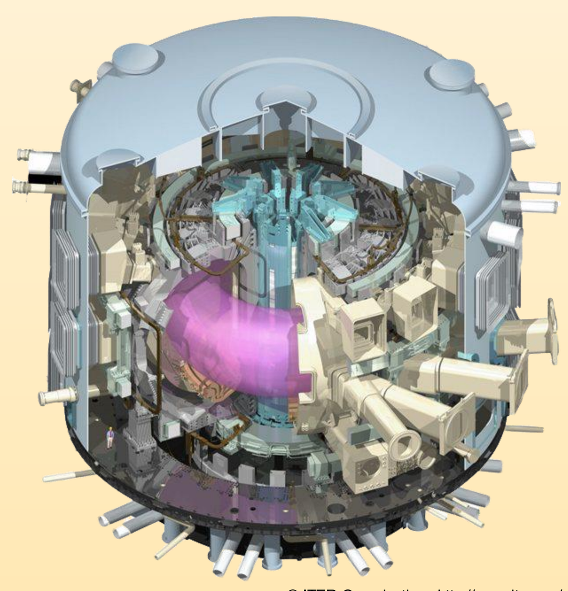
Institute for Applied Materials

The Production of Lithium-rich Ceramic Pebbles from a Molten Jet

O. H. J. B. Leys, M. H. H. Kolb, R. Knitter

Fusion Energy

Fusion energy is seen as a **clean and renewable** energy source for the near future. The two fuel sources, **deuterium and tritium**, react in a magnetically confined plasma at approximately 150 000 000 °C.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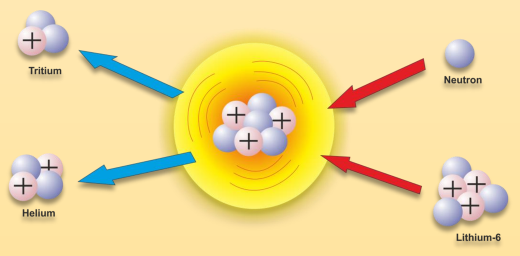
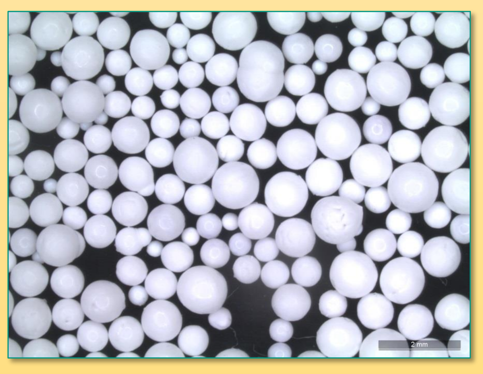
While deuterium can be distilled directly from water, tritium will have to be produced on-site. Therefore **lithium-rich ceramics** in the form of **pebble beds**, are to be installed in the wall of the reactor. Upon irradiation, the lithium will decompose into helium and **tritium**.

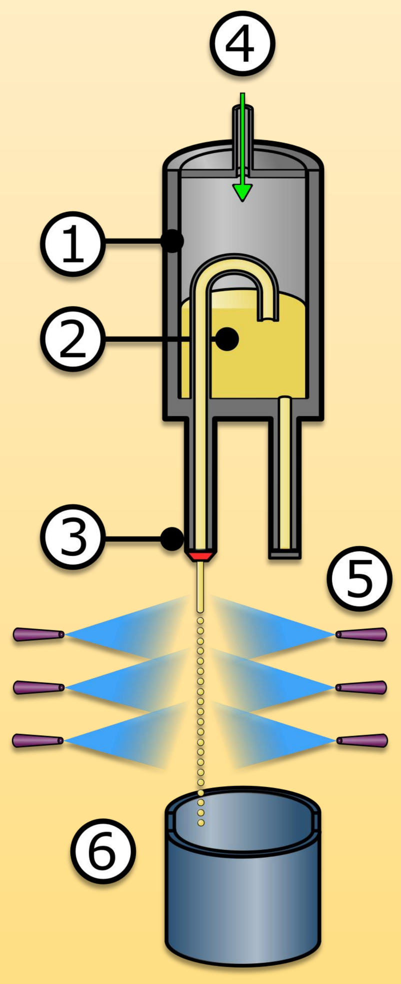


Although the pebbles themselves have no structural function, they still need to have the **mechanical strength** to withstand neutron irradiation and thermal-expansion forces within the pebble bed.

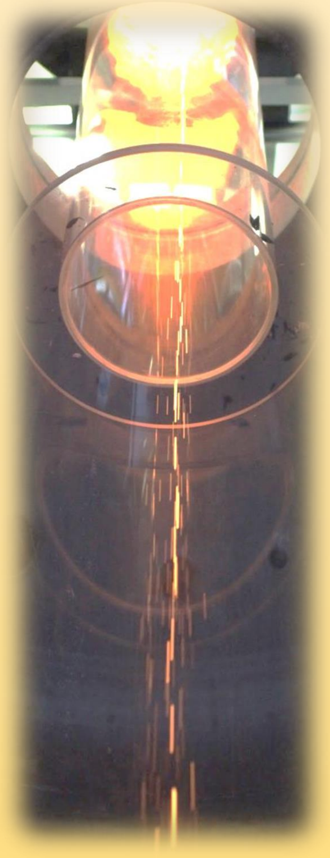


Pebble Fabrication Process

A melt-based process is used for the production of ceramic pebbles composed of **lithium orthosilicate**, Li_4SiO_4, with a secondary phase of **lithium metatitanate**, Li_2TiO_3.



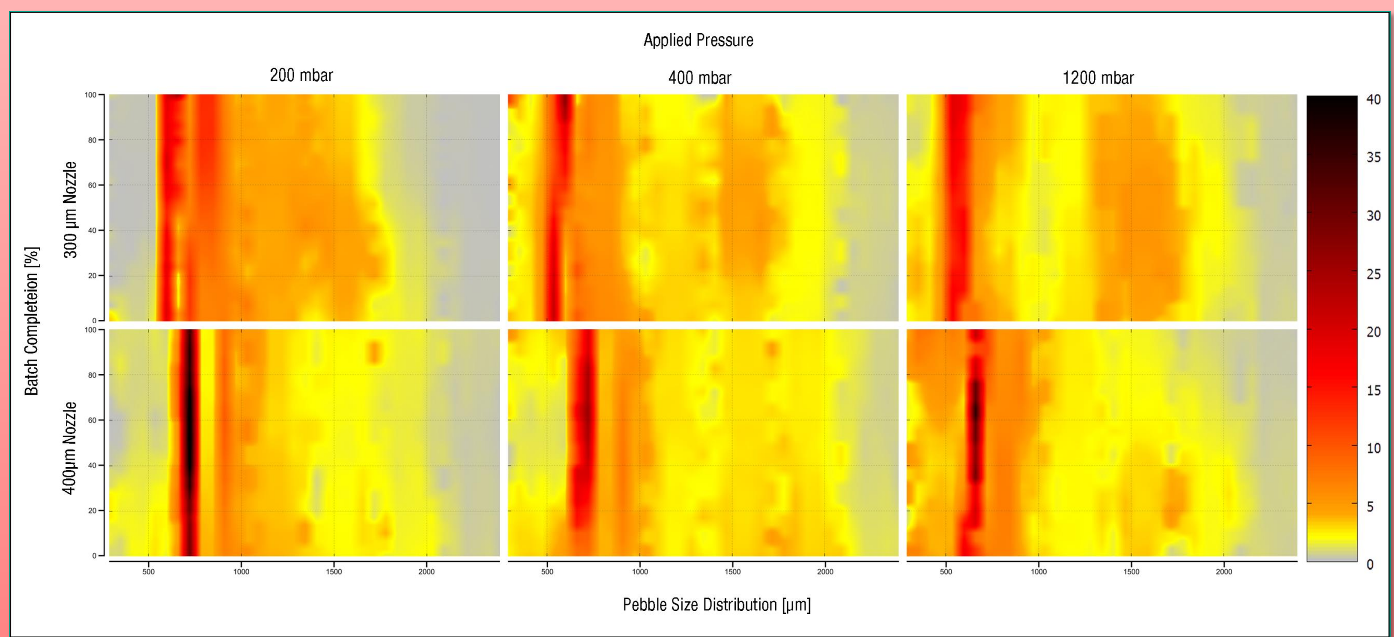
1. Crucible temperature: **1300-1400 °C**
2. Precursors: **LiOH, SiO_2 and TiO_2**
3. Nozzle diameter: **300 µm**
4. Filling tube and inlet for **400 mbar synthetic air**
5. LN_2 **spray cooling** method
6. LN_2 **quench** method



Pressure and Nozzle Effects

To create pebbles in the desired size range, it is essential to understand the effect of the **nozzle size** and the **applied pressure** on the pebble size distribution.

Pebbles were manually extracted throughout the process, so that pebble size distribution vs. batch completion charts could be plotted

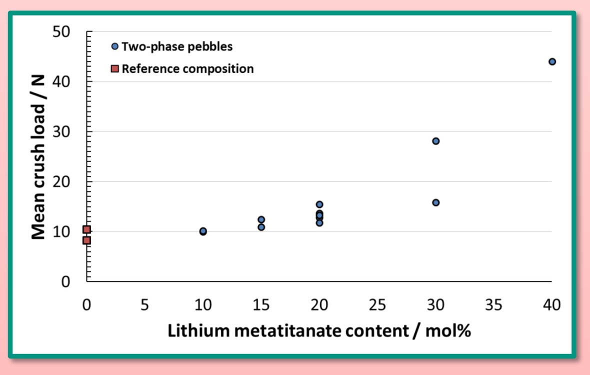


Compositional Variations

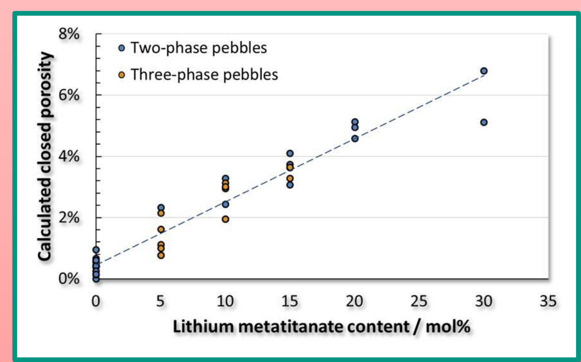
In order to increase the mechanical strength of the pebbles, lithium metatitanate was added as a **secondary phase**.

Due to the strong **increase in the melting point** above 30 mol%, it wasn‘t possible to produce pebbles with more than a 40 mol% lithium metatitanate phase.

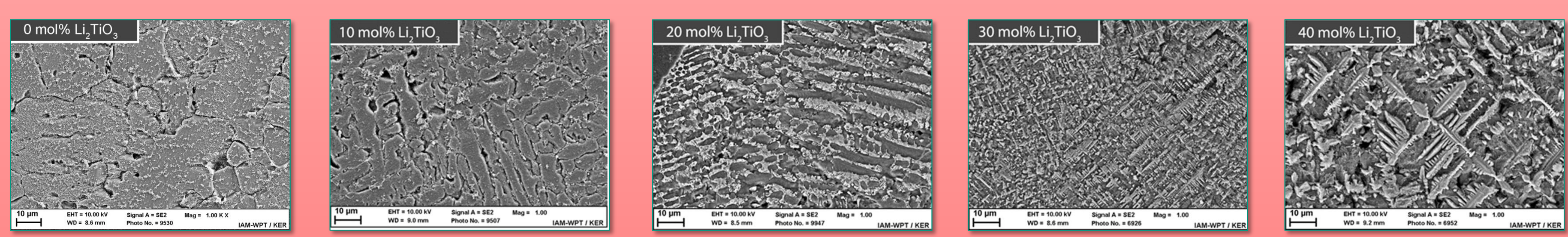
A side-effect of increasing lithium metatitanate content is also an increase in the **closed porosity**.



Crush-load



Porosity

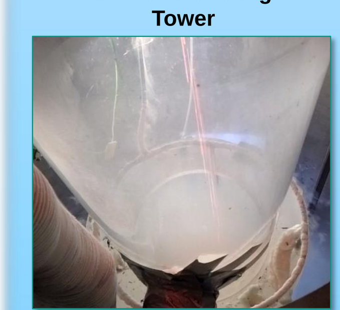


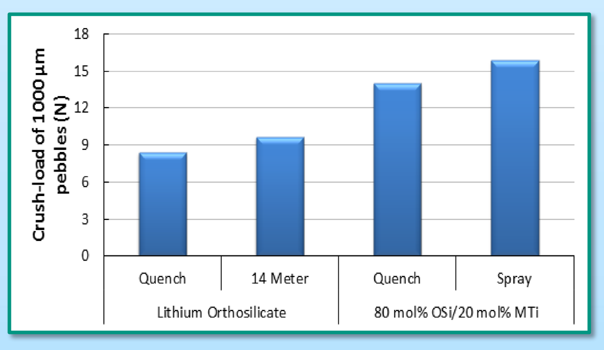
Lithium Metatitanate Content

Effect of Cooling Methods

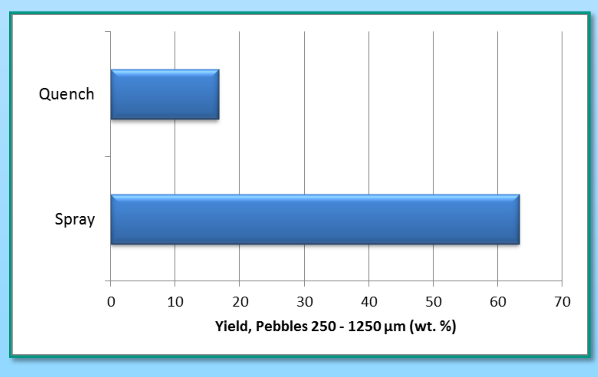

Quench


14 Meter Cooling Tower


Spray

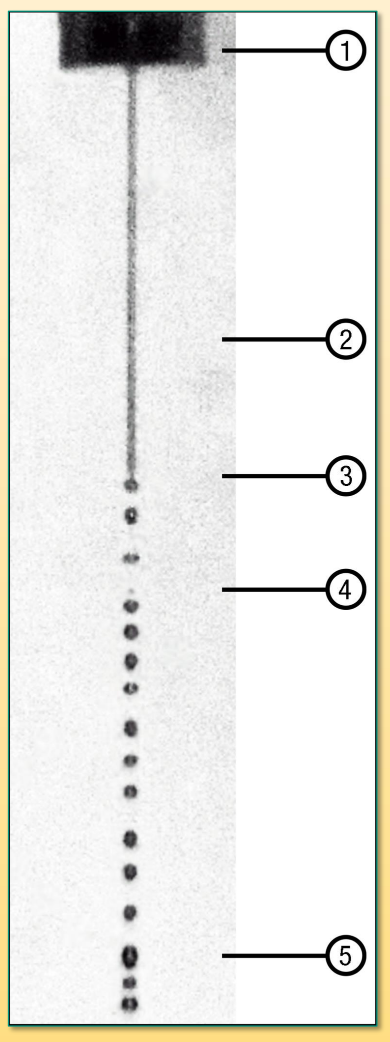


Crush-load

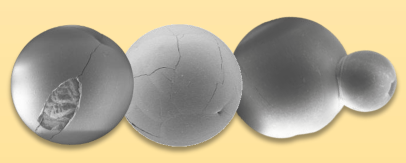


Yield

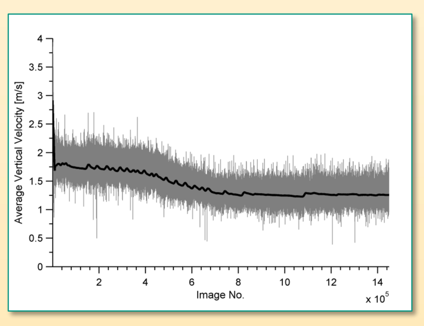
High-Speed Camera Analysis

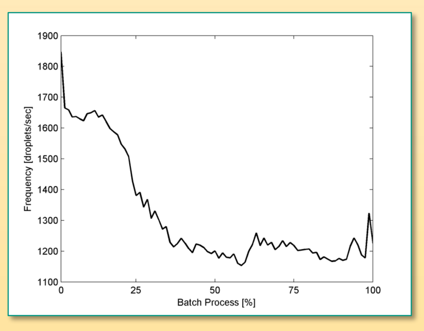


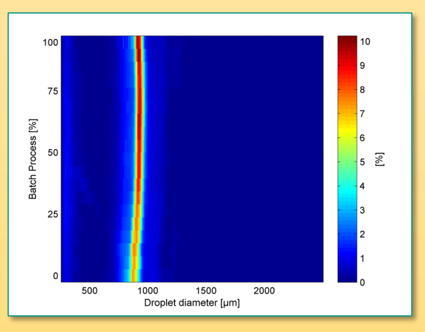
To understand the dynamics of the **droplet formation** process, analysis software, specifically written for this process, is used to determine many process characteristics



(1) Nozzle
(2) Jet
(3) Critical Length
(4) Satellite Droplet
(5) Fused Droplet







Outlook

- Improve the yield of the process based on knowledge gained from pressure-nozzle-cooling effects
- Optimise the crush-load based on the composition and cooling method
- Implement a control system as well as high end instrumentation into the process