Multiple Recycling Study of Advanced Breeder Pebbles by Melt Process.

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Multiple tritium breeder recycling is an attractive option to make a future fusion power reactor ecologically and economically sustainable. In the recycling scheme, breeder pebbles are used in a reactor for a few years and will then to be stored for a waiting period until the material reaches the remote handling level (10 mSv/h). Thereafter, the pebbles are re-melted at a high temperature for fabricating new pebbles, while simultaneously replenishing the lithium burn-up. The melt-based fabrication process in principle enables a facile recycling without any additional process step, such as wet-chemical treatment which is known to be a costly and time-consuming step. For multiple recycling, it is necessary to verify the feasibility of pebble reproduction by the melting process, while maintaining pebble properties (e.g. microstructure and mechanical strength). In addition, the activation characteristics of the pebbles after multiple recycling must be assessed because an accumulation of radio-isotopes possibly results in a negative impact on the waiting period.

In order to prove the viability of melt-based reprocessing, a series of experiments was performed. Firstly, breeder pebbles with pure starting powders were produced and subsequently characterized. The remaining pebbles were then filled back into the production crucible and reprocessed using the standard process parameters. Again, a sample was taken for characterization and the remaining pebbles were reprocessed until the material was reprocessed a total of 4 times. The results showed that pebble properties were not significantly affected by the reprocessing. However, a contamination of impurities was observed result from the melting crucible alloy, while the other impurities remained at the same level as the initial concentrations. Secondly, pebbles with a lithium deficit (representing expected levels after 3 years' use) were produced. It was shown that the lithium level could be replenished by reprocessing the pebbles with additions of LiOH.

In parallel to the experiments, computer simulations were performed by means of the MCNP code and the FISPACT code in order to determine the effect of impurities on the waiting periods for the remote handling level and the hands-on level (10 μSv/h). The change of the averaged activation properties with each recycling step was assessed by increasing the concentration of the noble metal based on the extrapolated curves from the impurity contaminations mentioned above. The results showed that the pebbles can still be reused after an acceptable storage period of approximately 22 years, even after 15 recycling steps. The calculated results identify influential impurities in the current breeder pebble composition and give some future recommendations for minimizing the waiting periods.