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# Electrochemical impedance spectroscopy and cyclic voltammetry study of carbon-alloyed iron aluminides in sulfuric acid

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## Abstract

The electrochemical behaviour of three carbon-alloyed iron aluminides Fe–11.0Al–0.5C, Fe–10.5Al–0.9C and Fe–10.5Al–0.8C–0.2Ce (in wt%) has been studied in 0.25 mol/l $H_2SO_4$ solution using electrochemical impedance spectroscopy (EIS) and cyclic voltammetry techniques. A 0.05% C steel was used for comparison purposes. EIS studies were conducted after 1 h and 24 h of immersion in the acidic solution. The results obtained indicated improved surface film properties in the case Ce-alloyed iron aluminides as compared to the other two iron aluminides. This has been attributed to enhancement in surface passivity with Ce addition. Cyclic voltammetry experiments indicated that addition of Ce modified the electrochemical reactions on the surface.

*Keywords:* Iron aluminide; Electrochemical impedance spectroscopy; Cerium addition

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## 1. Introduction

Iron aluminides, based around the stoichiometric compositions of $Fe_3Al$ and FeAl, offer excellent resistance to oxidation and sulphidation at high temperatures, with low material cost and density than austenitic and ferritic stainless steels [1]. The effect of carbon addition on the room temperature strength [2–4] and corrosion behaviour [5,6] of iron aluminides has been studied. The corrosion rate of these alloys increases with increasing carbon content [5,6].

Yangshan et al. [7] reported that small additions of Ce to $Fe_3Al$-based alloys increased ductility and strength at ambient temperature. The effect of Ce addition on the microstructure and corrosion behaviour of carbon-alloyed iron aluminides in freely aerated 0.25 mol/l $H_2SO_4$ solution was earlier studied [8]. Potentiodynamic studies revealed that all the alloys exhibited active–passive behaviour in the acidic solution. The iron aluminide with Ce addition exhibited lower corrosion rates. Scanning electron microscopy of corroded surfaces indicated that the carbon-alloyed intermetallics were susceptible to localized galvanic corrosion due to the presence of carbides in the microstructure. The attack was more uniform in the case of Ce alloyed iron aluminide due to the finely dispersed morphology of the carbides. The aim of the present study was to understand the effect of Ce addition on the corrosion behaviour of carbon-alloyed iron aluminides using EIS and cyclic voltammetry techniques [9].

## 2. Experimental

The chemical composition of alloys used in the present study, in atomic percent, was Fe–20.0Al–2.0C, Fe–18.5Al–3.6C and Fe–19.2Al–3.3C–0.07Ce. The composition of these alloys in weight percent are, respectively, Fe–11.0Al–0.5C, Fe10.5Al–0.9C and Fe–10.5Al–0.8C–0.2Ce. A mild steel sample of composition Fe–0.062C, 0.005Si, 0.006P, 0.02Ni, 0.004Co, 0.185Mn, 0.042Cr, 0.005Mo, 0.024Cu, 0.0007Ti, 0.032Al and 0.012S (in wt%) was also utilized for comparison purposes.

The details of processing of iron aluminides are available [10]. The ingots were hot forged to a reduction ratio of 70%. Specimens for corrosion studies were cut from the forged strips using a high speed abrasive silicon carbide cut-off wheel.

Square sections, of 1 cm side, were sectioned and connected to a conductive wire. These specimens were mounted in a cold setting epoxy such that the rolling direction (RD) plane was exposed. Typical microstructure from the RD section of all the intermetallics have been presented in [8]. Prior to each experiment, the specimen surface was polished to 600 grit surface finish and cleaned with acetone. All the electrochemical experiments were performed in a round bottom electrochemical cell of 1 l capacity using a potentiostat (EG&G Model Parstat 2263), interfaced to a personal computer. The potential was monitored using a saturated calomel electrode (SCE) attached to a Luggin capillary. All the potentials referred in this paper are with respect to SCE. A graphite rod was used as the counter electrode. A freely aerated 0.25 mol/l $H_2SO_4$ solution of pH = 0.74 was used as the electrolyte (20–25 °C).