Analysis of Dissolution Behavior of Doped Gadolinia Burnable Absorber

Hyeong Jin Kim [a], Hyeongju Bae[b], Ho Jin Ryu [a] *
[a]Department of Nuclear and Quantum Engineering, KAIST, Daehak-ro 291, Yuseong-gu, Daejeon, 34141, Korea
[b]Department of Nuclear Engineering, UNIST, Ulju-gun,Ulsan 44919, Republic of Korea
[*]*Corresponding author: hojinryu@kaist.ac.kr*

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1. Introduction

Neutron poisons are used to control nuclear reactor reactivity and fuel cycle. Boron and gadolinium are the main poison materials. Boric acid is commonly used in pressurized water reactors but can cause a positive moderator temperature coefficient (MTC) problem. To prevent the issue, solid-state burnable absorbers with low or no use of boron, can be adopted (Fig. 1.).

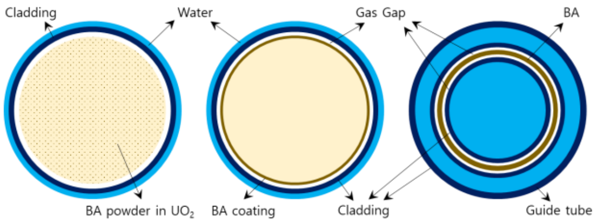

Fig. 1. Common fuel-burnable absorber design for commercial reactors

However, gadolinia forms hydroxide when it reacts with water under high temperature and high pressure PWR conditions, resulting in swelling and cracking (Fig. 2.). Further dissolution due to thermal decomposition and following pore formation reduces heat transfer, raise the fuel temperature and increase reactivity due to gadolinia loss. Accordingly, this dissolution issue is one of limiting factor in the use of UO_2-Gadolinia composite fuel.

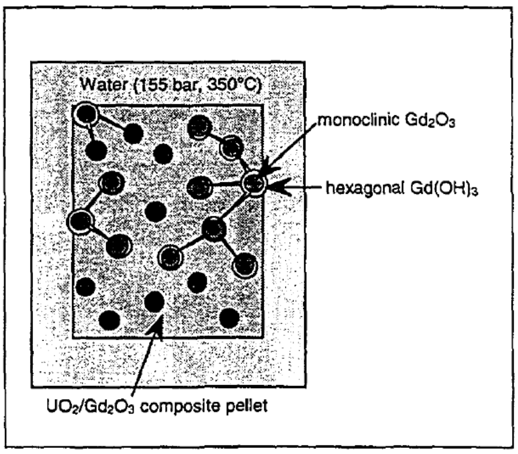

Fig. 2. Schematic representation of the pellet destruction [1]

One attempt is to adopt another Gd-based compound prohibiting Gd dissolution. Highly Intensive and Discrete Gadolinia/Alumina Burnable Absorber (HIGA) concept includes $GdAlO_3$ perovskite, stable phase prohibits monoclinic to cubic phase transition in high temperature and irradiation condition (Fig. 3.).

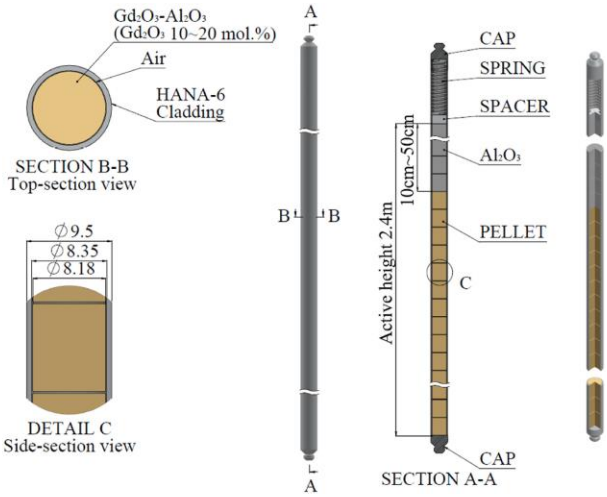

Fig. 3. HIGA rod concept [2]

However, HIGA rod includes 10-20 mol.% Gd_2O_3 + Al_2O_3 which has low Gd content. For the UO_2-Gd_2O_3 composite fuel, higher Gd composition to effectively control the reactivity is preferred.

In this study, we investigated the effect of various doping element and composition on sintered gadolinia to prevent the hydration with low doping.

2. Methods and Results

2.1 Fabrication of doped gadolinia burnable absorber

To investigate the Gd dissolution with changing the doping elements and its composition, first the doped Gd_2O_3 pellets were fabricated. Doping elements were selected considering phase diagram and reference to precedents. Russian reactors adopted Al, Zr, Nb as a doping element for gadolinia burnable absorber [3,4], we started from those elements. The specimens with varying doping elements and composition were then fabricated by conventional sintering method.

2.2 Phase analysis of fabricated burnable absorber

Phase analysis for the fabricated burnable absorber was conducted using XRD. Gadolinia undergoes irreversible phase change from cubic to monoclinic phase around 1200ºC, so the pure gadolinia forms monoclinic phase with sintering condition of typical fuel pellet fabrication (>1700ºC). However, with specific doping elements, cubic gadolinia phase was found with low doping, and cubic gadolinia is expected to provide better protection from hydration.

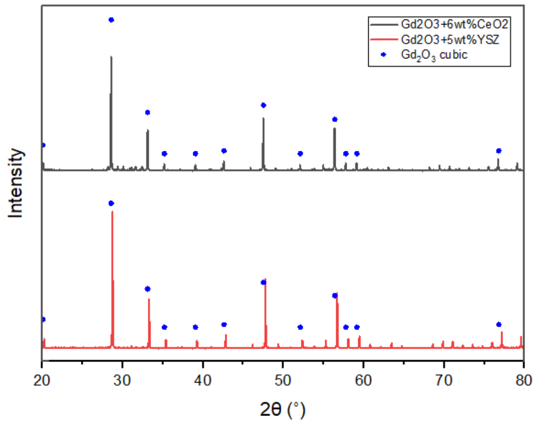

Fig. 4. XRD results for CeO_2 and YSZ doped Gd_2O_3

2.3 Dissolution analysis

To evaluate the dissolution characteristics of doped gadolinia burnable absorbers, leaching test was then conducted. Experimental procedure followed the product consistency test (PCT) and ANSI/ANS-16.1 standard leaching test methods. Leaching concentration of pure and doped gadolinia was then compared and evaluated.

Fig. 5. Leaching test of doped gadolinia burnable absorber

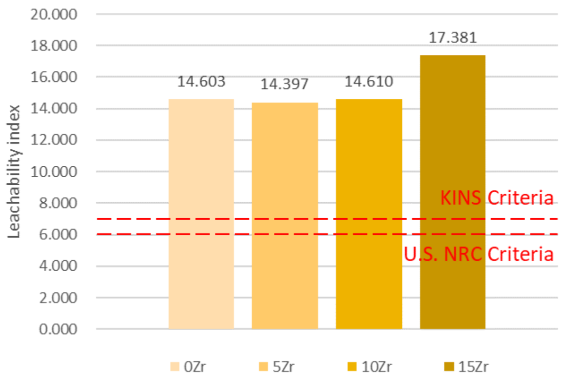

Fig. 6. ANSI/ANS-16.1 leachability index results with increasing Zr content

3. Conclusions

This study focused on preventing the hydration and following dissolution of gadolinia burnable absorber with low doping. Phase analysis and dissolution analysis were conducted. XRD results showed stable cubic phase is formed with low doping of specific elements such as Ce or Zr. The leaching test results show that even small amounts of doping on gadolinia burnable absorber can effectively prevent hydration. This work is expected to contribute to the enhanced fuel safety and accelerates the development of the innovative nuclear fuel.

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