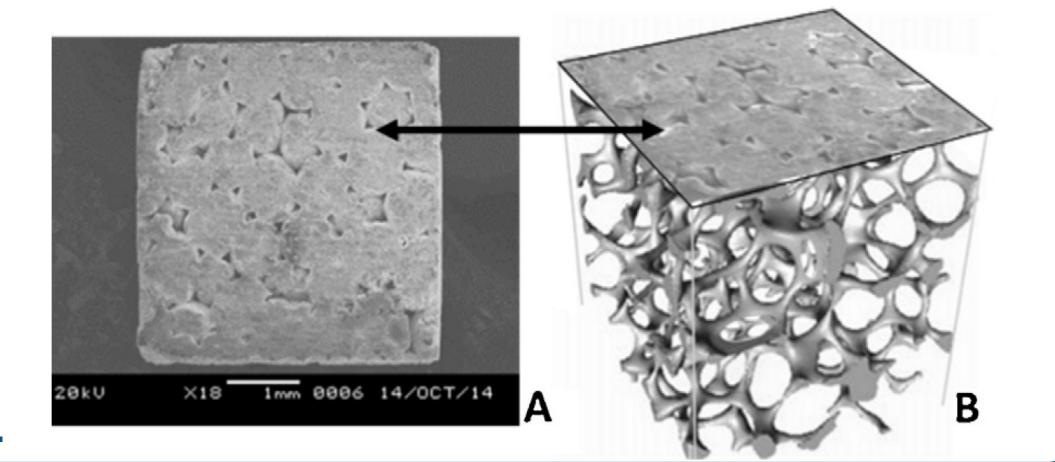
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## Introduction

- Fusion reactors rely on the blanket material to breed tritium at the same rate or faster than it is consumed.
- Cellular ceramic breeder (CCB) is a potentially transformative enabling tritium fuel cycle technology.
  - >90% theoretical density = higher tritium breeding ratio than pebble-bed ceramic breeders.
  - Network of highly interconnected pores that facilitate tritium release.
- We are developing a mechanistic, multiphysics model for tritium transport on the scale of the pores of the breeder material using the Multiphysics Object Oriented Simulation Environment (MOOSE) application TMAP8.



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## Modeling Approach

The tritium concentration in the ceramic is locally defined as

$$\frac{dc}{dt} = -\nabla \cdot (D_c \nabla c) + \dot{q} - \frac{dc_{trap}}{dt}$$

With the concentration of trapped tritium governed by

$$\frac{dc_{trap}}{dt} = K_t c(c_{trap}^0 - c_{trap}) - K_d c_{trap}$$

The surface absorption/desorption reactions are defined as  $XY(g) \to X(s) + Y(s)$   $rate: K_{g \to s}[XY](1-\theta)^2$   $X(s) + Y(s) \to XY(g)$   $rate: K_{s \to g}[X][Y]$  with X, Y = tritium or hydrogen and  $\theta$  as the fraction of used available sites.

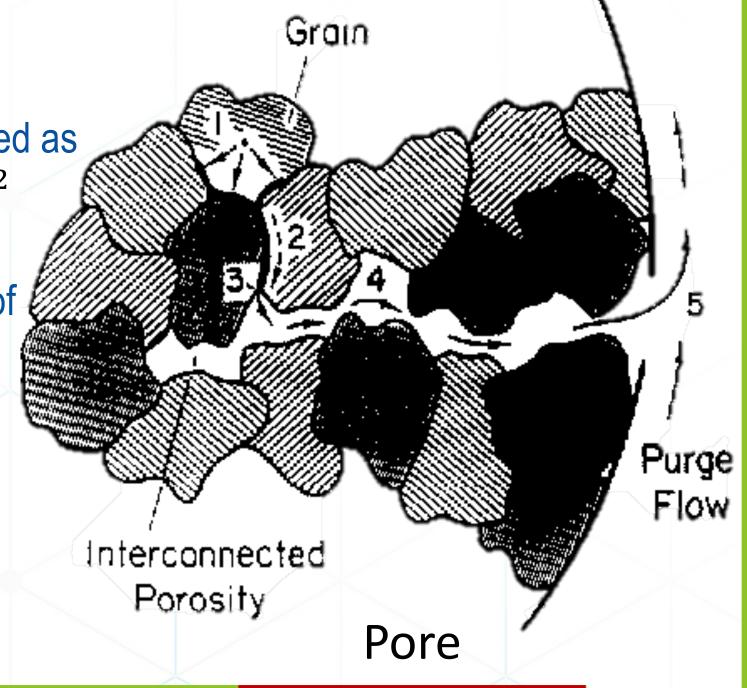
The gaseous molecules then diffuse out in the pore.

A 1D domain is used to perform a parametric study.

Ceramic material

### Mechanisms of Tritium Transport:

- 1. Intragranular diffusion + trapping
- 2. Grain boundary diffusion
- 3. Surface absorption/desorption
- Pore diffusion
- 5. Purge flow convection

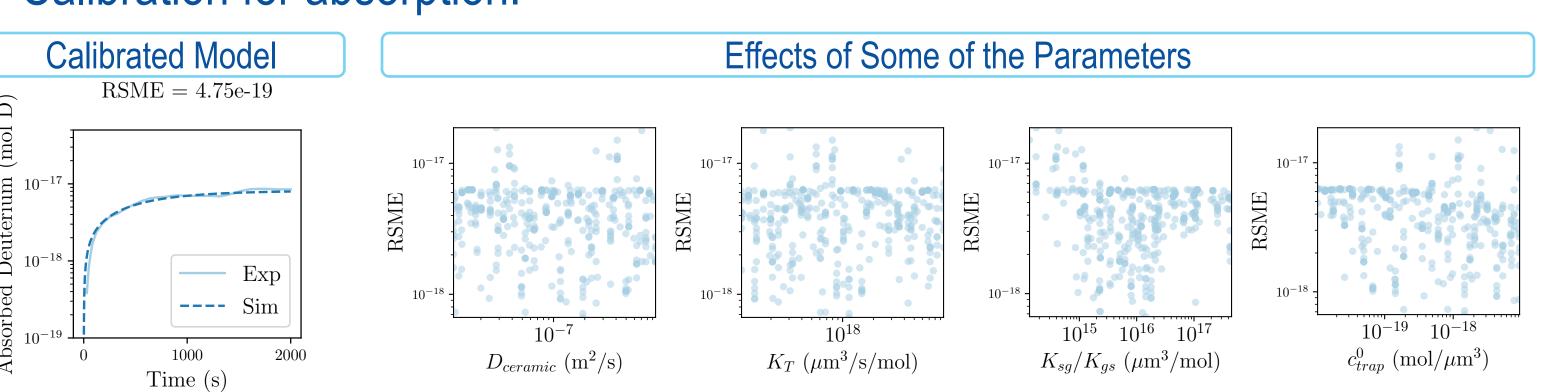


### gaseous molecules then diliuse out in the pore.

The model is calibrated by comparing its predictions to temporal experimental data. The quality of a prediction is measured with the root-mean-square error (RSME).

## Results

Calibration for absorption.



By performing a parametric study and comparing the model's predictions against experimental data, we calibrate the model and gain insights on the effect of each parameter.

## Conclusion and Future Work

- This modeling effort is crucial to track the tritium population in fusion reactors.
- This approach helps us calibrate a mechanistic model for tritium transport.
- Using more experimental data will help cross-calibrate the parameters.
- Investigating the effect of pore interconnectivity on tritium release in 2D and 3D geometries enabled by TMAP8 will be the focus of future work.

Sharafat et al. 2016. "Development of a new cellular solid breeder for enhanced tritium production." Fusion Engineering and Design 109–111 119–127. https://doi.org/10.1016/j.fusengdes.2016.03.041. Federici. 1989. "A Comprehensive Model for the Prediction of Tritium Behavior in Solid Breeder Materials During Steady-State and Transient Conditions." Ph.D. Dissertation, University of California.

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