Dissolution Behavior of Rare Earth Oxides Doped Gadolinia Burnable Absorber (REGA)

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1. Introduction

Due to the high neutron absorption cross-sections of gadolinium, gadolinia-based materials can be adopted to achieve the low-boron or boron-free concept in operating power plants or small modular reactors (SMR). However, gadolinia reacts with water under the high-temperature and high-pressure conditions of pressurized water reactors (PWR), leading to swelling and cracking, which limit the applicability of UO_2-gadolinia composite fuels [1]. Previous studies have attempted to mitigate the hydration, or dissolution issue by utilizing Gd-based compounds, such as $GdAlO_3$. Mixing 50+mol.% of Al_2O_3 with gadolinia forms a stable perovskite phase, which suppresses phase transformations under high-temperature and irradiation conditions.

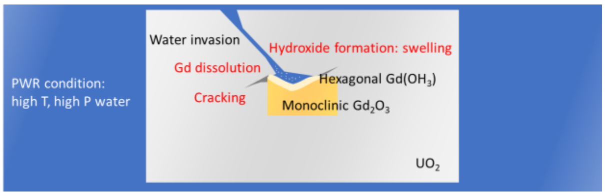

Fig. 1. Schematic representation of the pellet destruction

However, the formation of such intermediate phases results in a reduction of Gd content by at least 50% compared to pure gadolinia, leading to a decrease in neutron absorption cross-section and following a decrease in reactivity control ability. Additionally, previous studies have reported that alumina materials undergo significant amorphization under irradiation, and exhibit extremely low thermal conductivity [2].

This study aims to control the dissolution behavior of gadolinia-based burnable absorbers by doping small amounts of additive elements. Specifically, rare earth oxides doped gadolinia burnable absorber (REGA) were synthesized and their dissolution behavior was evaluated.

2. Methods and Results

2.1 Fabrication of rare earth oxides doped gadolinia burnable absorber

To investigate the dissolution behavior of burnable absorbers as doping elements, REGA pellet fabrication was conducted. The selection of additive elements and their composition was determined based on ionic radius and phase diagrams [3]. For comparison, pure gadolinia and $GdAlO_3$ pellets were also fabricated. Powder mixing was performed using planetary milling, and the mixed powders were fabricated into pellet form under the conventional sintering method.

2.2 Phase analysis

X-ray diffraction (XRD) phase analysis was conducted on the fabricated burnable absorbers. Pure gadolinia is known to undergo an irreversible cubic to monoclinic phase transition at around 1250°C. Consequently, during the nuclear fuel sintering process, which typically exceeds 1700°C, gadolinia forms a monoclinic structure. However, with doping of specific oxide elements, the formation of a solid solution leading to phase stabilization was observed.

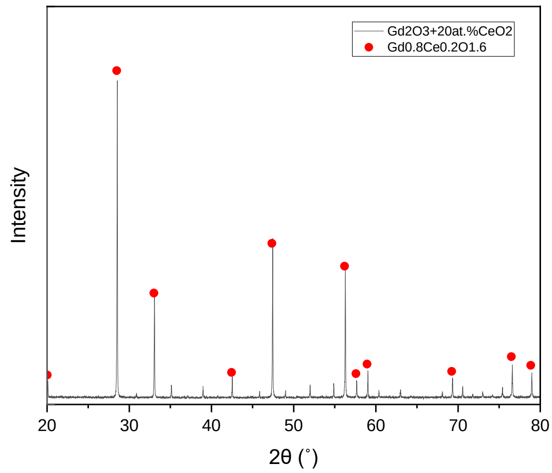

Fig. 2. XRD results for CeO_2 doped gadolinia burnable absorber.

2.3 Dissolution analysis

To evaluate the dissolution behavior of the fabricated burnable absorbers, an autoclave leaching test was conducted. The leaching behavior of Gd into water under conditions of up to 350°C temperature and 22 MPa pressure was measured using inductively coupled plasma mass spectrometry (ICP-MS). Based on the measured dissolution data and the initial Gd content for each sample, the hydration resistance was evaluated as a doping element and composition.

3. Conclusions

This study focused on preventing the hydration and following the dissolution of gadolinia burnable absorber with low doping of REO. Phase and dissolution analyses were conducted on fabricated REGA samples. XRD results showed the formation of a stable cubic phase with low doping of specific elements such as Ce. Autoclave leaching test results show that small amounts of doping of REO on gadolinia burnable absorber can effectively prevent hydration. This work contributes to the enhanced fuel safety and development of innovative nuclear fuel.

REFERENCES

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