Tailored Compositionally Complex Claddings for Enhanced Pulsed Power Performance

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Thermal desorption of hydrogen from magnetically insulated transmission line (MITL) surfaces can lead to plasma formation and ultimately cause current loss in MA-scale accelerators. MITLs are traditionally comprised of austenitic stainless steel, which has relatively high hydrogen solubility and enhanced hydrogen diffusion along grain boundaries. While other conventional alloys may have superior hydrogen characteristics, their usage in transmission lines is limited by their ability to meet other critical criteria, such as achieving optimal time to melt.

The development of compositionally complex alloys, such as high-entropy alloys (HEAs), allows for compositional tailoring of a material to enhance hydrogen behavior without sacrificing the desired material properties, providing an advantage over traditional alloys and claddings. Compositional design of HEAs permits flexible development of alloys with increased time to melt compared to stainless steels, through tuning of parameters like melting temperature and electrical conductivity. Critically, the addition of H-insoluble constituents in HEAs has been shown to reduce hydrogen solubility, providing an avenue for reduction of hydrogen concentration based on the enthalpy of hydride formation. This allows for the development of a novel alloy that mitigates contaminant desorption without sacrificing performance.

We discuss the design and development of an additively manufactured, functionally graded tungsten-containing HEA cladding, $(CoCrFeMnNi)_{0.95}W_{0.05}$, aimed at usage on MITL surfaces. $(CoCrFeMnNi)_{0.95}W_{0.05}$ is designed to minimize hydrogen desorption from MITL surfaces through a multi-pronged approach of slowing hydrogen diffusivity, decreasing subsurface hydrogen concentration, and lowering heating rate. The reduction of hydrogen desorption is anticipated to reduce formation of plasma in the MITL gap. Additionally, melting temperature and electrical resistivity are both tailored to increase time to melt compared to stainless steel. The influence of this cladding on hydrogen transport and desorption is quantified, and the potential role of HEAs in other pulsed power applications is discussed.

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