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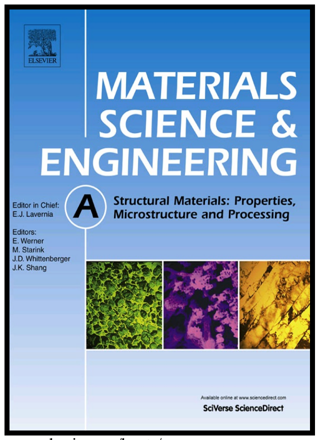

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σ and η Phase Formation in Advanced Polycrystalline Ni-base Superalloys

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Abstract

In polycrystalline Ni-base superalloys, grain boundary precipitation of secondary phases can be significant due to the effects they pose on the mechanical properties. As new alloying concepts for polycrystalline Ni-base superalloys are being developed to extend their temperature capability, the effect of increasing levels of Nb alloying additions on long term phase stability and the formation of topologically close packed (TCP) phases needs to be studied. Elevated levels of Nb can result in increased matrix supersaturation and promote the precipitation of secondary phases. Long term thermal exposures on two experimental powder processed Ni-base superalloys containing various levels of Nb were completed to assess the stability and precipitation of TCP phases. It was found that additions of Nb promoted the precipitation of η-Ni_6AlNb along the grain boundaries in powder processed, polycrystalline Ni-base superalloys, while reduced Nb levels favored the precipitation of blocky Cr and Mo – rich σ phase precipitates along the grain boundary. Evaluation of the thermodynamic stability of these two phases in both alloys using Thermo-calc showed that while σ phase predictions are fairly accurate, predictions of the η phase are limited.

Keywords: Superalloy, Stability, Secondary Phases, Sigma, Ni6AlNb, Thermocalc

Introduction

High strength along with considerable fatigue resistance when exposed to corrosive environments at elevated temperatures are the properties that make nickel-based superalloys the material of choice for use in the “hot section” of modern gas turbine engines and power generation applications [1-9]. The unique microstructure consisting of the ordered $L1_2$ intermetallic precipitates γ′ (Ni_3Al) distributed coherently within a disordered FCC A1 matrix γ (Ni), provides substantial order and coherency type strengthening by restricting dislocation motion during plastic deformation. Hence, much of the superior high temperature properties of Ni-base superalloys can be attributed to microstructural strengthening. Additions of refractory alloying elements, such as W, Mo, Cr and Co, in modern polycrystalline Ni-base superalloys, provide strength to the γ matrix phase through solid solution strengthening. Additionally, concentrations of γ′ formers Al, Ti, Nb and Ta are utilized to produce an optimized volume fraction of the γ′ strengthening phase. Although modest improvements in the properties of the alloy can be attained by increasing the volume fraction of the γ′ precipitates, these changes are often accompanied by debits in processing capabilities, environmental resistance and overall alloy cost. Additions of Nb, Ta and Ti at relatively low alloying concentrations will preferentially partition to the γ′ phase and serve to increase the anti-phase boundary energy as well as to strengthen the precipitate′s resistance to deformation [10]. When present at elevated concentrations, residual levels of γ′ forming solutes may remain within the γ phase and subsequently serve as potent solid solution strengtheners [11-14].