Development of a New Cellular Solid Breeder for Enhanced Tritium Production

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A new high-performance cellular solid breeder is presented that has several times the thermal conductivity and is substantially denser compared with sphere-packed breeder beds. The cellular breeder is fabricated using a patented process of melt-infiltrating ceramic breeder material into an open-cell carbon foam. Following solidification the carbon foam is removed by oxidation. This process results in a near 90% dense robust freestanding breeder in a block configuration with an internal network of open interconnected micro-channels for tritium release. The network of interconnected micro-channels was investigated using X-ray tomography. Aside from increased density and thermal conductivity relative to pebble beds, high temperature sintering is eliminated and thermal durability is increased. Cellular breeder morphology, thermal conductivity, specific heat, porosity levels, high temperature mechanical properties, and deuterium charging-desorption rates are presented.

Keywords: cellular solid breeder, melt-infiltrated, micro-channels, interconnected porosity, enhanced tritium production.

1. Introduction

Lithium-containing ceramic breeder materials have been under development for several decades as a tritium breeding material and to convert energy into heat in solid breeder blankets. Early blanket conceptual design activities considered bulk ceramic breeder materials in form of sintered blocks [1-3]. However, the limited tritium recovery and thermal and radiation stability of sintered blocks, soon led to an alternative breeder configuration that of a pebble bed, where the breeder is in the form of small pebbles (0.5 to ~1.5 mm diam.) and mixed with even smaller pebbles (0.1 to 0.3 mm) in order to maximize packing fractions (PF). The fundamental issue of using a sphere-pack configuration is the low thermal conductivity and the inherently low PF (<72% dense) results in low lithium to structure volume fractions, which result in marginal tritium breeding ratios (TBRs).

A new cellular breeder material is presented here with substantially higher densities and thermal conductivities relative to pebble beds. The cellular breeder contains a network of interconnected micro-channels, which are engineered during the fabricated process and which facilitate tritium release rates similar to those of pebble beds. Aside from increased density and thermal conductivity, high temperature sintering is eliminated and thermal durability is increased due to the morphology of the cellular breeder. Cellular breeders can be fabricated using any lithium-containing ceramic material, however here we report on the development of lithium zirconate (Li_2ZrO_3) as the first cellular breeder with Li_2TiO_3 to follow shortly.

Previous analysis and experiments on sintered blocks identified thermal stress induced cracking, as a feasibility issue leading to physical and thermal integrity concerns [4]. However, the newly developed cellular material appears to be stronger in that it is capable of sustaining prototypical temperature gradients without cracking. Because tritium release is a critical aspect of the solid breeder, a substantial fabrication effort was focused on control of micro-channel size and we show that the diameters of the tritium micro-purge channels can be tailored to meet breeder density requirements. A series of deuterium thermal desorption tests were conducted at Idaho National Laboratory (INL), which showed that release rates are efficient and comparable to those of packed beds. These preliminary characterizations encourage further development of cellular breeder materials for solid breeder blanket applications.

2. Cellular Breeder Fabrication

2.1 Fabrication Process

Figure 1 shows the schematic of cellular breeder fabrication. The new breeder is constructed by casting breeder material into a highly porous open-cell carbon foam skeleton. The carbon skeleton is then removed by oxidation, leaving a three-dimensional (3D) network of finely spaced interconnected and open tritium purge channels. Processing begins with reticulated vitreous carbon (RVC) foam. Various pore sizes are available from 3 to 130 pores per linear inch (ppi). RVC foam is 3 vol.% dense (97% open porosity), independent of pore size. The

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thickness of the foam ligaments is then increased by infiltrated with carbon using chemical vapor infiltration (CVI) until the material reaches a desired density (~10 vol.%). This step allows to vary the purge channel diameter/volume. Next, the breeder material, in powder form, is heated above its melting point and melt infiltrated (cast) into the carbon foam. The final step is to burn out, oxidize the carbon foam, leaving behind an interconnected network of purge channels for tritium. Just a single infiltration step is needed to completely fill the void space in the foam. Components up to 30 cm square $\times$ 7 cm thick have been fabricated.

Fig. 1: Schematic of cellular breeder fabrication process.

2.2 Foam Protective Interlayer

Prior to melt-infiltration of the lithium-containing ceramic, a thin metal or ceramic interlayer is first applied to the foam to protect ligaments from reacting with the molten ceramic. A thin tungsten metal layer was applied by chemical vapor deposition to protect the foam during melt infiltration and to promote wicking of the molten ceramic. Figures 2A-C show 45- and 65-ppi tungsten-coated carbon foams used to fabricate cellular breeder specimens and a cut section of an individual 65-ppi carbon foam ligament coated with tungsten. The tungsten interlayer must be thick enough to prevent reaction between the underlying carbon foam and the lithium compounds but thin enough to prevent excessive strengthening of the foam. If the foam is too strong, stresses caused by thermal expansion mismatch with the lithium compound occur, resulting in micro-cracking of the lithium compound during solidification. The foam must be sufficiently weak that micro-cracking during solidification occurs in the foam ligaments rather than in the lithium compound. An optimal amount of tungsten of a few vol. % was established to prevent micro-cracking in the lithium compound. Some of the tungsten is removed during foam removal and the rest uniformly diffuses throughout the structure.

This tungsten should not inhibit permeation of hydrogen. However, neutron irradiation of this tungsten will create bulk defects that will retain tritium. The impact of tungsten on tritium release and microstructure evolution in the Li_2ZrO_3 cellular breeder material should be investigated further via neutron irradiation tests.

Fig. 2A-C: SEM images of W-coated carbon foams (A) 45-ppi, (B) 65-ppi, and (C) cut individual 65-ppi carbon foam ligament (dark triangle) with W (light coating).

2.3 Initial Cellular Breeder Samples

Through melt process optimization (temperature, pressure, time) and use of timed vibrations, Li_2ZrO_3 cellular breeder specimens with high overall densities of ~90% were produced. Figures 3A-D show SEM images of a Li_2ZrO_3 cellular breeder sample after removal of the carbon foam by oxidation. Li_2ZrO_3 was melt infiltrated into a 1" diameter $\times$ 0.180" thick carbon foam, after a thin tungsten interlayer was first deposited on the foam. The cellular breeder has an overall density of ~92.9% or a total porosity of about 8%, which consists of the micro-channels and closed pores. The channel spacing shown in Fig. 3 is similar to that in current pebble beds. The micro-channel width is about ~100 μm and the average cell diameter (Li_2ZrO_3) is ~850 μm , which translates to a maximum tritium diffusion length of ~425 μm . The geometric features of the Li_2ZrO_3 cellular breeder shown in Fig. 3 are relatively similar to those of pebble beds.

Fig. 3A-D: SEM images of nominally ~90% dense Li_2ZrO_3 cellular breeder development specimen [scale bars: 1-mm (A, C); 500- μm (B, D)].

3. Cellular Breeder Characterization

3.1 Tomography

Efficient tritium release, i.e. release by convection requires a stable network of interconnected micro-channels that lead to the free surface of the cellular breeder. To verify the network of interconnected micro-channels, several Li_2ZrO_3 cellular breeder samples were sent for micro-tomography scanning at the High-Resolution X-ray Computed Tomography Facility at the University of Texas at Austin [5], which has an X-ray

energy of 15 kV with a resolution of 5 μm . The dimensions of the 88.7% dense specimen were $0.165 \times 0.165 \times 0.071$ ", with a weight of 0.1289 g, a bulk density of 4.069 g/cm³, a tungsten density within the specimen of 0.386 g/cm³, and a Li₂ZrO₃ density within the specimen of 3.683 g/cm³. An SEM image of a specimen is shown in Figure 4A-B along with a superimposed tomography scan showing the structure of the interconnected micro-channels within the cellular breeder and Fig. 5 shows details of a tomography scan highlighting the structure of the interconnected micro-channels.

Fig. 4A-B: SEM image of cellular breeder (A) and tomography scan showing network of interconnected micro-channels (purg channels) within (B).

The micro-channels shown in Fig. 4 and 5 were made visible by post processing of tomography scans. It is interesting to note that the structure of the micro-channels is a “negative print” of the original carbon foam used for melt infiltration. The low level of closed porosity can be seen as small, scattered brown spots in Fig. 5.

Fig. 5: X-ray tomography scan Li₂ZrO₃ cellular breeder (65-ppi, 92.9% dense), showing structure of open interconnected micro-channels inside the breeder.

The maximum distance between tritium purge channels (micro-channels) in the cellular breeder is dictated by the pore size of the foam skeleton used during construction. To date, a foam pore size of 0.8 mm has been successfully used in cellular breeder fabrication, resulting in a maximum tritium diffusion distance of 0.4 mm (comparable to current solid breeder pebble

diameter). In future work, processing may be feasible using foam with a 0.5 mm pore size which is available, yielding a further reduced tritium diffusion distance of 0.25 mm.

3.2 Composition Analysis

Chemical analysis was performed to determine if the lithium content was reduced as a result of melt processing. The results of XPS compositional analysis for lithium, oxygen, zirconium, and carbon are shown in Table I. After melt processing, the lithium level did not appear to change significantly from that of the virgin Li₂ZrO₃ powder. The as received powder contains residual lithium carbonate, which is one of the precursors used to manufacture lithium zirconate. During melt processing the carbon content decreased, because most of the lithium carbonate impurity was removed during the purification process. The lithium content for all specimens was significantly higher than that of stoichiometric Li₂ZrO₃ (33 at. %) and the oxygen content was lower than that of stoichiometric Li₂ZrO₃ (50 at. %). The zirconium content of the cellular specimens was close to that of stoichiometric Li₂ZrO₃ (16 at. %). The compositional analysis showed that melt processing does not significantly alter the lithium concentration. The tungsten level in 90% dense cellular breeder samples 381T and 380T was determined by EAG using secondary ion mass spectroscopy to be ~2 at.% and ~0.6 at.%, respectively.

The IGA results for C and O content performed by EAG on the same three specimens are shown in Table II. The O content of the Li₂ZrO₃ cellular breeder specimens was virtually the same as that of the as-received Li₂ZrO₃ powder, similar to the results of oxygen analysis by XPS. The carbon concentration of the Li₂ZrO₃ cellular breeder specimens was slightly higher than that of the as-received powder, which is different from the results of C analysis by XPS in which the carbon concentration of the as-received powder was shown to be several times higher.

Table I: Compositional Analysis of Li₂ZrO₃ (at.%)

Specimen	Li	O	Zr	C
381T Cellular (93.0 % dense)	52.2	28.1	15.2	1.3
380T Cellular (90.5 % dense)	52.6	26.8	16.2	0.3
Li ₂ ZrO ₃ Powder(Alfa Aesar)	47.8	34.4	10.5	6.3

Table II: IGA Results for Cellular Li₂ZrO₃ (wt.%)

Specimen	Carbon	Oxygen
381T Cellular Breeder (93.0 %)	790	26
380T Cellular Breeder (90.5 %)	710	26
As received Li ₂ ZrO ₃ (Alfa Aesar)	600	25

3.3 Density Measurements

To determine the bulk density, which includes the solid material, the open porosity (interconnected micro-channels), the closed porosity within the bulk breeder material, the absolute density (which includes all solid material and closed pores), and the cellular porosity percentage, cellular breeder samples were sent for mercury intrusion porosimetry and He-pycnometry

testing. Virtually all specimens were estimated to be $\geq 90\%$ dense. The amount of tungsten was estimated using EDS compositional analysis. The Li_2ZrO_3 density was calculated by subtracting the tungsten density from the bulk density. Density data is summarized in Table III.

The residual tungsten inside the breeder ceramic may result in the formation of tungsten oxides, which are known to interact with hydrogen to form hydrates. However, in the presence of water or tritium oxide at elevated temperatures ($>550^\circ\text{C}$), tungsten oxides are reduced to the pure metal. It is well-known that in metallic form, tungsten does not inhibit permeation of hydrogen. The impact of tungsten on tritium release and microstructure evolution in the Li_2ZrO_3 cellular breeder material should be investigated further via neutron irradiation tests.

Table III: Densities of 65-ppi Cellular Breeders

Sample	Bulk (g/cm^3)	Tungsten (g/cm^3)	Li_2ZrO_3 (g/cm^3)	Density (%)
371T	4.135	0.386	3.749	90.3
374B	4.435	0.579	3.856	92.9
377T	4.255	0.482	3.773	90.9
378B	4.195	0.482	3.713	89.5
378T	4.318	0.579	3.739	90.0
380T	4.237	0.482	3.755	90.5
381T	4.437	0.579	3.858	93.0
382T	4.352	0.579	3.773	90.9

4 Thermal-Mechanical Properties

4.1 Thermal Conductivity

Two high density Li_2ZrO_3 cellular breeder specimens were tested for thermal conductivity from RT to 1200°C . Each contained 2–3 vol.% tungsten. Thermal diffusivity was determined using laser flash diffusivity and thermal conductivity (Fig. 6) was calculated using the measured specific heat and diffusivity data TPRL [6].

Figure 6: Thermal conductivity of 65-ppi Li_2ZrO_3 cellular breeder samples 371T (90.3% dense) and 378B (89.5% dense); Li_2ZrO_3 pebble bed data are shown for comparison.

4.2 Cyclic Compression Testing

Cyclic compression tests comprised three samples (380T, 377T, and 378T) on 90.5% dense, 65-ppi Li_2ZrO_3 cellular breeder material at room temperature and 750°C . All specimens were tested under a cyclic loading pattern of 5, 10, and 15 MPa. Two loading/unloading cycles were applied at each pressure at a constant loading/unloading rate of 1 MPa/min. Stress-strain curves for sample 378T is shown in Fig. 7. Nonlinear elastic behavior was observed for both the loading and unloading paths in all samples. After the completion of unloading, a residual strain appeared that increased with applied pressure.

Figure 7: Stress-strain curves for Li_2ZrO_3 cellular breeder at RT and 750°C (378T: 65-ppi, 90.0% dense).

For a peak load of 15 MPa, the maximum residual strain was 1.23%, whereas the residual strains for the peak loads of 5 and 10 MPa were 0.90% and 1.09%, respectively. Because of the material hardening effect, the modulus increased with applied load. The stress-strain data from the unloading paths were used to evaluate Young's modulus. A modulus of 1.9 GPa, 2.9 GPa, and 3.3 GPa were found at the peak loads of 5, 10, and 15 MPa, respectively. Table-IV lists the estimated Young's modulus at test temperatures and loads.

Table-IV: Young's Modulus of Li_2ZrO_3 Cellular Breeders

	Young's Modulus, GPa			
	Part 380T		Part 378T	
	Room Temperature	Part 377T	Run-1	Run-1
5 MPa	2.7(a)	1.6	1.4(b)	2.1(a)
10 MPa	4.2(a)	1.9	1.9(b)	3.1(a)
15 MPa	5.0(a)	2.1	2.5(b)	4.2(a)
750°C				
5 MPa	2.5	2		1.9
10 MPa	(c)	2.7		2.9
15 MPa	(c)	3.1		3.3

(a) Obtained after 750 C test; (b) Obtained before 750 C test; (c) Could not be determined due to specimen thickness

4.3 Applied Thermal Gradient

As a preliminary confirmation that Li_2ZrO_3 cellular breeder could withstand expected thermomechanical loads relevant to fusion reactor environments, testing was performed under high temperature operation ($\sim 600^\circ\text{C}$) and high thermal gradient ($\sim 40^\circ\text{C}/\text{mm}$) conditions. The thermal loads are expected to induce significant stress and

strain in the material. The tests were performed using the Zwick test stand with a customized piston rod (UCLA). A disk of Li_2ZrO_3 cellular breeder (sample 381T, 93% dense) was placed in the compression/tension test frame and placed under 400 N of compression. A furnace around the test frame was used to heat the sample to $\sim 600^\circ\text{C}$, and an auxiliary heater on the upper test frame piston was used to produce a temperature differential across the sample of $\sim 200^\circ\text{C}$. At steady-state average temperature and temperature gradient, the sample was loaded in compression to 5, 10, and 15 MPa with five cycles at each load (Fig. 8). The loading cycles were selected to first approximate the expected thermal stress loading in a fusion reactor environment (5 MPa) and then to successively increase to 10 and 15 MPa to approximate the expected maximum stresses.

Figure 8: Cyclic loading in force control (A) and crosshead displacement during cyclic testing (B).

Figure 9 shows average temperature as function of time (A) and temperature differential per millimeter developed across sample (B). The axial thermal expansion was $\sim 2.5\ \mu\text{m}$, or ~ 650 micro-strain. Based on previous tests in this program, the Young's modulus at these temperatures was expected to be ~ 5 GPa, leading to an estimated thermally induced stress of 3.25 MPa. After mechanical load cycling, the sample was removed and inspected and no changes were observed. The thermal gradient tests results indicate that the Li_2ZrO_3 cellular breeder material could withstand expected fusion reactor thermal loading conditions. The tests were not an exhaustive qualification of the material for use in a fusion environment, but serve only as an indication that the material merits further development.

Figure 9: Average temperature as function of time and temperature differential per millimeter developed across sample.

5 Deuterium Absorption-Desorption Test

To provide an initial indication of tritium diffusion in the cellular breeder, a deuterium absorption/desorption experiment was performed at INL. Personnel at the Safety and Tritium Applied Research facility at INL built a static

deuterium gas absorption system (SGAS) to evaluate deuterium gas absorption and desorption behavior in plasma-facing components under sub-atmospheric hydrogen/deuterium pressure (< 1 atm) at elevated temperature ($\leq 950^\circ\text{C}$). Ultramet delivered four 65-ppi Li_2ZrO_3 cellular samples ranged in density from 82 to 93 % (each specimen contained $\sim 0.5\ \text{g/cm}^3$ tungsten). Due to time constraints, only one Li_2ZrO_3 cellular breeder (P/N 382-1, 82% dense) was tested for deuterium absorption and desorption behavior. To remove residual moisture (H_2O), the sample was outgassed under vacuum ($\sim 1.3 \times 10^{-5}$ Pa) at elevated temperature (950°C) for more than 5 hours before the absorption test and then held under vacuum ($\sim 1.3 \times 10^{-5}$ Pa) at room temperature for more than 10 days.

Figure 10 shows thermal desorption behavior of deuterium-containing species (HD, D_2 , HDO, D_2O) after 950°C exposure with 720-Pa deuterium pressure. Because a calibrated source of HDO or D_2O was unavailable, the initial desorption behavior was performed without a calibrated source. A significant amount of H_2O , HDO, and D_2O existed in the Li_2ZrO_3 even after a 1-hour bake-out. Most of the deuterium-containing species were desorbed as HDO and D_2O and peaked at $\sim 500^\circ\text{C}$, whereas the HD and D_2 peaked at $\sim 700^\circ\text{C}$. The rapid release rates measured by INL indicate that the geometric features of the cellular structure do not inhibit deuterium release.

Figure 10: Desorption behavior of deuterium-charged cellular breeder sample 825 dense) following 950°C exposure with 720 Pa deuterium pressure for 2700 s.

6 Adjusting Cellular Morphology

6.1 Decreasing Breeder Cell Size

Tritium release rates are influenced by the length of the diffusion path from the center of a breeder cell to an open micro-channel.

To decrease the average tritium diffusion length, from the center of a breeder cell to an interconnected micro-channel a 65-ppi foam was used. The 65-ppi foam was chosen to take advantage of the smaller pore size ($400\ \mu\text{m}$

vs. 800 μm for 45 ppi), which leads to a shorter tritium diffusion distance in the finished cellular breeder

6.2 Tailoring Micro-Channel Diameter

Control of geometric features of the network of interconnected micro-channels is a critical aspect for optimization of cellular breeder material performance. For example, with an increase in channel diameter the density of breeding material decreases and thus tritium production will be reduced. On the other hand, if channels are too small, the purge flow pressure drop might become infinitively large. Two samples with different channel size were produced of $\sim 80\ \mu\text{m}$ and $\sim 150\ \mu\text{m}$ diameter, which increased the volume of the interconnected micro-channels by roughly a factor of 3.5 times.

6.2.1 Small Micro-Channels

Figures 11A-D show Li_2ZrO_3 cellular breeder fabricated using 65-ppi carbon foam but with no pyC, resulting in small-diameter tritium purge channels of about 80 μm . The material was estimated to be 88% dense, with the 12% porosity composed of 3% carbon foam/4% tungsten interlayer/ 5% residual porosity related to unfilled foam cells and small pores within the solid Li_2ZrO_3 . After additional process optimization, Li_2ZrO_3 cellular breeder was fabricated in excess of 90% dense.

Figure 11A-D: SEM images of Li_2ZrO_3 cellular breeder fabricated using 65-ppi carbon foam (88% dense) [scale bar: 1 mm (A), 500 μm (B – D)].

6.2.2 Large Micro-Channels

Figures 12A-D shows the Li_2ZrO_3 cellular breeder material made using 65-ppi carbon foam, but with a 10-vol% pyC coating, before application of the protective tungsten layer, as a means of increasing the foam ligament diameter, which ultimately increases the diameter of the network of interconnected passages (tritium purge channels). This approach demonstrated the tailor ability of the fabrication process through control of the foam ligament diameter as well as ppi (pores per linear inch). The material was estimated to be 78% dense, with a 22% porosity composed of the 3% carbon foam/10% pyC coating/4% tungsten interlayer/5% residual porosity related to unfilled foam cells and small pores within the

solid Li_2ZrO_3 . By depositing additional carbon on the foam ligaments, the internal passage diameter in the finished cellular breeder product increased from nominally 80 μm to 200 μm . The ability to tailor the passage diameter to maximize density for tritium generation while keeping purge flow pumping requirements reasonable is a unique characteristic of the cellular breeder.

Figure 12A-D: SEM of Li_2ZrO_3 cellular breeder material using 65-ppi C-foam coated with pyC (78% dense).

7. Breeder-Wall Contact

A major concern regarding solid breeder materials is maintaining wall-contact between breeder and cooling structures during operation. The cellular breeder is fabricated as a stand-alone block or mono-block configuration, which can be cooled by cooling tubes as shown in Fig. 14A-B.

Regarding the thermal contact between the cellular breeder and the structure, multiple options exist including establishing intimate contact between the two by allowing the breeder to expand into and contact the structure or by mechanical application of a low pressure to ensure contact. Diffusion bonding through brazing is also an option. A brazed interface would yield the greatest thermal contact but would also generate greater stress within the breeder, therefore the blanket would need to be designed to maintain breeder stress at an acceptable level. It should be noted that the cellular breeder offers significant advantages over a pebble bed in terms of thermal contact requirements. The Li_2ZrO_3 cellular breeder is thermally stable to near the 1750 $^{\circ}\text{C}$ fabrication temperature, therefore the cooling requirements are much less restrictive than those for the much lower use temperature pebble beds. In addition, the cellular breeder is nominally 90% solid (10% porous), therefore the surface area contacting the structure, whether through intimate contact or brazing, is far greater than the area of deformed pebbles contacting the structure in a pebble bed.

Fig. 14A-B shows a solid model of a cellular breeder mono-block with a coolant tube and coefficient of thermal expansion (CTE) contours as a function of temperature. The higher CTE of the F82H tube relative to the breeder

block results in positive contact forces. This configuration is similar to W-mono-blocks and Cu-tubing under development for divertor applications.

The CTE of the Li_2ZrO_3 cellular breeder is higher than that of F82H steel (F82H: $1.27 \times 10^{-5}/\text{K}$, Li_2ZrO_3 : $1.75 \times 10^{-5}/\text{K}$ at 700°C). Based on the thermal expansion mismatch, the gap between the coolant tube and the breeder mono-block can be tailored to create desired contact forces during operation.

Figure 14A-B: (A) Solid model of a cellular breeder mono-block and coolant tube; (B) CTE contours as a function of temperature in breeder and F82H tube.

8. Summary

A new cellular solid breeder material has been developed based on melt-infiltration of lithium-containing ceramic material into highly porous open-cell carbon foam. Following melt-infiltration and solidification the carbon foam is removed by oxidation. The process leaves a $\sim 90\%$ dense robust freestanding breeder material which contains an internal network of interconnected micro-channels for efficient tritium release. Thermal conductivity is substantially increased (2 to 3 times) relative to pebble beds; high temperature sintering is eliminated; and thermal durability is increased.

Processing conditions were established for fabrication of $\sim 93\%$ dense lithium zirconate (Li_2ZrO_3) cellular breeder material with adjustable micro-channel size and volume selected in accordance with tritium release requirements. High temperature ($\sim 750^\circ\text{C}$) cyclic compression tests demonstrated good structural integrity (no cracking) and low Young's modulus of < 5 GPa. Cyclic thermal testing with thermal gradients of about $40^\circ\text{C}/\text{mm}$ did not result in cracking, indicating good resistance to thermal stress caused by prototypical fusion relevant temperature loads. Deuterium absorption-desorption tests performed at INL demonstrated release rates that were comparable with those from pebble beds of similar characteristic T-diffusion lengths.

Thermo-mechanical characterizations, and deuterium-release data of the new cellular solid breeder material with a network of interconnected open micro-channels were presented. The higher density ($\sim 90\%$ solid) and the higher thermal conductivity (~ 2 to $3\times$) of the cellular breeder relative to pebble bed configurations, along with its efficient tritium release could enhance solid breeder blanket performance and increase tritium breeding ratios.

The cellular breeder can be fabricated in block configuration, which can be cooled using tubes with reliable contact by brazing or based on thermal expansion mismatch between breeder and steel tubes.

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