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Determination of the Optimum Lithium Metatitanate Content for Advanced Lithium Orthosilicate Breeder Pebbles

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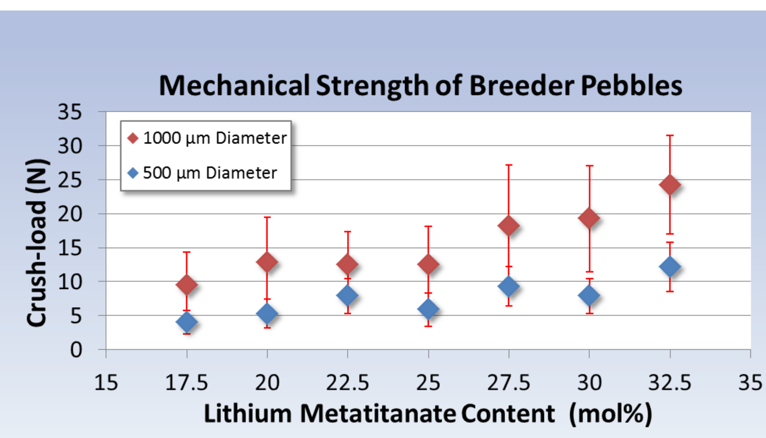
Ceramic tritium breeder pebbles are currently being fabricated using a melt-based process at KIT composed of lithium orthosilicate (LOS) with a secondary phase of lithium metatitanate (LMT) in place of the original metasilicate phase (LMS). The initial aim of the secondary phase was to combine the enhanced mechanical strength of pure metatitanate with the increased lithium density of orthosilicate.

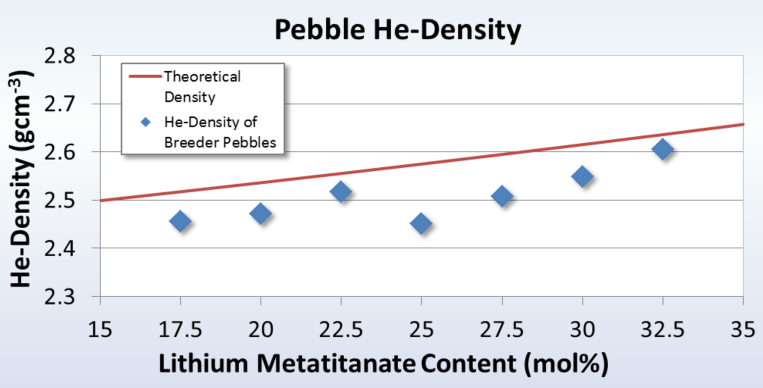
However, other properties are also affected by a change in composition. In order to make sure that the pebbles are suitable for the conditions in the blanket of the reactor, both radiation and long-term stability at relevant temperatures are critical. Additionally, the impact on deuterium release characteristics was reviewed, as well as their durability under irradiation and the formation of possible long-life radioactive isotopes.

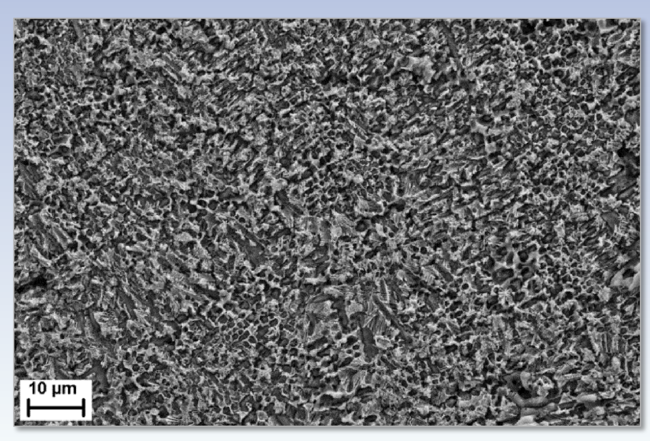
Pebble Properties

Pebbles were produced with lithium metatitanate contents ranging from 17.5 to 32.5 mol%. Results show:

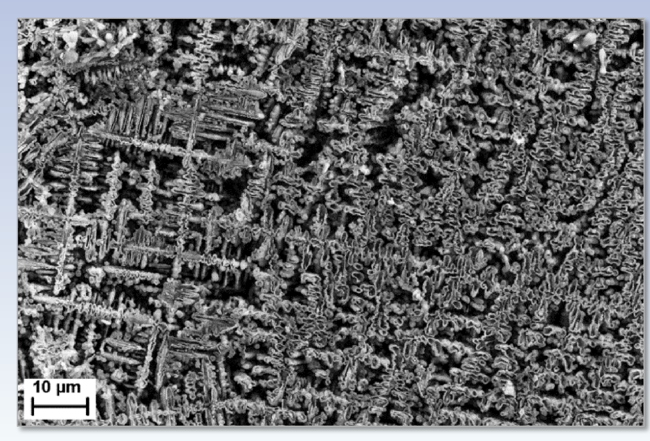
- Increasing mechanical strength with LMT content
- Pebble density increases, but closed porosity is not affected, with increasing LMT content







22.5 mol% LMT Microstructure



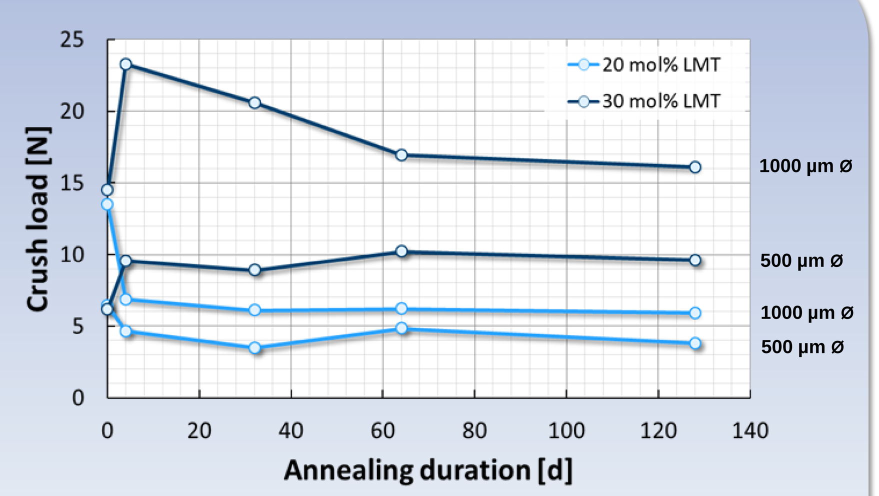
32.5 mol% LMT Microstructure

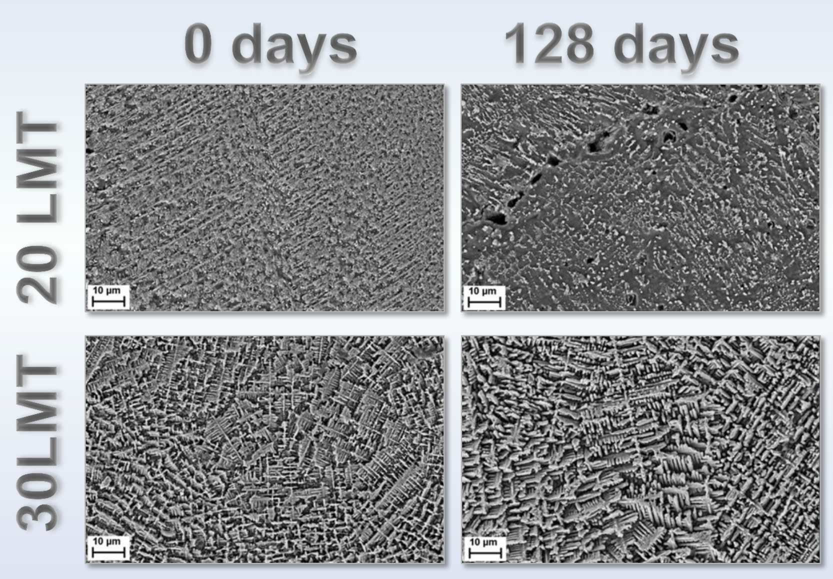
- A clear change in the crystallisation behaviour occurs between 20 and 30 mol% LMT

Long-Term Stability

Pebbles with different LMT contents were subjected to atmospheres and temperatures that are expected in the breeder blanket for a significant amount of time.

- The mechanical strength of 30 mol% LMT pebbles deteriorated the least over the testing period
- The microstructure also remains very stable





Release Characteristics

Deuterium release experiments were performed at CIEMAT [1]:

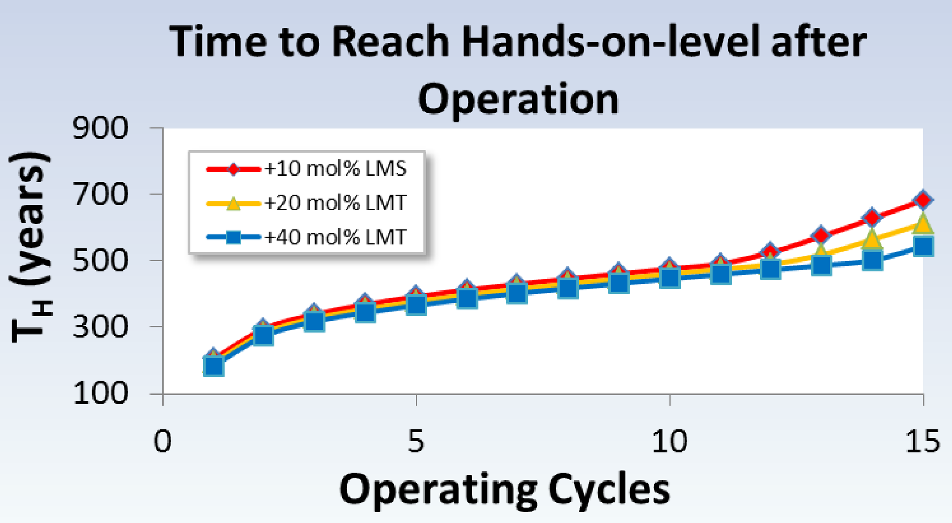
- Pebbles were exposed to a high pressure D_2 atmosphere
- γ-Irradiated with up to 4 MGy
- Heated to 800 °C and D_2 release measured

Two distinct release mechanisms (at approx. 300 and 750 °C) are identifiable and correlate to the phase contents. It appears that increasing LMT content, increases the amount of D_2 released by the lower temperature mechanism.

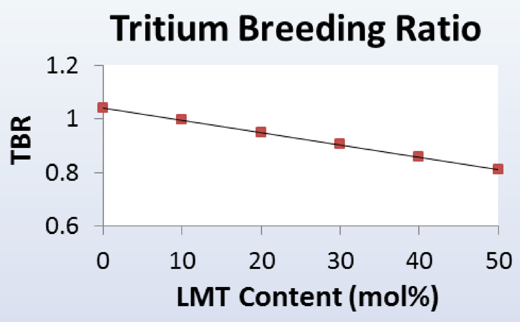
[1] *M. Gonzalez & E. Carella*, FED (2015), *In Press*

Radiation & Transmutation Stability

- Cool-down periods for different LMT contents



- The TBR decreases with increasing LMT content



The tritium breeding ratio for pebbles with a 60% ^{6}Li enrichment

- Experiments at the University of Latvia studied the radiolysis behaviour of the breeder pebbles [2]
- Replacing the LMS phase with LMT slightly increases the amount of paramagnetic radiation-induced defects
- However, a clear dependence on the phase composition is not observed

[2] *A. Zarins & L. Avotina*, FMNT (2015), *Vilnius, LT*

Conclusions

- Pebbles with increased LMT contents show greater mechanical strength and greater long-term stability
- Increasing LMT content increases the amount of D_2 released at lower temperatures
- Simulations show that increasing LMT content will not affect the cool-down periods significantly until approx. 12 usage cycles
- **A minimum LMT content of 27.5 mol% is required to ensure adequate mechanical strength and long-term stability**
- **Above 35 mol%, the pebbles become increasingly difficult to process due to the increase in melting point**

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