MATERIALS ENGINEERING
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"Microstructure Evolution and Mechanical Behaviors of Triphase Immiscible Nanocomposites Under Extreme Environments"

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ABSTRACT

Materials performance under extreme conditions is pivotal to the design of advanced nuclear reactor materials. Nanocrystalline metals possess improved radiation resistance and superior mechanical properties. However, it remains a major challenge to stabilize the fine grains in nanocrystalline materials at elevated temperatures. The response of abundant interfaces and triple junctions to thermal annealing, plastic straining and radiation damage profoundly influence the overall performance of nanocrystalline metals. The objective of this thesis is to illustrate a new alloy design strategy via engineering the interfaces and triple junctions of triphase nanocomposites to enhance the thermal stability, mechanical strength and radiation tolerance of nanocrystalline metallic materials simultaneously.

In triphase nanocomposites where each phase is nearly immiscible to the others, the triple junctions and phase boundaries form a 3D interlocking network that could significantly increase the thermal and radiation stability. In this thesis, two distinct triphase architectures were explored: nanolaminate and nanocrystalline Cu-Ag-Fe composites fabricated by magnetron sputtering. The effectiveness of Cu-Ag-Fe triphase triple junctions in mitigating thermal grooving was evaluated by considering grooving kinetics. Additionally, micropillar compression tests on Cu-Ag-Fe nanolaminate composites demonstrated substantial enhancement of strength and strain hardening capability comparing to Cu/Fe multilayers. The nanocrystalline Cu-Ag-Fe composites exhibited a distinct texture evolution and greatly enhanced resistance to grain coarsening. *In situ* sequential dual beam (He + Kr) irradiation studies show nanocrystalline Cu-Ag-Fe composites have a remarkable bubble swelling resistance, suggesting the strong He storage and defect annihilation capability of the triphase nanocomposites. The results obtained from this thesis provide innovative perspectives on the design of high strength nanostructured metals with enhanced thermal stability and radiation tolerance.

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