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Pierre-Clement A Simon, Paul Humrickhouse, Alexander D Lindsay, Larry K Aagesen Jr

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Idaho National Laboratory
Idaho Falls, Idaho 83415

http://www.inl.gov

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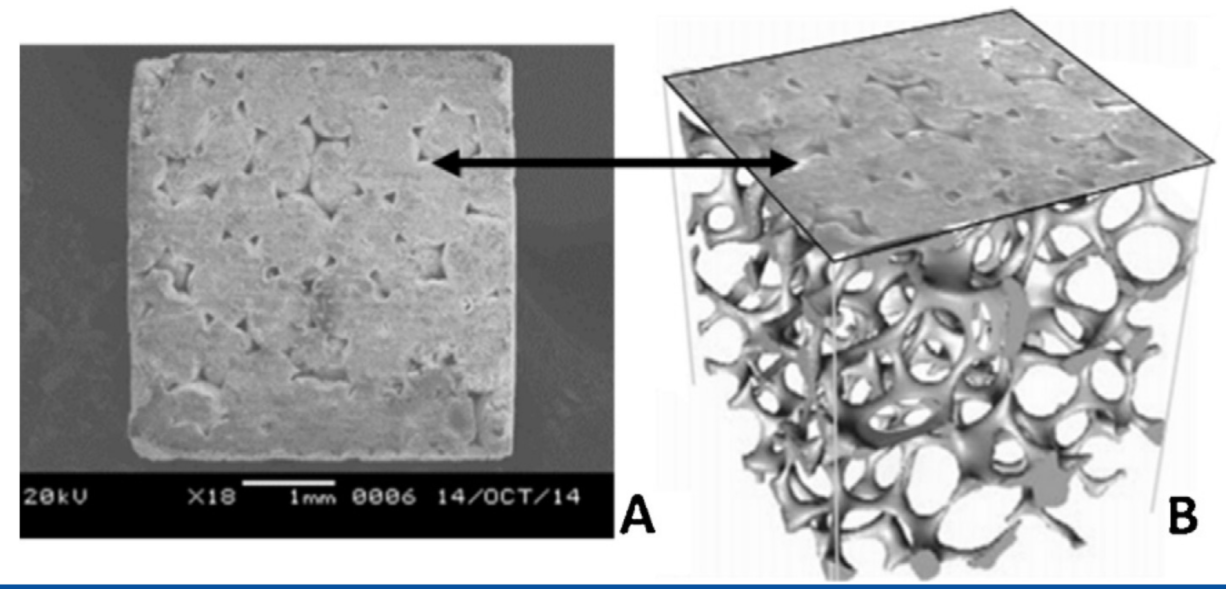
Introduction

- 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.



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

$XY(g) \rightarrow X(s) + Y(s)$ $rate$: $K_{g\rightarrow s} [XY](1-\theta)^2$

$X(s) + Y(s) \rightarrow XY(g)$ $rate$: $K_{s\rightarrow g}$ $[X][Y]$

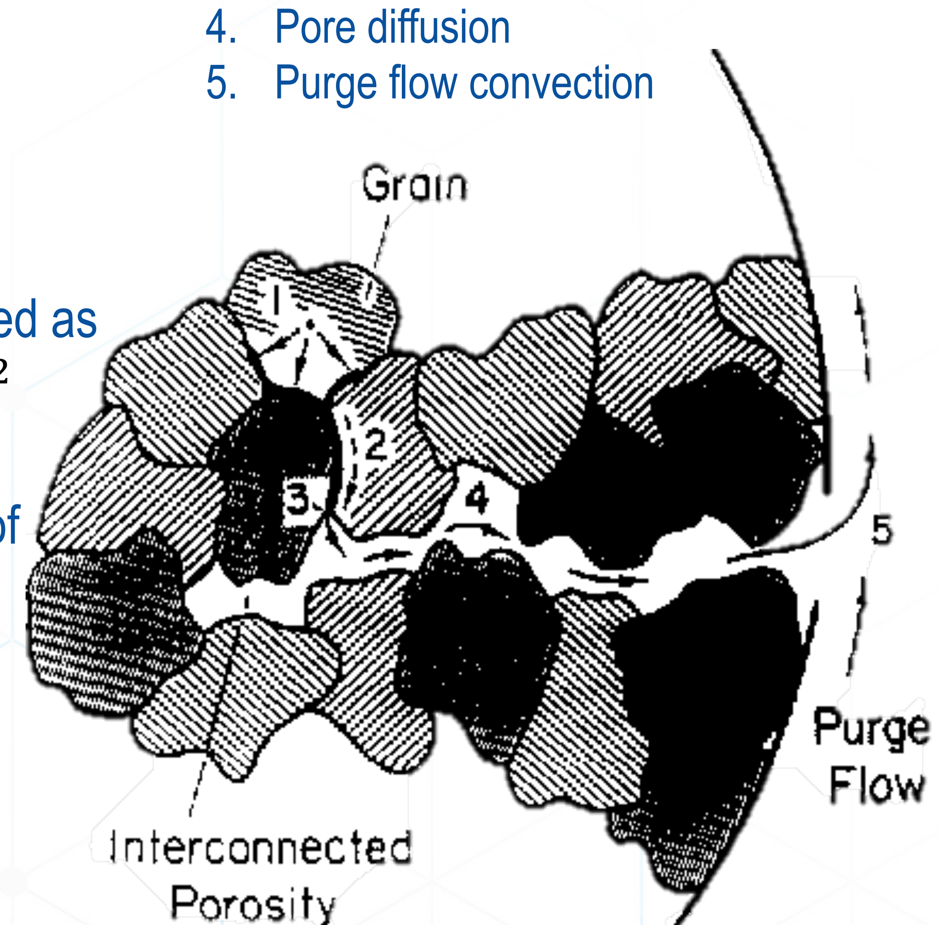
with X, Y = tritium or hydrogen and θ as the fraction of used available sites.

The gaseous molecules then diffuse out in the pore.

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

Mechanisms of Tritium Transport:

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



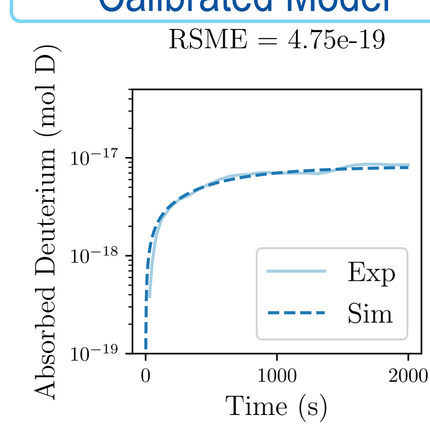
Ceramic material | Pore

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).

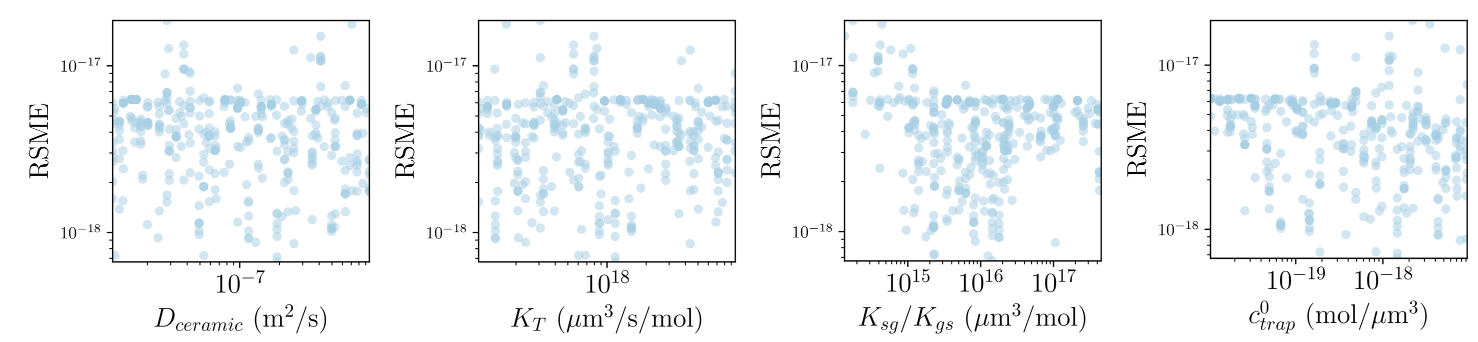
Results

- Calibration for absorption.

Calibrated Model



Effects of Some of the Parameters



- 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.

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Contact: pierreclement.simon@inl.gov

Idaho National Laboratory