Synthesis of $LaYO_3$ Crucible Material by Solid-state Reaction at Elevated Temperature

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1. Introduction

U-TRU-Zr-RE metal fuels generally have a low centerline temperature and a fuel cycle economy [1]. RE is composed of rare-earth elements consisting of 53wt.% Nd, 25wt.% Ce, 16wt.% Pr, and 6wt.% La. Metal fuel slugs have been fabricated with an injection casting process operating under atmospheric pressure [2]. The metal fuel is melted in a graphite crucible slurry-coated or plasma-spray coated with Y_2O_3 to prevent melt/material interactions [3]. Since highly reactive RE is included during the pyro-processing process, even the plasma-spray coated Y_2O_3 layer on the melting crucible is reacted with RE in the metal fuel and forms the reaction products of RE-Y-O system, which produces a considerable amount of fuel loss and a large amount of radioactive crucible waste. Therefore, it is necessary to develop an alternative reaction-resistant crucible material that prevents high reactivity with fuel melt to control the fuel loss and reduce the radioactive waste.

In this study, the perovskite $LaYO_3$ was introduced as an alternative reaction-preventing crucible material in this study, referring to a fabrication feasibility and a phase stability. $LaYO_3$ pellets for the melting crucible of metal fuel were prepared and characterized by a sintering method according to pseudo-phase diagram of $LaYO_3$ and Y_2O_3.

2. Methods and Results

Mixed powder slurries of La_2O_3 and Y_2O_3 powder were obtained through wet ball milling of La_2O_3 and Y_2O_3 powders for 24 hrs. La_2O_3 powder with a purity of 99.999% and a particle size of approximately 2.5 ㎛ and Y_2O_3 powder with a purity of 99.9%. The powder slurry was then annealed by heating at 1100 ℃ for 10 hrs to remove foreign adhering substances including moisture. Wet ball milling was again performed for 24 hrs to obtain a powder slurry with a uniform composition of the calcined powder. At this time, when the powder slurry was put into the spray-drying apparatus. Spherical mixed powders were prepared from the slurry of mixed powders through a spray drying and a sieving process. Green compacts using the mixed powders of La_2O_3 and Y_2O_3 were made by cold isostatic pressing (CIP). $LaYO_3$ pellets were synthesized at elevated temperatures. The density of the sintered $LaYO_3$ pellets was determined using an Archimedean immersion method. The microstructure of the sintered $LaYO_3$ synthetics was investigated by scanning electron microscopy combined with energy dispersive spectroscopy (SEM/EDS). The phase structure of the sintered $LaYO_3$ synthetics was examined by X-ray diffraction (XRD).

The X-ray diffraction patterns of the $LaYO_3$ synthetic according to sintering temperature and molar ratio of 1:1.1 (La_2O_3 and Y_2O_3) are shown in Fig. 1. The $LaYO_3$ sintered bodies had a similar X-ray diffraction pattern at sintering temperatures ranging from 1450ºC to 1550ºC for 10 hrs as shown in Fig. 1. The X-ray diffraction patterns of the sintered bodies indicated the formation of a crystallized orthorhombic $LaYO_3$ phase with a perovskite structure (Pnma) at a sintering temperature of below 1550ºC irrespectively of the molar ratio of La_2O_3 and Y_2O_3. The perovskite orthorhombic $LaYO_3$ phase is a thermodynamically stable phase from room temperature to 1585ºC based on the pseudo-phase diagram between La_2O_3 and Y_2O_3. The perovskite structure comprised an orthorhombic atom arrangement of the oxide ions and alternating layers of transition metal ions in the monoclinic coordination. However, it was confirmed that an ordered monoclinic phase (B phase) was formed partially in the $LaYO_3$ pellet at a sintering temperature of 1600ºC, regardless of the molar ratio of La_2O_3 and Y_2O_3. The $LaYO_3$ formed a stable monoclinic phase (B phase) in the range of 1585ºC to 1730ºC based on the pseudo-phase diagram between La_2O_3 and Y_2O_3.

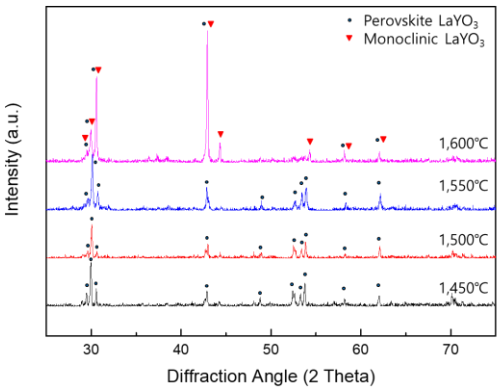

Fig. 1. The X-ray diffraction patterns of the $LaYO_3$ synthetics according to sintering temperature.

The scanning electron micrographs of the $LaYO_3$ pellet according to sintering temperature are shown in Fig. 2. The cross-sectioned micrographs of the $LaYO_3$

pellet showed a similar densification at a constant sintering temperature, independently of the molar ratio. The $LaYO_3$ pellets sintered at 1450ºC and 1500ºC showed many pores and an insufficient densification due to a lack of consolidation. The $LaYO_3$ pellets sintered at 1550ºC and 1600ºC indicated a considerable densification and small pores, resulting in a high relative density of 89.8% and 97.1% with the progress of consolidation.

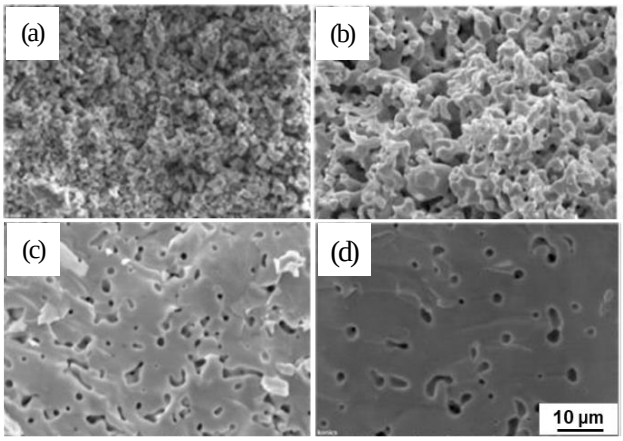

Fig. 2. The scanning electron micrographs of the $LaYO_3$ pellets according to sintering temperature: (a) 1450°C, (b) 1500°C, (c) 1550°C, (d) 1600°C.

3. Conclusions

$LaYO_3$ material as an alternative reaction-preventing crucible material was synthesized by a sintering method. The $LaYO_3$ pellets were composed of a perovskite orthorhombic $LaYO_3$ phase with phase stability by sintering ranging from 1450ºC to 1550ºC, irrespectively of the molar ratio of La_2O_3 and Y_2O_3. The $LaYO_3$ pellets sintered at 1550ºC and 1600ºC, independently of the molar ratio. It is thought that the $LaYO_3$ synthetic is a promising candidate for reaction-preventing crucible material for the injection casting of U-TRU-Zr-RE metal fuels.

REFERENCES

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