Accepted Manuscript

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PII: S0925-8388(18)33517-5

DOI: 10.1016/j.jallcom.2018.09.265

Reference: JALCOM 47684

To appear in: *Journal of Alloys and Compounds*

Received Date: 8 February 2018

Revised Date: 31 July 2018

Accepted Date: 21 September 2018

Thermodynamic Assessment of the Fe-Te System. Part I: Experimental study

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Abstract

A thermodynamic description of the Fe-Te system needs to be developed in order to model internal corrosion by fission products in fuel pins of Generation IV nuclear reactors. In preparation for a thermodynamic assessment of the system, an experimental study has been performed in order to clarify some unknown or conflicting phase diagram data. New phase diagram data have been obtained using Differential Thermal Analysis and isothermal heat treatments followed by electron microscopy with EDS and WDS analysis. The DTA analysis revealed new phase boundary data, and confirmed a very steep Fe-rich liquidus, supporting the possibility of a liquid miscibility gap in the Fe-FeTe region. The analyses also confirmed the probable eutectoid reaction $\delta \rightarrow \beta + \delta'$ at 523 $°C$. The invariant arrests of the unknown γ phase were consistent with information available in literature, but the phase was not identified via XRD of samples at its postulated composition. However, metallography of the samples revealed an unexpected microstructure pertaining to the δ phase, which might be the γ phase, and is discussed in this paper. The monoclinic space group $C2/m$ is proposed for the δ phase based on XRD. The collected data will be used together with that available in literature to perform a thermodynamic Calphad assessment in a subsequent paper *Part II: Thermodynamic modeling*.

Keywords: "nuclear reactor materials", "thermal analysis", "scanning electron microscopy, SEM", "metallography", "X-ray diffraction", "phase transitions"

1. Introduction

Most commercial light water reactors (LWR) operate in a thermal neutron spectrum, with zirconium alloys as the fuel encapsulation (cladding). Among Generation IV nuclear reactors currently under development are the Sodium cooled Fast neutron Reactors (SFR), operating with a fast-neutron spectrum and a liquid sodium coolant. The MOX fuel (mixed oxide of uranium and plutonium) pellets are contained in stainless steel cladding. Post irradiation examination of MOX fuel pins from SFR reactors have revealed an internal corrosion process where some fission products initiate Fuel-Cladding Chemical Interaction (FCCI) and Fission-Product induced Liquid Metal Embrittlement (FPLME) [1-3]. This corrosion is facilitated by the release and migration of these volatile fission