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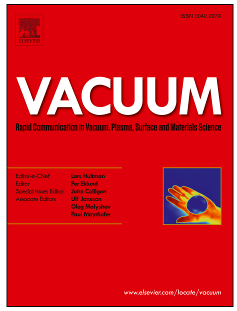

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The effect of oxide scale roughness on the plasticity of iron aluminide alloy

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Abstract

Iron aluminides based on the stoichiometric compositions of Fe_3Al and FeAl exhibit poor room temperature ductility due to environmental embrittlement. The embrittling agent is hydrogen liberated from water vapour in contact with an aluminium-rich surface. The formation of Al_2O_3 oxide scale can act as a barrier retarding the hydrogen penetration from the atmosphere inside the alloy. This barrier effectiveness depends on the scale surface roughness caused by the formation of Al_2O_3 whiskers. This paper presents a way to suppress the growth of these whiskers. The application of a two-stage isothermal oxidation enabled creating at a lower temperature an intermediate layer, consisting of metastable γ and θ oxides, which contributed to the limitation of α-Al_2O_3 oxide whiskers growth at a higher temperature and this way to reducing the scale roughness. It has been found that a decreased roughness of scale surface has a favourable influence on iron aluminide plasticity at room temperature.

Keywords: iron aluminide; environmental embrittlement; thermal oxidation; roughness; plasticity

1. Introduction

The environmental embrittlement is a major problem that needs to be solved before using iron aluminides as structural materials. This embrittlement results from the interaction of hydrogen released during the reaction of moisture in the air and aluminium atoms in the alloy [1-4]:

$$2Al + 3H_2O \rightarrow Al_2O_3 + 6H \qquad (1)$$

Aluminium atoms in aluminides react with moisture in the air, resulting in the generation of atomic hydrogen that penetrates into crack tips and causes brittle cleavage crack propagation and premature failure at ambient temperatures [1]. Zhu et al. have used a time-of-flight (TOF) mass spectrometer to successfully prove that the atomic hydrogen can be produced in the bulk when FeAl is exposed to water [2]. The minimum amount of moisture required to cause embrittlement of iron aluminides is very small (< 10 p.p.m. for Fe-36 at.% Al [4]). A partial moisture pressure of as little as 133 Pa (1 torr) can produce significant loss of ductility for Fe_3Al based alloy [1]. The underlying mechanisms suggested for hydrogen embrittlement in iron aluminides include the reduction of atomic bonding across cleavage planes and the influence of hydrogen on dislocation activities and crack-tip plasticity [1, 5]. The understanding of the cause of environmental brittleness has led to new directions in the minimization of hydrogen penetration into Fe-Al intermetallics. The introduction of

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