Effects of the lithium concentration on tritium release behaviors from advanced tritium breeding material $Li_{2+x}TiO_3$

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Hiromichi Uchimura (1), Makoto Kobayashi(1), Kiyotaka Kawasaki(1), Yuto Miyahara(1), Tomohisa Taguchi(1), Kensuke Toda(1), Toshiyuki Fujii(2), Hajimu Yamana(2), Yasuhisa Oya(1) and Kenji Okuno(1)

(1) Radioscience Research Laboratory, Shizuoka University (2) Research Reactor Institute, Kyoto University

➢E-mail: r0232002@ipc.shizuoka.ac.jp

静岡大学 理学部 Shizuoka University Faculty of Science
Kyoto University Research Reactor Institute

Introduction

Li_2TiO_3 : Candidate of tritium breeding materials

To increase the efficiency of tritium generation

Lithium-riched materials : $Li_{2+x}TiO_3$

•$Li_{2+x}TiO_3$: Mixture of Li_2TiO_3 and Li_4TiO_4 structures

Previous study[1]

Elucidation of tritium release behavior from $Li_{2+x}TiO_3$

✓Observation of two tritium release stages (470 and 600 K) in $Li_{2+x}TiO_3$

✓Increase of Peak 1 (470 K) with increasing the Li concentration

Tritium release stage from $Li_{2+x}TiO_3$ structure as Peak 1 was observed in Li_4TiO_4.

Tritium release from $Li_{2+x}TiO_3$ was consisted of that from Li_2TiO_3 and Li_4TiO_4

In blanket system : Necessity of estimation for tritium inventory

Irradiation defects : Control of tritium release behavior

The deference of annihilation behavior of irradiation defects with increasing the Li concentration

Elucidation of the Li concentration effects on annihilation kinetics of irradiation defects for tritium release behavior

[1]M. Kobayashi, et al., Jour. Nucl. mater. in submitted.

Experimental

Sample : $Li_{2.0}TiO_3$, $Li_{2.4}TiO_3$ powder (Kaken Co. Ltd.)

Preheating
R.T. – 1173 K for 3 h
Under He gas with less than few Pa

Neutron irradiation @ KUR
Neutron flux : 5.5×10^{12} n cm^{-2} s^{-1}
Neutron fluence : 3.3×10^{15} n cm^{-2}

Fig. Pre-irradiated sample

ESR measurement

To clarify the annihilation behaviors of the defect for $Li_{2.0}TiO_3$ and $Li_{2.4}TiO_3$

To evaluate the kinetics of the defects annihilation

Isochronal annealing
Heating region : R.T.-773 K
Heating step : 25 K

Isothermal annealing
Heating region : 573 – 673 K
Heating time : up to 8 h

※ The amount of defects : Estimated by $CuSO_4 \cdot 5H_2O$

Results and discussion

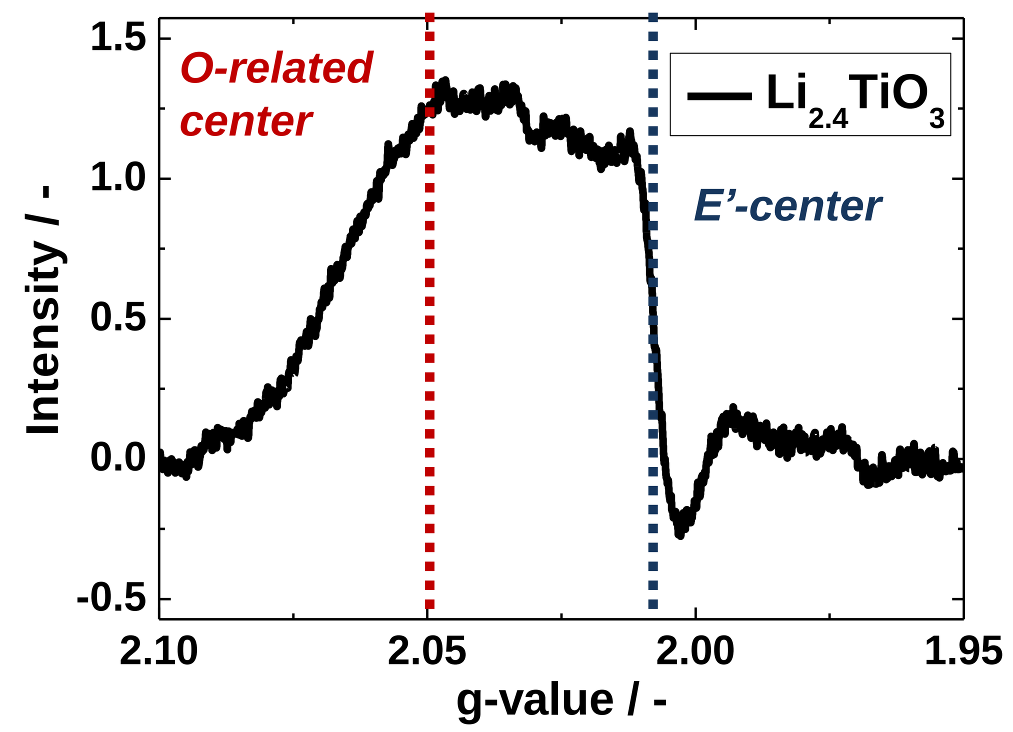

Fig. ESR spectra for $Li_{2.4}TiO_3$

Two irradiation defects : E'-center, O-related center

•E'-center(g = 2.01)
Oxygen vacancies trapping one electron

•O-related center [O^--center, O_2^--center](g = 2.05)
Oxygen atoms in interstitial of lattice

Tritium trapping site

Frenkel pair : Annihilation by recombination

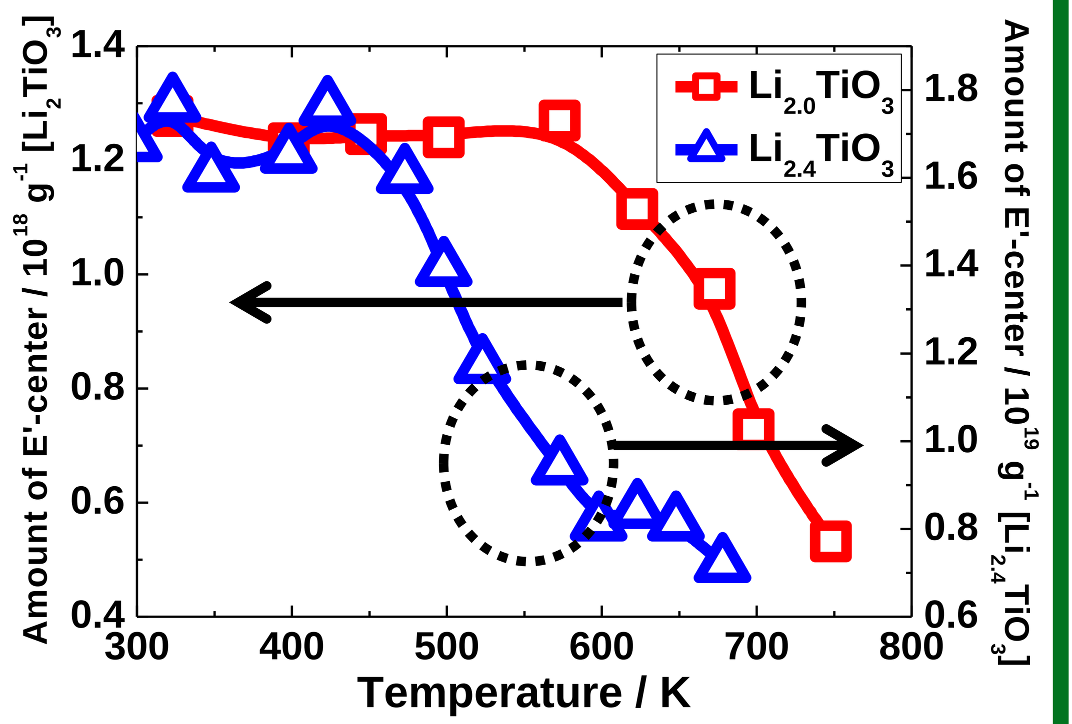

Fig. Annihilation behavior of E'-center in isochronal heating

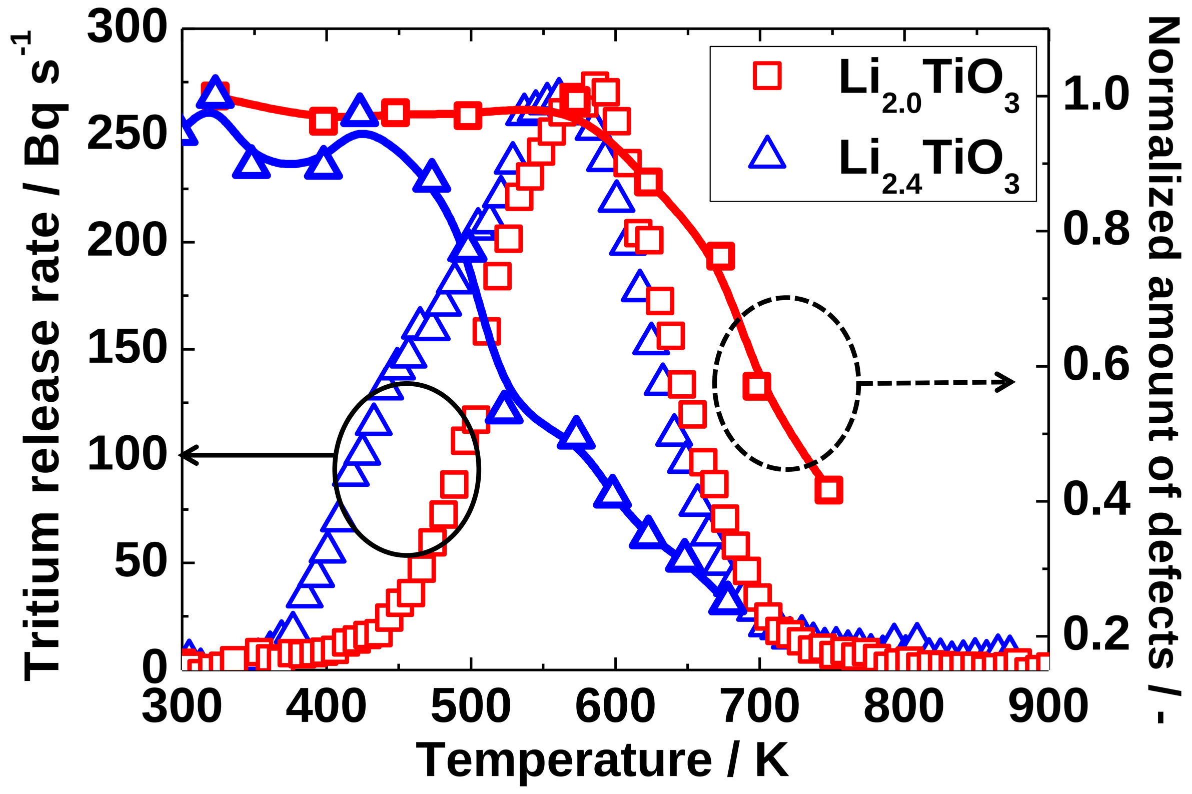

Fig. Comparison of TDS spectra and annihilating behaviors

E'-centers in $Li_{2.0}TiO_3$ were decreased above 600 K

E'-centers in $Li_{2.4}TiO_3$ were decreased around 400 – 700 K

In Li-riched samples : Existence of Li_4TiO_4[2]

Irradiation defects formed in Li_4TiO_4 structure were annihilated easily.

Peak 1 (450 K) : Tritium release from Li_4TiO_4 structure

Peak 2 (600 K) : Tritium release from Li_2TiO_3 structure

Annihilation temperature region of defects formed in $Li_{2.4}TiO_3$⇒Corresponding to Peak 1

Peak 1 : Tritium release triggered by annihilation of defects formed in Li_4TiO_4

Isothermal annealing

Annihilation rate of E'-center was expressed as follows,

$$N(t) = N_0 \exp(-kt)$$

$N(t)$: The amount of E'-centers in time
N_0 : Initial amount of E'-center
k : Rate constant of reaction

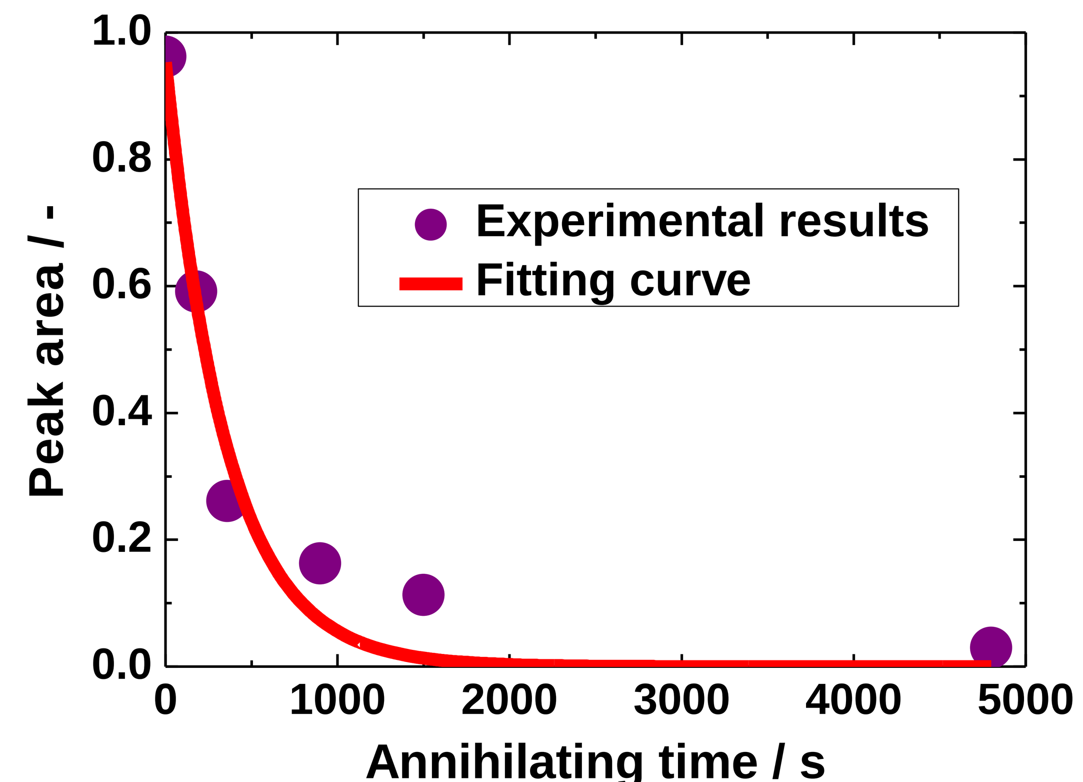

Fig. Typical fitting result of isothermal experiment for $Li_{2.4}TiO_3$ at 673 K

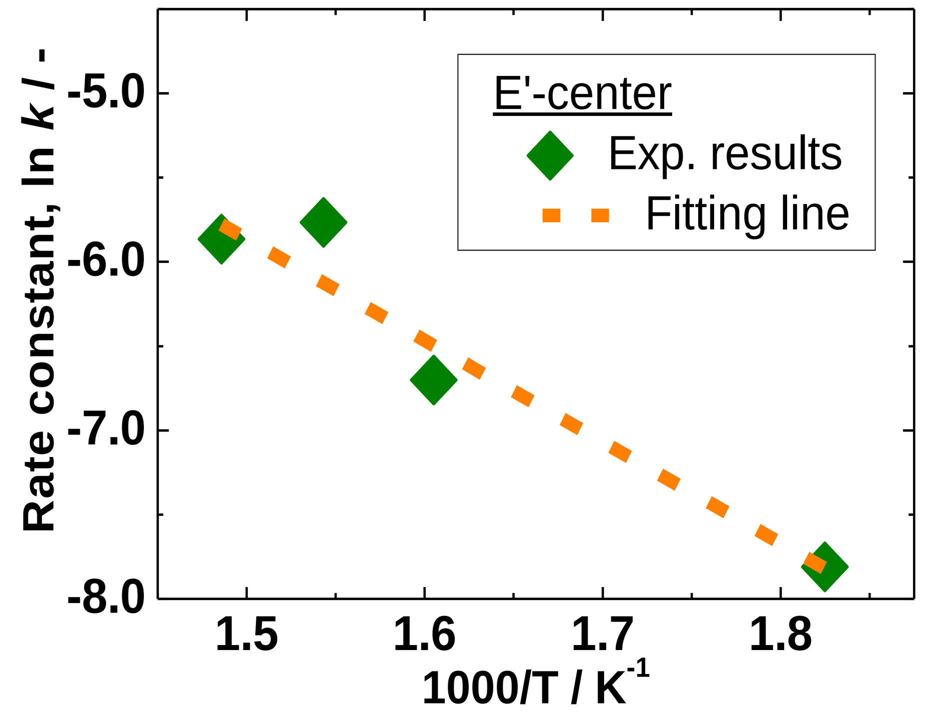

Fig. Irradiation defects annihilation kinetics for $Li_{2.4}TiO_3$

Activation energy in $Li_{2.4}TiO_3$ **0.5±0.1 eV**

Almost same in $Li_{2.0}TiO_3$ (0.5±0.1 eV)[3]

1. $Li_{2.0}TiO_3$ and Li_4TiO_4 have the same constituent atom.
2. $Li_{2.0}TiO_3$ is the predominant structure.

Contribution of Li_4TiO_4 structure for the apparent activation energy was underestimated.

[2] M. Hara., et al., Jour. Nucl. Mater. 404(2010)217-221
[3] J. Osuo., et al., Fus. Eng. Des. 86(2011)2362-2364

Conclusion

•Irradiation defects formed in Li_4TiO_4 structure were annihilated easily compared to that in Li_2TiO_3.

•Tritium trapped by defects in Li_4TiO_4 structure was triggered with annihilation of defects.

•Tritium inventory in $Li_{2+x}TiO_3$ will be reduced with the increasing of Li concentration in the actual fusion reactor.