Thermal Expansion of $(U,Dy)O_2$ as a Function of Dy_2O_3

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1. Introduction

Thermal expansion of nuclear fuel is an important parameter in determining the performance of pins during their irradiation because it affects fuel-clad mechanical interactions and fuel temperatures. Thermal expansion data of sintered UO_2 are well reported in the literature [1]. $(U,Dy)O_2$ pellets can be used as burnable poison[2] fuels for PWR reactor for the purpose of high burnup and extended cycle operation. This work deals with the results and analysis of measurement of room temperature lattice parameter and thermal expansion of $(U,Dy)O_2$.

2. Methods and Results.

The UO_2 powder was mixed with weighed amounts of Dy_2O_3 powder, at concentrations of 5, 10 and 20at%, by a Turbula® mixer and then successively milled by a dynamic ball mill. The milled oxide powders were compacted with a compaction pressure of 300 MPa and the green pellet specimens were sintered at 2023K in flowing H_2 for 6 hours. The XRD patterns were recorded in the range of $20°<2\theta<120°$ by using a monochromatic Cu-Kα radiation on an X-ray diffractometer(MXP 3A-HF, MacScience). The bulk thermal expansion of all the products is investigated in the temperature range of 298-1673K in Ar atmosphere on the pellets using a thermo-mechanical analyzer(Model:SETARAM TMA 92 16/18).

2.1. Lattice Parameter

Figure 1 shows the variation of the lattice parameter of the $(U_{1-y}Dy_y)O_2$ solid solutions as a function of the Dy content. The lattice parameter of the $(U_{1-y}Dy_y)O_2$ linearly decreases as a function of the Dy_2O_3 content and follows Vegard's law, indicating the formation of a complete solid solution between the UO_2 and Dy_2O_3 phases.

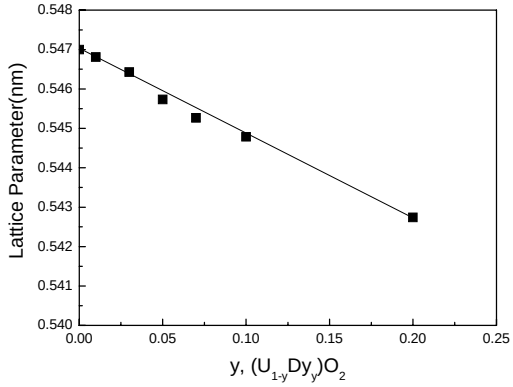

Figure 1. Lattice parameters of the $(U_{1-y}Dy_y)O_2$ solid solutions as a function of the Dy_2O_3 content

A regression was performed on the measured lattice parameters of $(U,Dy)O_2$ to express the variation of the lattice parameters(L.P.) as a linear equation. It can be expressed as :

$$L.P.(nm) = 0.54695-0.0215y(0\leq y\leq 0.2) \quad (1)$$

where y denotes the Dy content.

2.2. Thermal Expansion

Martin [3] examined the data from macroscopic measurements of Conway et al. [4] and lattice parameter measurement of Hutchings [5]. He concluded that both data showed good agreement up to 2523K. The linear thermal expansion(LTE) as a function of temperature for $(U,Dy)O_2$ pellets is shown

in Figure 2. The lattice parameter of $(U,Dy)O_2$ pellets is lower than that of UO_2 but the linear thermal expansion is vice versa.

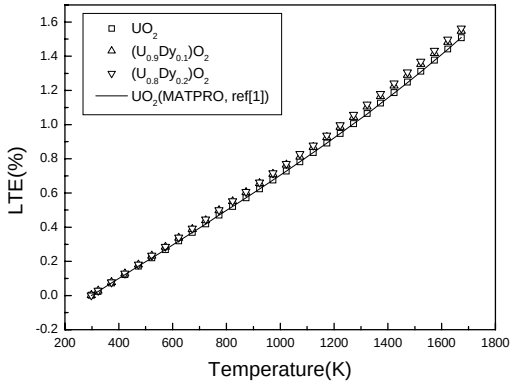

Figure 2. Comparison between the thermal expansions of UO_2 and $(U,Dy)O_2$ pellets

The expansion data of all the samples were fitted using a polynomial regression as shown below.

For pure UO_2,

$$LTE(\%) = -0.3 + 0.001T - 1.0\times10^{-7}T^2 + 8.2\times10^{-11}T^3 \quad (2)$$

For $(U_{0.9}Dy_{0.1})O_2$,

$$LTE(\%) = -0.3 + 0.001T - 1.4\times10^{-7}T^2 + 8.5\times10^{-11}T^3 \quad (3)$$

For $(U_{0.8}Dy_{0.2})O_2$,

$$LTE(\%) = -0.3 + 0.001T - 7.8\times10^{-8}T^2 + 6.5\times10^{-11}T^3 \quad (4)$$

The values of the average linear thermal expansion coefficient($\overline{\alpha}$) in the temperature range of 298-1673K are given in Table 1. As can be seen from Table 1, the average linear thermal expansion coefficient($\overline{\alpha}$) exhibits a definite trend as a function of Dy contents. For example, $\overline{\alpha}$ values of UO_2 in the same temperature range was found to be 10.97x10^{-6} K^{-1} and increased to 11.37x10^{-6} K^{-1} in $(U_{0.8}Dy_{0.2})O_2$ pellet, indicating that the partial substitution of U^{4+} with Dy^{3+} results in weakening the inter-atomic bonding in the solid solution matrix.

Table 1. Coefficients of average linear thermal expansion($\overline{\alpha}$) for pure UO_2 and $(U,Dy)O_2$ in the temperature range of 298-1673K

Composition	average cte($\times10^{-6}$ K^{-1})
Pure UO_2	10.97
$(U_{0.9}Dy_{0.1})O_2$	11.26
$(U_{0.8}Dy_{0.2})O_2$	11.37

3. Conclusion

Lattice parameter of $(U,Dy)O_2$ pellets is lower than that of UO_2 and decreased as a function of Er content. As the Dy content increased in $(U,Dy)O_2$ pellets, linear thermal expansion and average thermal expansion coefficient values continuously increased.

Acknowledgements

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