An Innovative Solid Breeder Material for Fusion Applications

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A new form of solid breeder morphology is proposed, which has the potential of increased breeding ratio, long term structural reliability, and enhanced operational control compared to conventional approaches, such as packed bed). Breeding ratios are dictated by breeder material density, while tritium release depends on diffusion path length to free surfaces. Packed bed concepts for solid breeder materials have offered a venue for large free surface areas to accommodate high release rates. However, the maximum breeder material packing factors are limited to about 65% for single size pebbles, which can be raised only with the addition of very small (e.g., 80-150 μm) pebbles.

The pebble bed configuration introduces several operational limits due to thermo-mechanical uncertainties caused by pebble bed wall interaction, potential sintering and subsequent macro-cracking, and a low pebble bed thermal conductivity, all of which result in small characteristic bed dimensions and operation windows. Consequently, long term and reliable performance of pebble beds remains a critical and complex issue for fusion reactors.

We suggest here for the first time the use of a solid ceramic “breeder foam” material, which offers several and significant advantages over the use of pebble bed configurations. In recent years the development of refractory and ceramic foams has matured to a degree that detailed thermo-mechanical properties can be micro-engineered into these advanced structures. For fusion breeder applications, “breeder foams” offer several advantages over pebble beds: (1) increased breeder material densities (>80%), (2) higher thermal conductivities (fully interconnected structure instead of point contacts between pebbles), (3) bonded contacts to cooling structures (instead of point contacts between pebbles and wall), (4) no major configurational changes between beginning-of-life and end-of life (such as sintering in pebble beds); and (5) structural integrity because foams are freestanding and self-supporting structures with significant thermo-mechanical flexibility.

Thermo-mechanical properties of oxide ceramic foams are discussed, and manufacturing techniques for lithium-based oxide foams are presented based on current day ceramic oxide foam manufacturing processes. Also, high-temperature foam-to-solid-surface bonding techniques are presented.