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Experimental and thermodynamic description of the Er-Zr system

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Abstract – Erbium may be used as a burnable poison in nuclear reactors. An innovative concept consists in introducing Er directly into the zirconium-alloy cladding. In this work, the Er-Zr binary system has been completely re-determined experimentally and assessed by the Calphad method.

This work is a contribution to the development of innovating concepts for fuel cladding in pressurized water nuclear reactors (PWR). Increasing the reactor efficiency implies to use new materials to control the neutron flux. Burnable poisons, such as erbium or gadolinium, are added in the heart of the reactor to capture neutrons. They have an interesting absorption cross section to regulate the fuel life. Recent improvements [1] have led to the introduction of these poisons directly in the zirconium-alloy cladding. It is therefore essential to study the Er-Zr phase diagram in order to understand the interaction between the Er-Zr layer and the Zr alloy.

This system has been investigated experimentally by the analysis of several arc-melted samples of various compositions and equilibrated at different temperatures. They were characterized using electron microprobe analysis, scanning electron microscopy and X-ray diffraction. The phase transformations were studied by differential thermal analysis and differential scanning calorimetry. Due to the high vapour pressure of erbium, such measurements at high temperature (> 1200℃) ar e very difficult to perform. To overcome this problem, an original technique was developped to measure phase transformations involving liquid by simple thermal analysis with a pyrometric measurement of the temperature of the sample in an induction furnace.

The obtained experimental data have been used to optimize the Er-Zr system with the Calphad method. This semi-empirical thermodynamic modelling method consists in describing the Gibbs energy of the different phases by fitting to the experimental data (Figure 1). Good agreement was obtained between the observed and calculated phase diagrams. The Er-Zr system may therefore be included in the Zircobase [2], a thermodynamic database dedicated to zirconium-based alloys in order to perform predictive calculations in multi-element systems.

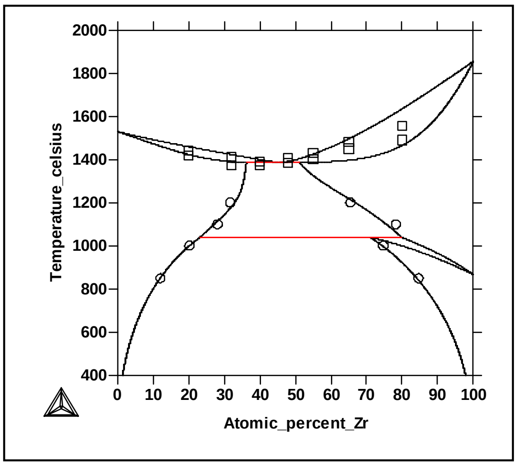

Figure 1: Er-Zr phase diagram, experimental points and calculated diagram (line).

References

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