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Single stage recycling of tritium breeder pebbles by remelting

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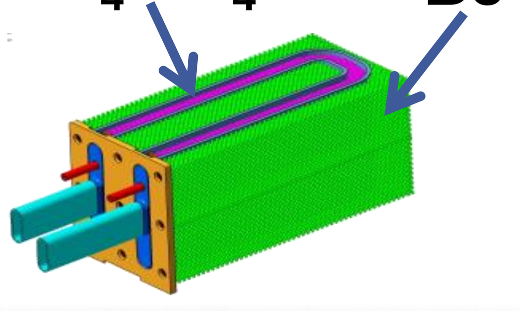
Lithium orthosilicate pebbles, with a secondary phase of lithium metatitanate, are currently being developed as ceramic tritium breeders for the EU Test Blanket Module. After a period of 3 – 5 years in the wall of the fusion reactor, a significant amount of the lithium will have been transmuted into tritium for the fuel cycle. It is also expected that the pebbles will fragment due to the stresses whilst in operation leading to a decline in the pebble-bed properties.



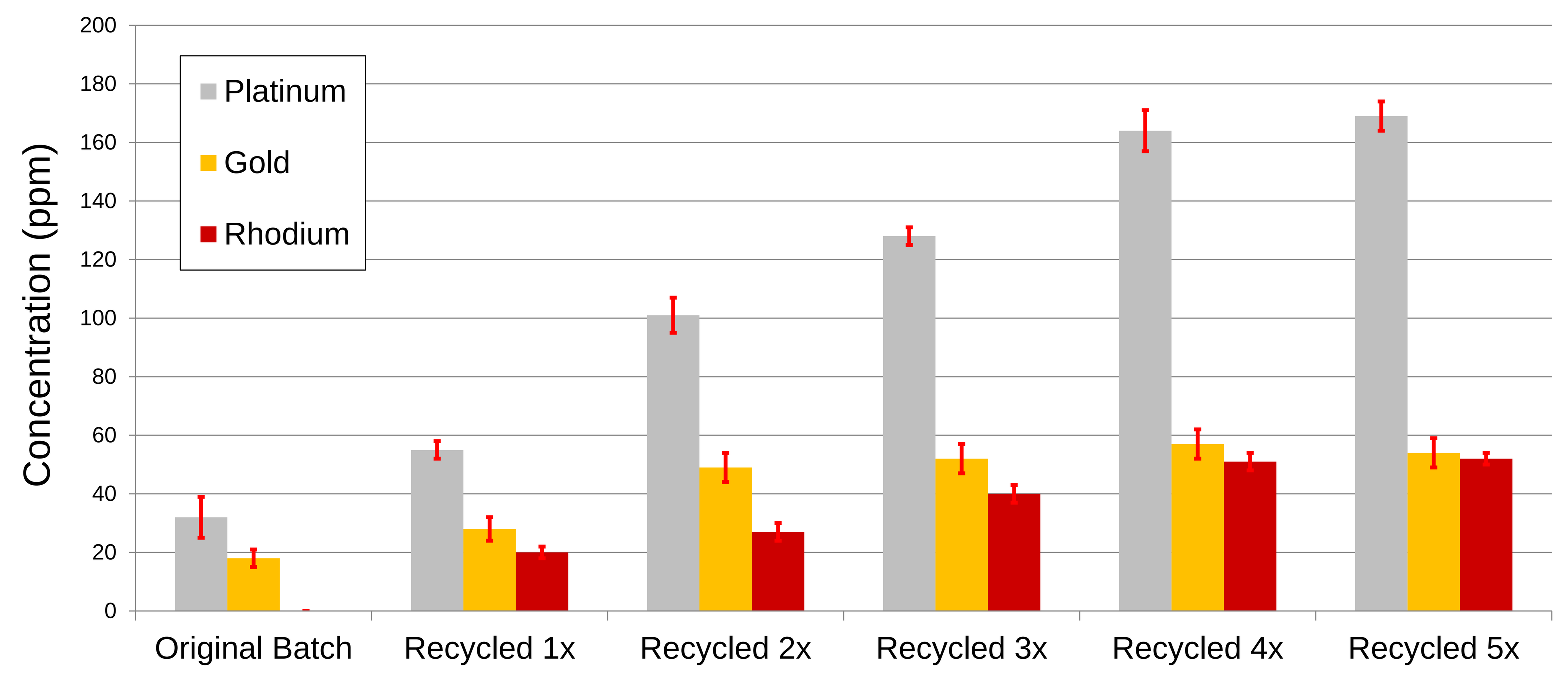
Due to the nature of the melt based process used at KIT, it is proposed that the depleted pebbles can be reenriched with lithium by remelting them in the standard process crucible with additions of LiOH. In order for this method to be considered as a suitable reprocessing route, as opposed to wet chemical processing, it is necessary to demonstrate the feasibility of both recycling the material, as well as replenishing the ^6Li after burn-up, whilst minimising impurities.

Remelting

A large quantity of pebbles was produced and subsequently refilled into the process crucible to produce another batch. This was repeated multiple times, and after each batch, a sample of the produced pebbles was characterised.

- Remelted pebbles show the same properties as standard pebbles (e.g. crush-load, porosity, microstructure…)
- The amount of impurities in the pebbles depends on the purity of the starting powders
- The only accumulation of impurities results from the corrosion of noble metals from inside the crucible alloy

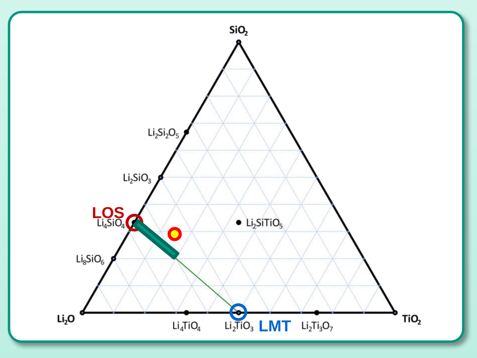
Accumulation of Impurities in Ceramic Breeder Pebbles



Reprocessing

Pebbles were produced that represented a burn-up of 15% with an enrichment of 50% ^6Li (expected to occur during the lifetime in the reactor wall) resulting in pebbles with the following composition:

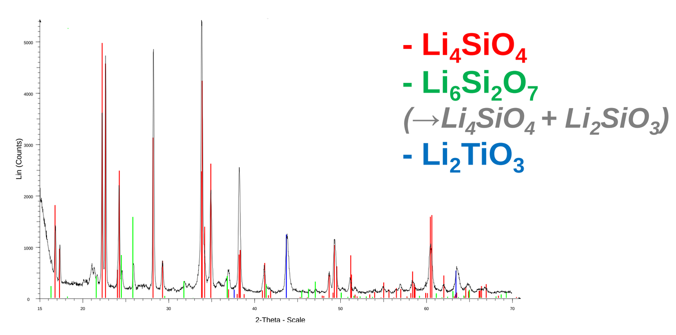
66.5 mol% Li_4SiO_4
13.5 mol% Li_2SiO_3
20.0 mol% Li_2TiO_3



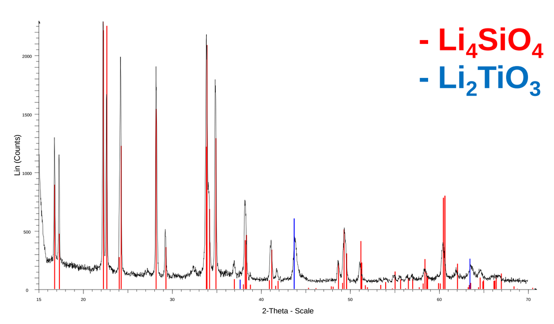
The pebbles were remelted with corresponding quantities of LiOH to gain the intended composition of the starting material.

Phase Analysis

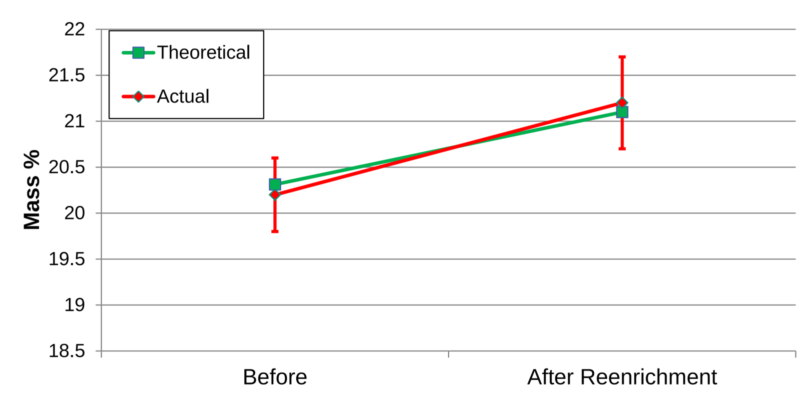
Before



After



Lithium Content



XRD was used to check if the desired phases were formed, and ICP-OES to measure lithium levels before and after reenrichment

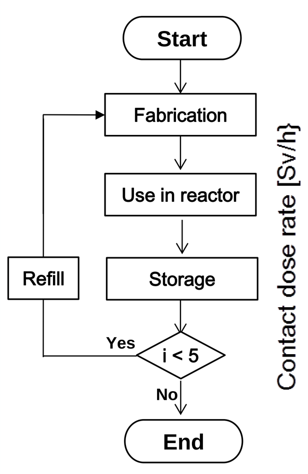
Simulation

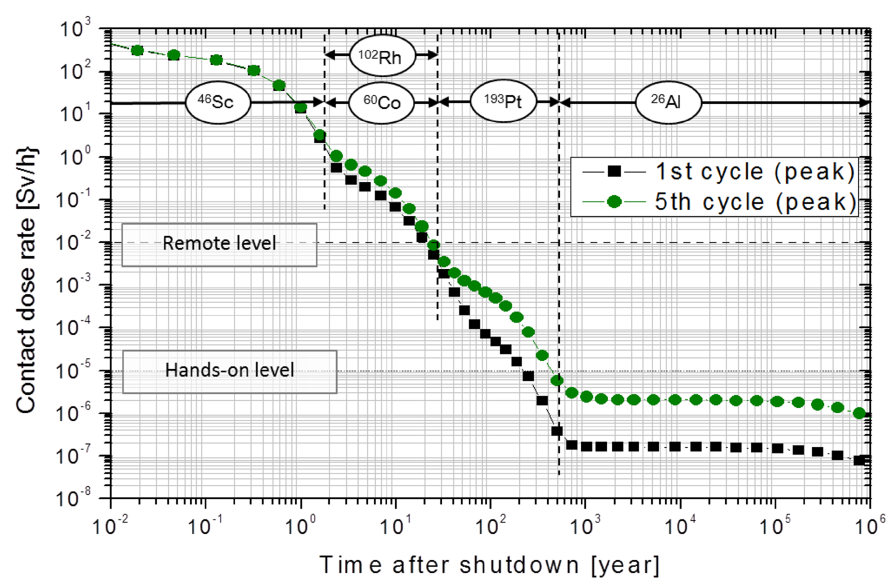
Using results from the practical experiments, simulations were performed to examine the effect of the various impurities on the handling times after 5 usage and reprocessing cycles.

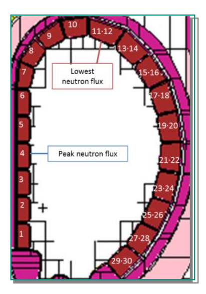
Assumptions:

- Breeder pebbles are used for 3 years in the HCPB-DEMO* reactor
- Irradiated pebbles are stored until the remote handling level is reached (<10 mSv/h)
- ^6Li is replenished after storage
- Pt, Rh and Au impurities from the crucible alloy are added after each cycle

Effect of Impurities on Handling Times







	Waiting time 1st cycle	Waiting time 5th cycle	Dominant nuclide ($t_{1/2}$)
Remote level	17-21 y	21-24 y	^{103}Rh (207 d) ^{60}Co (5.3 y)
Hands-on level	180-224 y	366-439 y	^{193}Pt (50 y)

* P. Pereslavtsev et al. Fusion Eng. Des. 89 (2014)1979–1983

Conclusions

- Pebbles can be recycled using the standard process setup
- The purity of the starting powders determines the level of impurities in the pebbles
- Only noble metal impurities from the crucible alloy are added after each cycle
- Remelting depleted ^6Li pebbles with additions of LiOH is suitable for reenrichment
- Simulations show that the pebbles can be reprocessed after an acceptable waiting time

These findings prove that the melt-based, single stage recycling of the pebbles is a viable option for breeder reprocessing