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Helium ion irradiation effects on Nd and Ce co-doped $Gd_2Zr_2O_7$ pyrochlore ceramic

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Abstract: This paper studies the helium ions irradiation effects on Nd and Ce co-doped $Gd_2Zr_2O_7$ ceramics, where Nd replaces the Gd site and Ce replaces the Zr site respectively. A series of $(Gd_{1-x}Nd_x)_2(Zr_{1-y}Ce_y)_2O_7$ ($0 \leq x, y \leq 1$) ceramics were irradiated with a 500 keV He ions at room temperature at fluences ranging from 1×10^{15} to 1×10^{17} ions / cm^2. The irradiated samples were characterized using GIXRD, Raman and SEM measurements. From the GIXRD and Raman observations, the results indicate that all the samples display a deficient fluorite structure after irradiation. The irradiation toleration increases with the irradiation depth increasing under experimental conditions, and $Nd_2Ce_2O_7$ has the best irradiation stability in the $(Gd_{1-x}Nd_x)_2(Zr_{1-y}Ce_y)_2O_7$ ($0 \leq x, y \leq 1$). Based on SEM results, the irradiated samples are still relatively dense and uniform, and no second phase exists.

Keywords: helium ion irradiation; ceramic; pyrochlore; co-doping

1 Introduction

The development of nuclear power has become an excellent solution to the increasing energy problems, lacking fossil fuels and exhausting greenhouse gas. However, the safe disposition of increasing nuclear waste, especially high level radioactive waste (HLW), has become a major challenge for sustainable development of the nuclear industry [1, 2]. Among the different treatments, long term disposal in a safe repository with a so-called "deep geological disposal" is currently regarded as the technically feasible and safe manner [3, 4]. A material selected for this application has to follow stringent criteria: high incorporation of nuclear waste, excellent physical properties, high chemical durability and remarkable resistance to radiation [5-9].

Since Ringwood et al.[5] put forward the idea of using assemblages or composites of mineral analog, named as SYNROC, as a potential host for HLW immobilization in 1978. The materials such as pyrochlore, zirconolite, monazite, zircon, montmorillonite and apatite have received intensive attention [6-12]. Among them, gadolinium zirconate pyrochlore ($Gd_2Zr_2O_7$) has attracted the attention of researchers as a suitable host material for immobilization [13]. The structure of $Gd_2Zr_2O_7$ is well known as the compound with general formula $A_2B_2O_7$, belongs to $Fd\bar{3}m$ space group, which is a

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