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TRItium Permeation Real-Time In-line Sensor for Monitoring (TRI-PRISM): Development of hydrogen isotope permeation sensors for tritium monitoring in LIBRTI and fusion liquid metal breeder systems

Thursday 5 February 2026 14:20 (30 minutes)

The transition to commercial fusion energy hinges on robust, real-time tritium monitoring within breeder blanket systems. This work, developed under the TRI-PRISM Project and led by Kyoto Fusioneering UK in collaboration with ENEA, Canadian Nuclear Laboratories, and the University of Birmingham, presents the latest advances in hydrogen isotope permeation sensor (HPS) technology for lithium-lead (LiPb) breeder applications.

HPS technology, established as the reference for ITER and a leading candidate for DEMO [1-3], enables near real-time, in-line detection of hydrogen isotopes in liquid metal breeders. This capability is critical for operational safety, tritium accountancy, and performance optimisation in next-generation fusion reactors. The project aims to elevate HPS from Technology Readiness Level (TRL) 4 to 6 by addressing key challenges: quantifying performance indicators (response time, accuracy, precision, and limit of detection), ensuring material compatibility with tritium, characterise best welding techniques, mitigating oxidation effects on sensor membranes. Experimental campaigns are being conducted at ENEA HyPer-QuarCh II facility (Italy) in gas phase and static LiPb, and Kyoto Fusioneering UNITY-1 facility (Japan), in flowing LiPb (see Figure 1), leveraging advanced manufacturing and welding techniques developed at the University of Birmingham. These campaigns will validate sensor performance, using protium and deuterium as proxies for tritium, and will calibrate computational models for scaling to tritium. Tritium compatibility assessment has been developed by CNL.

The project outcomes directly support the LIBRTI facility mission to develop and demonstrate breeder technology, while also generating new UK intellectual property and strengthening domestic supply chains. Beyond fusion, the developed HPS technology has potential applications in fission reactors, metallurgy, and hydrogen purification industries. The collaborative, international approach ensures knowledge transfer, environmental stewardship, and the upskilling of UK-based engineers and researchers.

References:

[1] L. Candido, et al., “Overview of Tritium Management in WCLL Test Blanket System of ITER,”Fus. Eng. Des. 200, 114163 (2024). https://doi.org/10.1016/j.fusengdes.2023.114163

[2] L. Candido, et al., “Characterization of Pb-15.7Li Hydrogen Isotopes Permeation Sensors and Upgrade of Hyper-Quarch Experimental Device,”IEEE Trans. Plas. Sci. 48(6), 1505-1511 (2020). https://doi.org/10.1109/TPS.2020.2992345

[3] L. Candido, et al., “Development of advanced hydrogen permeation sensors to measure Q2 concentration in lead-lithium eutectic alloy,”Fus. Eng. Des. 124, 735-739 (2017). https://doi.org/10.1016/j.fusengdes.2017.02.011

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