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The saga of nonferrous metallurgy in the quest of new radiation-resistant fusion materials beyond pure tungsten

Innovative materials development is essential for advancing nuclear fusion energy technologies, which require high-performance materials capable of withstanding extreme conditions such as intense heat and radiation exposure. Tungsten (W) has historically been a preferred material due to its high melting point, availability, and cost-effectiveness [1]; however, it remains highly susceptible to radiation damage. This limitation highlights the need for alternative materials that can meet the demanding requirements of fusion reactors, posing a problem for contemporary non-ferrous metallurgy. In this work, we will review the scientific data accumulated all over the decades in the radiation damage of W and its binary alloys [2–8]. Although recent high-entropy materials, such as multicomponent equimolar refractory alloys and carbides [9–12], offer improved performance in energetic particle environments compared to traditional W and W-based alloys, they remain impractical for developing new radiation-resistant materials needed for fusion energy applications [13]. Recent strategies towards new "chemically simplified alloys"will be introduced to show that the fundamental metallurgical concept of terminal solid solution may still be a suitable approach for the quest of new radiation-resistant fusion materials [13,14]. This approach aims to bridge the gap between using simple pure W and complex high-entropy alloys, offering a potential pathway for innovation in nuclear fusion research.

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