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Repassivation behaviour and surface analysis of Fe₃Al based iron aluminide in 0.25 M H₂SO₄

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Abstract

The repassivation kinetics of iron aluminide having a composition of Fe–16Al–0.14C (wt.%) were investigated in 0.25 M H₂SO₄ along with pure Al and Fe using a rapid scratched electrode technique. The repassivation behaviour of iron aluminide demonstrated was faster compared with Al, whereas the repassivation behaviour of Fe was slower than Al despite having a lower passive current density than Al. The repassivation behaviour was analyzed in terms of current density [i/t] as a function of charge density [q/t] that flowed from the scratched surface based on high-field ion conduction model and surface chemistry of the passive film. A mechanistic model is presented to explain the passivation/repassivation behaviour of iron aluminide based on the new findings.

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1. Introduction

Though iron aluminides are mainly developed for the structural applications at elevated temperatures. Nevertheless considering their low cost and avoiding the use of strategic elements such as Cr and Ni, they are also considered for room temperature applications in replacement of stainless steels [1–3]. In view of this, the electrochemical corrosion behaviour of iron aluminides has been studied by a

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number of researchers [4–6] but understanding its passivation behaviour still remains a matter of obscure compared with the stainless steels. The role of Fe and Al and their contribution in the passivation behaviour of iron aluminide need to be understood more precisely. Most of the reported work in this regard is concerned with the mechanisms of thickening of preformed oxide film because it is difficult to obtain the oxide free surface [5–9]. This is because adsorbed hydrogen or water and precursors of oxide film always exist on the surface of an alloy at open circuit potential. The rapid scratched electrode technique allows the passive film formation to be studied from the earliest stage of film formation in the absence of any kind of interference from pre-existing oxide films. Extensive works have been reported in the literature on the repassivation behavior of Al [10,11], Fe [12,13], and stainless steels [14–17], whereas a little work exists on the repassivation behaviour of iron aluminide. About one decade ago Madsen and Adler [18] studied the repassivation behaviour of Fe–(5–25wt%)Al alloys using potential step and scratch tests with a motivation to understand interaction of wear and corrosion behaviour in acid media. During this one-decade, Fe₃Al based iron aluminides have made deep roots in development of the materials for high temperature applications as well as room temperature applications. Therefore, the present work is undertaken to examine the repassivation behaviour of Fe₃Al based iron aluminide in 0.25 M H₂SO₄. For a better understanding of the subject its constituent elements namely Al (99.99%) and Fe (Armco iron) are investigated, simultaneously.

2. Experimental

Iron aluminide, having the nominal composition of Fe–16Al–0.14C (wt%) used in the present study was prepared by electroslag refining technique. Addition of C in the alloy was made to reduce embrittlement tendency of iron aluminide. Detailed production and mechanical properties of the alloy can be found elsewhere [19]. Specimens for optical microscopy as well as scratched test were prepared by polishing them through successive grades of silicon carbide emery papers starting from 220 to 1000 grit, followed by 1 μ diamond paste. For microstructure analysis an etchant consisted of 33%CH₃COOH + 33%HNO₃ + 1%HF + 33%H₂O by volume was used.

An electrochemical cell was devised to measure the repassivation current on the rapidly scratched surface of the alloy. The set up consisted of specimen as the working electrode, platinum foil as the counter electrode and saturated calomel reference electrode (SCE), and a scratcher with alumina tip. To rupture the surface film by making a scratch, an alumina tip loaded on a spring was pulled rapidly along the surface of the specimen holder by an air pressure cylinder connected to solenoid valve. The contact time of the alumina tip with the surface of the specimen during scratching was <1 μs. Schematic of the cell system were described elsewhere in the literature [15]. The surface of the sample was scratched under potentiostatic condition after formation of a stable passive film, and current flow from the scratch was measured every millisecond during and after the scratching, and computer-processed

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