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Simultaneous Corrosion/Irradiation Testing in Lead and Lead-Bismuth Eutectic: The Radiation Decelerated Corrosion Hypothesis

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ABSTRACT:

Liquid lead and lead-bismuth eutectic (LBE) cooled fast reactors promise the best power density and economics for fission reactors, should they actually be deployed. For decades, the issues of corrosion and how it will change with irradiation have been the bottleneck in lead fast reactor (LFR) and LBE fast reactor (LBEFR) deployment, restricting outlet temperatures below 550°C[1]. Without precise knowledge of corrosion and irradiation performance of LFR/LBEFR materials, these reactors will never be deployed, stuck forever in a Catch 22. A far faster, yet reactor-accurate, method of combined corrosion/irradiation testing is required.

To break this bottleneck, we will test candidate materials from previous studies in a new, simultaneous corrosion/radiation facility[2]. Rather than rely on separate long-term corrosion and neutron irradiation, simultaneous exposure followed by microstructural characterization, mechanical testing, and comparison to existing data will rapidly down-select potential alloy candidates and assess how irradiation affects corrosion. This will bring the technology readiness of these potential LFR/LBEFR alloys to technology readiness level 5 (TRL-5)[3]. In addition, we will explore a controversial, yet massively impactful scientific hypothesis, that radiation *slows* corrosion in the LFR/LBEFR based on molten salt testing.

Thin foil specimens of FeCrSi and ferritic-martensitic alloys will be subjected to simultaneous 650°C LBE corrosion (whole sample) and proton irradiation (center spot). Following ion cross section polishing, the deceleration of corrosion between the two regions will be quantified by SEM/EDX. Microstructural characterization by TEM, Chemi-STEM, and APT will identify corrosion products and quantify elemental distributions, confirming whether Cr depletion from damage sinks is the corrosion deceleration mechanism. Large area EBSD will reveal whether LBE corrosion is orientation-dependent, while high-resolution transmission Kikuchi diffraction and synchrotron X-ray micro-beam Laue diffraction will probe lattice strain caused by simultaneous irradiation and LBE exposure. *In situ* TEM/DMA tests will explore the mechanical properties and embrittlement of selected sites within and outside grain boundaries suffering from corrosion and irradiation, while more bulk-like mechanical tests will be conducted using *in situ* SEM micropillar compression and foil stretching.

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[1] Kurata, Y., Saito, S., *Mater. Trans.*, 50(10):2410 (2009).
[2] Zhou, W. et al. *NIMB*, 440:54 (2019).
[3] Carmack, W. J. et al. *Nucl. Eng. Des.*, 313:177 (2017).