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チタン酸リチウムにおけるトリチウム滞留挙動に及ぼす照射損傷影響

Effect of irradiation damages on tritium retention behavior in lithium titanate

戸田 健介[1)]、小林 真[1)]、内村 大道[1)]、佐藤 美咲[1)]
藤井 俊行[2)]、山名元[2)]、大矢 恭久[1)]、奥野 健二[1)]
Kensuke Toda[1)], Makoto Kobayashi[1)], Hiromichi Uchimura[1)], Misaki Sato[1)]
Toshiyuki Fujii[2)], Hajimu Yamana[2)], Yasuhisa Oya[1)] and Kenji Okuno[1)]

[1]静岡大学大学院理学研究科 [2]京都大学原子炉実験所
[1] Graduate School of Science, Shizuoka University, [2] Research Reactor Institute, Kyoto University

Lithium titanate (Li_2TiO_3) is one of the candidates as the tritium breeding material for the test blanket module of ITER due to its good tritium recovery efficiency and chemical stability. Elucidation of migration processes of tritium produced by nuclear reaction, such as ^6Li (n, α) T in Li_2TiO_3, is important to establish the effective blanket system in fusion reactor. In actual condition, it is expected that irradiation damages will be introduced during neutron irradiation, and tritium retention behaviors will be affected by the interaction between tritium and irradiation damages. Therefore, understanding of correlation between recovery of irradiation damage and tritium retention behaviors is required. In this study, deuterium exposed Li_2TiO_3 was irradiated by γ-ray or neutron in order to introduce irradiation damages. Then, the deuterium release behavior and the annihilation behavior of irradiation damages were evaluated by thermal desorption spectroscopy (TDS) and electron spin resonance (ESR), respectively. In addition, fourier transform infrared spectroscopy (FT-IR) measurement was also performed for γ-ray irradiated sample to investigate the state of O-D bond. The effect of the irradiation damages on tritium retention behaviors was discussed.

Powder of Li_2TiO_3 purchased from Furuuchi Chemical Corporation was preheated at 1173 K for 3 hours under high vacuum. Then, the sample was exposed to deuterium gas at 673 K with the pressure of 2.0×10^5 Pa for 24 hours to introduce deuterium homogeneously. The deuterium gas exposed sample was introduced into quartz tubes and vacuum-encapsulated. Thereafter, γ -ray irradiation was performed at room temperature with the doses of 1 MGy using Co-60 γ-ray irradiation facility at Shizuoka University. For the other samples, thermal neutron irradiation was performed with the fluence of 3.3×10^{15} n cm^{-2} at Research Reactor Institute, Kyoto University (KURRI). TDS experiments were carried out for these samples to investigate the deuterium retention behavior from room temperature to 1173 K with the heating rate of 5 K min^{-1}. The ESR and FT-IR measurements were performed to elucidate the stability of irradiation damages and O-D bonds.

The ESR measurement showed that the amounts of oxygen vacancy (E'-center) and dangling bonds of oxygen such as O^--center and O_2^-center were increased by γ-ray irradiation, where E'-center is known as the trapping site of hydrogen isotopes. It was considered that most of deuterium dissolved in Li_2TiO_3 grains was trapped by oxygen vacancy. Figure shows the deuterium TDS spectra for γ-ray irradiated sample with the dose of 1 MGy and unirradiated sample. Three deuterium desorption stages were observed at around 400, 550 and 650 K, attributing to the desorption stage of deuterium adsorbed on the surface, trapped by oxygen vacancy and bound to oxygen as O-D bonds. FT-IR measurement revealed that there were two types of O-D bonds, namely O-D bond affected by Li vacancy and interstitial O-D bond. The deuterium retention as O-D bond was significantly enhanced, but the deuterium retention trapped by oxygen vacancy was clearly reduced by γ-ray irradiation. It was reported that the potential energy barrier of deuterium trapped by Li vacancy with bound to oxygen was lower than that retained in interstitial sites, considering that deuterium retained in Li_2TiO_3 would react with the dangling bond of oxygen, near the site such as Li vacancy, resulting the formation of O-D bond. It was clarified that the tritium retention as O-T bond in neutron irradiated Li_2TiO_3 was also increased with the irradiation damages as the case with γ-irradiated sample. Therefore, it was founded that the formation of O-T bond by irradiation damages would be significantly contribute to the tritium inventory

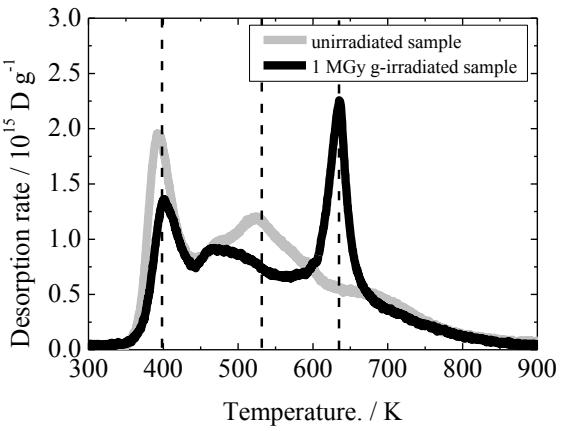

Fig. Deuterium TDS spectra for deuterium exposed Li_2TiO_3 with or without γ-ray irradiation at 1 MGy.