Advanced composites: High entropy crystalline and amorphous nanolaminates as promising candidates for nuclear materials

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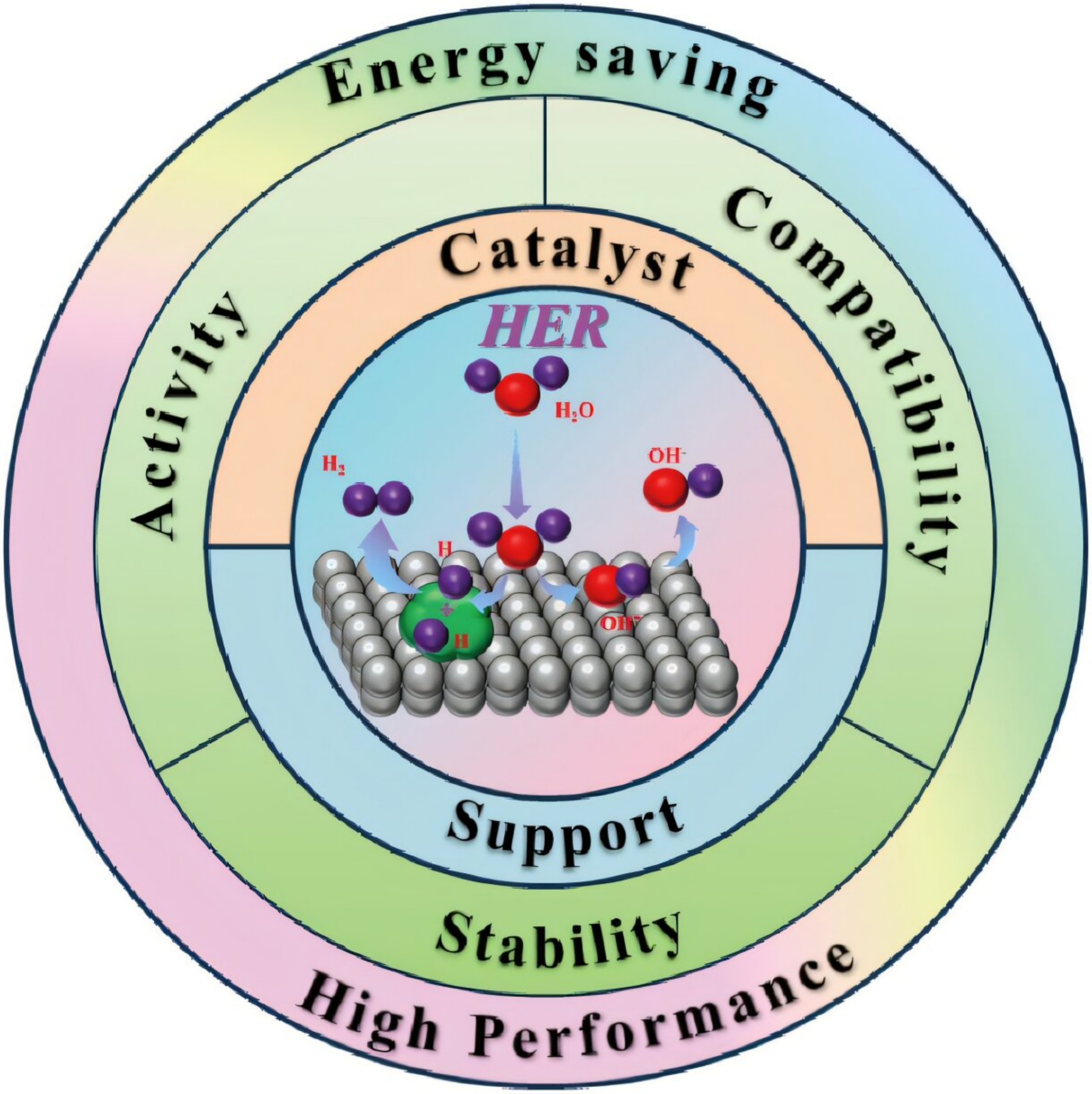

Atomic-scale mechanisms of irradiation-induced structural damage in high entropy crystalline/amorphous laminates. Credit: Daniel Şopu and Qi Xu from Erich Schmid Institute of Materials Science, Austrian Academy of Sciences.

A research team from the Erich Schmid Institute of Materials Science, Austrian Academy of Sciences, has unveiled an approach to improve irradiation resistance through high entropy crystalline and amorphous nanolaminates.

The research is published in the journal *Materials Futures*.

This innovative material architecture exploits interfacial and synergistic effects between high entropy crystalline and amorphous plates, exhibiting structural stability under extreme irradiation conditions. This study paves the way for the design of advanced nuclear materials with tailored properties.

Nuclear materials are subject to significant challenges when exposed to irradiation, including swelling, hardening and embrittlement, ultimately leading to material failure. High entropy alloys (HEAs) have attracted attention for their remarkable strength, corrosion resistance, irradiation tolerance and thermal stability due to their compositional complexity and lattice distortion.

Metallic glasses (MGs) are resistant to particle irradiation due to their lack of crystallographic defects. However, the stand-alone application of HEAs and MGs is limited by issues such as defect clustering in HEAs and poor plasticity in MGs under extreme conditions.

The research team incorporated bi-phase interfacial engineering and developed high-entropy crystalline/amorphous (HECA) nanolaminates, creating a bi-phase structure to effectively mitigate irradiation damage. Interfaces between the crystalline HEA and amorphous MG plates act as defect sinks, accelerating defect annihilation and minimizing structural damage.

Molecular dynamics simulations revealed that these interfaces trap interstitials while promoting vacancy recombination, resulting in a vacancy-rich bulk and an interstitial-rich interface. The synergistic interaction between the interface and defects further reduces defect propagation during irradiation.

In addition, the HEA plate promotes crystallization in the MG plate at the interface during irradiation, thereby increasing structural stability. This effect is coupled with a redistribution of free volume in the MG plate, ensuring minimal swelling and superior irradiation resistance.

Future research will focus on deepening the understanding of the atomic-scale structure and the excellent comprehensive properties of HEA nanolaminates by combining experiments with simulations, and exploring their applications in nuclear, aerospace and advanced electronics. Efforts to reduce production costs and improve interface engineering will further enhance its industrial viability.

This breakthrough could open up new possibilities for the design of radiation resistant materials tailored for extreme environments. By combining the excellent properties of crystalline and amorphous phases, high-entropy crystalline and amorphous nanolaminates set a new benchmark for high-performance materials in nuclear energy and aerospace.

More information: Daniel Şopu, Improved irradiation resistance of

high entropy nanolaminates through interface engineering, *Materials Futures* (2025). DOI: 10.1088/2752-5724/ada8c5

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