Synthesis of Porous $Li_{6.5}La_3Zr_{1.5}Ta_{0.4}O_{12}$(LLZO) for Nuclear Fusion Applications

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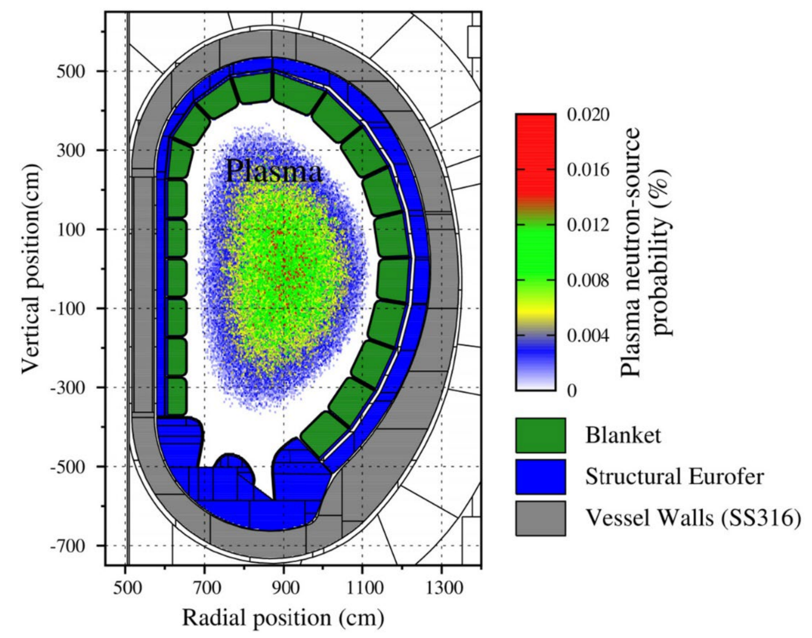
Background

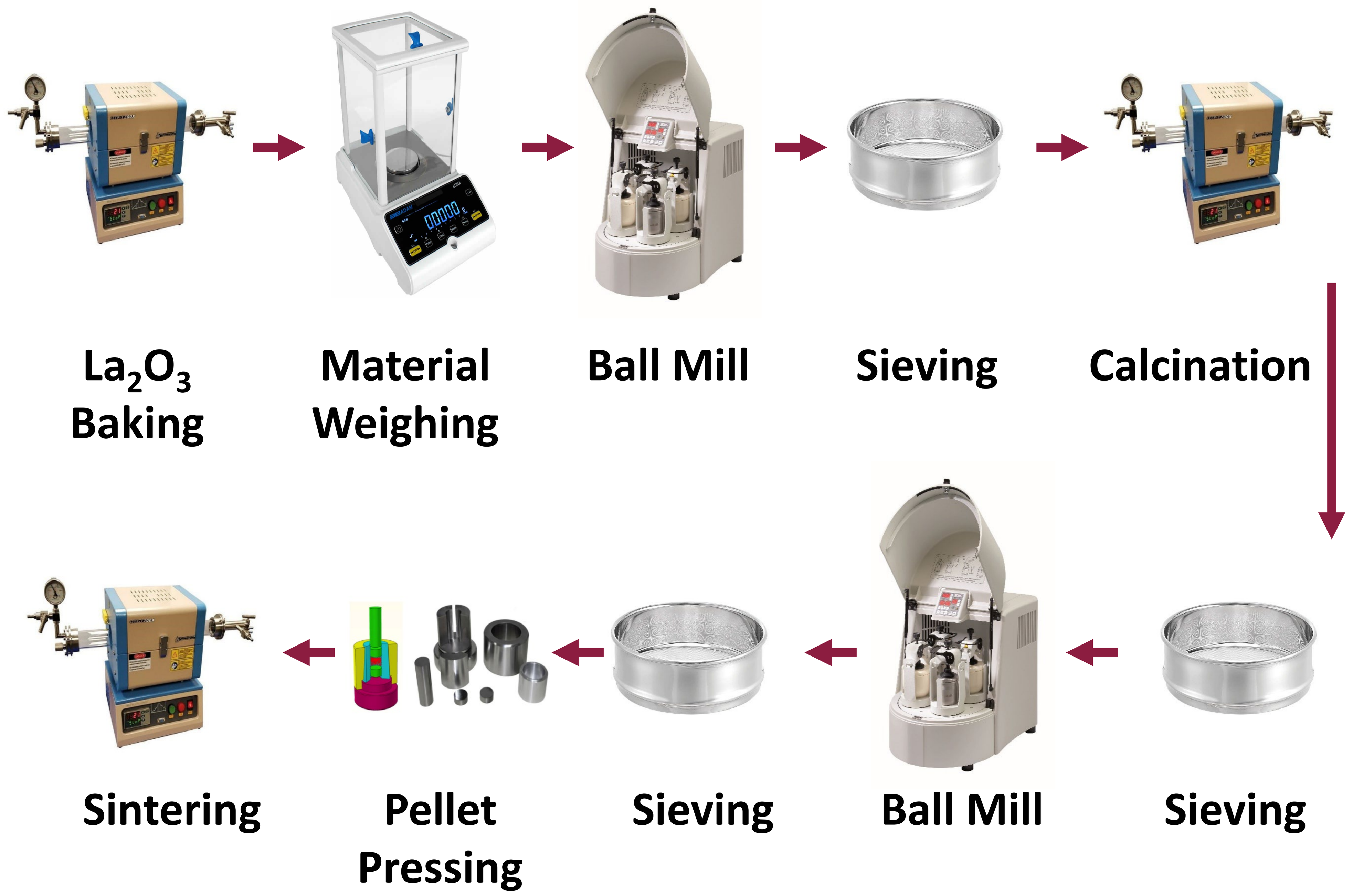
Future nuclear fusion reactors using the D-T cycle will require tritium, a radioactive isotope that does not exist naturally in significant quantities; to sustain operation, reactors must generate tritium internally through neutron interactions with lithium-containing materials. The aim of this research is to synthesize porous $Li_{6.5}La_3Zr_{1.5}Ta_{0.4}O_{12}$ (LLZO) pellets with desirable densities for use in future tritium breeding applications with the primary focus of understanding how synthesis conditions influence porosity, densification, and crystal structure. Tritium breeding blankets for nuclear fusion reactions can be potentially solved by creating a process to synthesize porous LLZO at desirable densities.

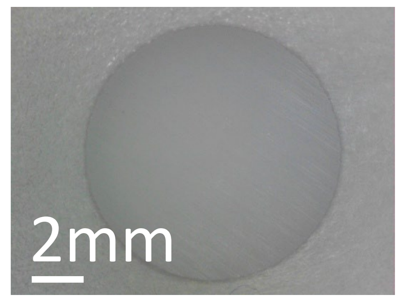


Model Fusion reactor simulation showing the Tritium Breeding blanked in dark green

Methodology

Solid-state synthesis is used to fabricate LLZO through the following procedure. Lanthanum Oxide(La_2O_3) is initially baked in a tube furnace to remove any water. Then La_2O_3, Lithium Hydroxide(LiOH), Zirconium Oxide(ZrO_2), and Tantalum Oxide(Ta_2O_5) are weighed, ball milled, sieved, and calcinated in a crucible. The calcinated powder is then sieved, ball milled and sieved again before being pressed into pellets in a die by a hydraulic press. Once the pellets have been pressed, they are put in another crucible and sintered.

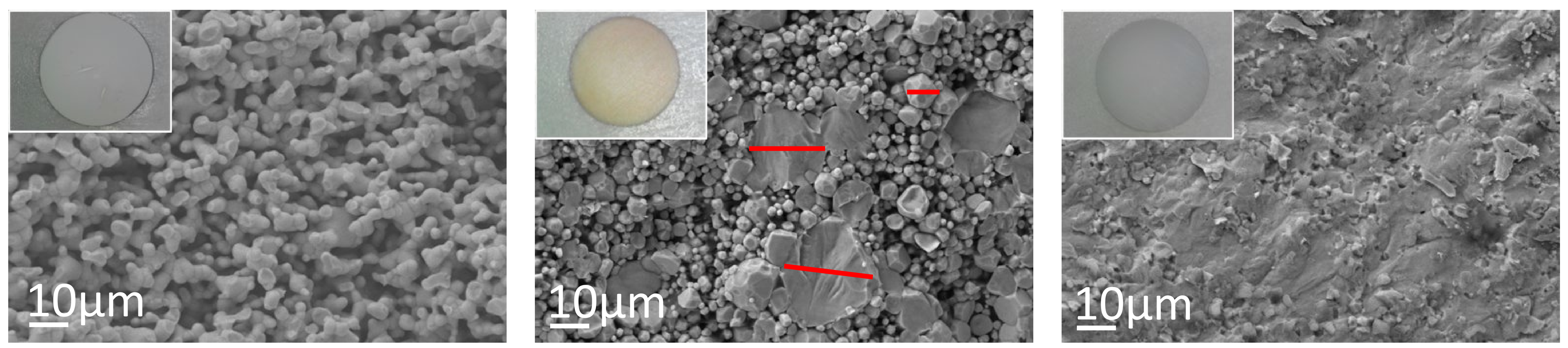




LLZO Pellet

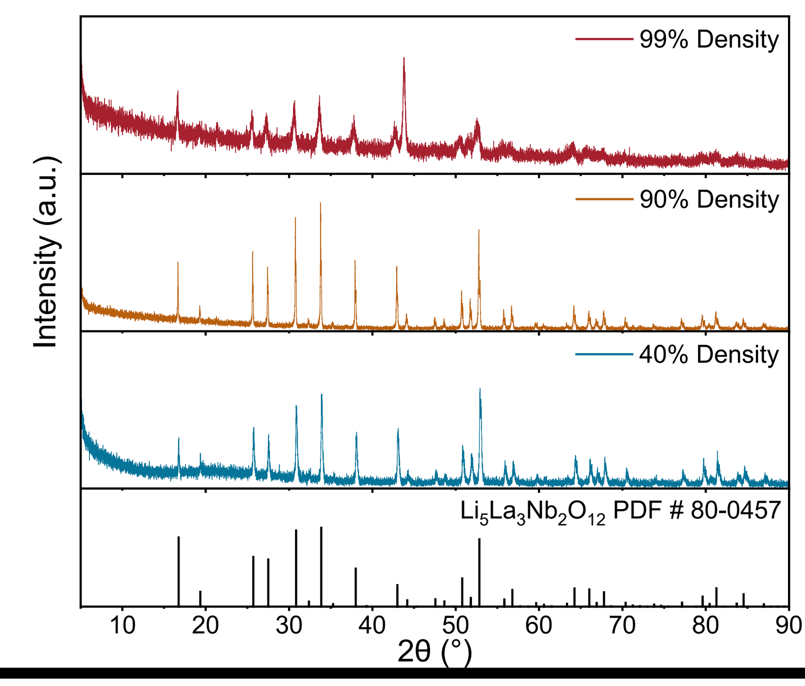
Results

Scanning Electron Microscope (SEM) images of LLZO samples at different porosities



Relative Density 40% | Relative Density 90% (Differing Grain Sizes) | Relative Density 99%

X-ray diffraction(XRD) results



Future Work

We have been able to consistently synthesize LLZO pellets at different porosities, showing that creating the optimally porous LLZO for nuclear fusion is possible. However, we don't have consistency on the grain size of the synthesized porous LLZO. Currently, neutron irradiation tests are being run at Oak Ridge National Laboratory; it will take months for results to come in. Once they are in, we can use the data for a more optimized synthesis.

Future work for this research is synthesizing the optimal porosity and grain size through further fine tuning of the synthesization process.

Acknowledgments

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References

[1] S. Lin, Y. Lu, W. Liu, Y. Sun, H. Zhou, and Y. Gao, "Tritium Breeder Materials for Nuclear Fusion Reactors: Current Status and Future Directions," Nov. 18, 2024, Engineering. doi: 10.20944/preprints202411.1336.v1.

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