Interstitial-Engineered Refractory Alloys

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BACKGROUND

The next generation of energy conversion, propulsion, space re-entry vehicles, and nuclear reactors requires structural materials that are strong, ductile, and that can withstand increasingly extreme thermal environments. However, materials engineered to endure extreme environmental conditions face a challenging balance between temperature resistance and strength. Multicomponent refractory alloys are a compelling choice for crafting structural materials, due to their exceptional strength and hardness at elevated temperatures unattainable in conventional body-center cubic (BCC) alloys; however, practical implementation is hindered by several challenges in processing due to their high melting points and complex phase behavior. An unavoidable yet tenacious challenge facing the adoption of BCC refractory alloys is their large affinity for interstitial elements that strengthen the material at the expense of debilitating embrittlement and oxidative resistance. The integration of multicomponent refractory alloys in advanced materials design frameworks holds the promise of mitigating some of the prevalent challenges faced by BCC alloys, including elevated ductile-to-brittle transition temperatures and embrittlement by interstitial elements, such as hydrogen, oxygen, carbon, and nitrogen. There is a need for a commercially viable method of fabricating BCC alloys with a balance between strength and ductility with higher melting points.

DESCRIPTION

Researchers at the University of California, Santa Barbara have devised a scalable alloy-design approach that uses dilute interstitial additions to direct phase decomposition pathways in BCC alloys, creating specifically tailored hierarchical architectures that exhibit unprecedented tensile strength exceeding 2 GPa in tension, while maintaining a good capacity for plasticity and fracture toughness. Interstitial engineering introduces small amounts of elements such as oxygen into group IV-based refractory powder alloys, promoting phase instability and the formation of nanoscale, spinodal and lamellar microstructures. Regulation of oxygen interstitial concentrations and specific heat treatment conditions can tailor the micro–architecture of the resulting alloy, and in turn the hierarchy of length scales that mediate deformation mechanisms, opening an avenue for new material design strategies in traditional metal alloy processing and emerging additive manufacturing routes.

ADVANTAGES

- Enhanced mechanical performance effectively overcoming the traditional strength-toughness tradeoff
- Improved processability of refractory materials while preserving desirable mechanical properties
- Offers flexibility in alloy composition and interstitial incorporation

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OTHER INFORMATION

KEYWORDS

Alloys, Nuclear, Energy, Aerospace, Storage

CATEGORIZED AS

- **Materials & Chemicals**
  - Composites
  - Other
  - Storage

RELATED CASES

2025-398-0

- Enables the use of high-melting-point materials in demanding applications
- Short processing time and low energy consumption of refractory alloys powders
- Enables the production of complex geometries without compromising mechanical performance in additive manufacturing platforms

APPLICATIONS

- Aerospace and propulsion systems
- Space re-entry vehicles
- Nuclear reactors and energy systems
- Energy conversion and storage components
- Additively manufactured structural parts and refractory alloy powders

PATENT STATUS

Patent Pending

ADDITIONAL TECHNOLOGIES BY THESE INVENTORS

- Vapor-Mediated Synthesis of Silicon Carbide Matrices for Ceramic Matrix Composites
- Metal-Elastomer Composite Edge Seal for Vacuum Insulated Glass Windows

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