

Multifunctional Coatings for Tritium

This technology introduces a class of nuclear-grade multifunctional thin-film coatings specifically engineered to act as tritium permeation barriers and corrosion-resistant layers within fusion reactor systems. Developed within the TITANS project, the coatings address a critical fusion safety challenge by reducing tritium losses from structural materials exposed to liquid metals and hydrogen isotopes under high-temperature, high-flux conditions typical of fusion and advanced fission environments.

■ Description of the technology

The multifunctional coating is an engineered barrier layer composed of advanced ceramic, nitride, oxides or carbide films applied through magnetron sputtering or similar deposition methods. The resulting film forms a dense, amorphous structure that tightly adheres to steel or alloy surfaces, preventing the migration of hydrogen isotopes, including tritium, while maintaining stability under thermal and mechanical stress.

By acting as a dual-function protection system, the coating simultaneously:

- Minimizes hydrogen and tritium permeation, lowering the potential for radioactive gas release.
- Provides corrosion resistance against reactive coolants or fuels such as liquid lithium or lead-lithium alloys.

The coating's microstructure and thickness can be tuned for different applications, from large reactor components to fine industrial parts. The system is compatible with standard industrial processes for thin-film deposition, making it adaptable to a broad range of high-performance materials.

■ Innovation and advantages of the offer

The main innovation of this technology lies in its ability to integrate two critical protective functions within a single, stable coating architecture. Unlike conventional surface treatments, the amorphous structure exhibits exceptional chemical inertness, ensuring minimal hydrogen isotope permeability even under harsh thermal and mechanical conditions. The improved adhesion achieved through optimized interlayers enhances the coating's long-term durability and prevents delamination during repeated heating cycles. From a performance standpoint, the coating extends the operational lifetime of structural materials, reduces maintenance and inspection needs, and contributes to higher environmental and radiological safety by minimizing tritium losses. Its scalable deposition process and adaptability to various industrial substrates make it a practical, cost-effective solution for energy systems, hydrogen infrastructure, and advanced manufacturing sectors.

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■ Non-fusion Applications

The coating concept extends naturally to several non-fusion industries where hydrogen or corrosive environments limit performance and component lifetime:

- **Advanced fission systems:** mitigation of tritium and hydrogen permeation in liquid-metal-cooled reactors (SFR, LFR), enhancing containment integrity.
- **Battery manufacturing:** use as a protective interlayer to prevent lithium diffusion and chemical degradation in solid-state or lithium-metal batteries.
- **Aerospace and propulsion:** barrier layers against hydrogen embrittlement and oxidation for fuel tanks, turbines, and high-temperature alloys.
- **Hydrogen storage and transport:** internal coatings for pipes, valves, and containment vessels to reduce hydrogen loss and extend system lifetime.
- **Chemical process industry:** corrosion-resistant linings for equipment exposed to aggressive or hydrogen-rich atmospheres.

■ EUROfusion Heritage

Developed under the TITANS project (Tritium Impact and Transfer in Advanced Nuclear reactorS) coordinated by CEA, this technology addresses a key EUROfusion objective: reducing tritium losses through advanced material solutions. The coating's design leverages experience from prior European programs (TRANSAT, DONES, EUROFUSION) in tritium permeation mitigation and materials compatibility with liquid metals.

The multifunctional coating now represents a cross-sector innovation opportunity, originating in fusion research but applicable wherever hydrogen management and corrosion control are critical to performance and safety.