Effect of Surface Water on Release Behavior of Bred Tritium from Li$_2$TiO$_3$

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The model to predict the tritium release behavior from solid breeder materials has been developed by the present authors, and it has been confirmed that such surface reactions as isotope exchange reaction between hydrogen in purge gas and tritium on surface of breeder grain, isotope exchange reaction between water vapor and tritium on surface, water formation reaction on surface consuming hydrogen in the purge gas and adsorption/desorption of water vapor from surface give profound effect on the tritium release behavior. The surface water plays an important role to control tritium transfer in this consideration. The recent study by the present authors shows that the amount of surface water on the solid breeder materials varies depending on the conditions of the vapor pressure in the purge gas or on the way of manufacturing because a solid breeder pebble has the similar nature of hydrophilic adsorbent of water as silica gel, molecular sieves or activated aluminum. Accordingly, it is important to know if the model constructed so far by the present authors can explain the tritium release behavior when the amount of surface water is varied.

It is observed in this study that the temperature programmed bred tritium desorption experiment using the as-received Li$_2$TiO$_3$ sample from CEA gives rather earlier tritium release peak than the release peak observed at the experiment using the sample which is preparatory dried in high temperature helium gas or helium gas with hydrogen and that some portion of bred tritium is released at purge with dry gas at the room temperature. The dry purge gas and the purge gas with hydrogen give the same release behavior. The chemical form of the released tritium is HTO at this experiment even when dry gas with hydrogen is used as the purge gas. It is also observed in this study that not a little amount of physically adsorbed water and chemically adsorbed water exist on the surface of as-received solid breeder materials.

The release behavior of surface water from various solid breeder materials is quantitatively discussed and a computer code to predict the release behavior of the surface water is made in this study. It is finally confirmed in this study that the model constructed by the present authors so far for prediction of release behavior of bred tritium
gives good estimation of the tritium release behavior from the as-received sample when the code for estimation of the amount of surface water is combined. The release behavior of bred tritium from the as-received sample is explained with desorption behavior of chemically adsorbed water on the breeder surface during the neutron irradiation procedure.

Mission of the breeding blanket system in a fusion reactor is to recover most of the bred tritium rationally. The whole blanket system, which consists of breeding part, piping part, recovery part and monitoring part, must be designed considering that some bred tritium is released to the purge gas in the chemical form of HTO even when hydrogen is added to the purge gas and that not a little amount of water is released from the surface of solid breeder materials from desorption of surface water together with water formation reaction because chemical form of tritium and existence of water vapor in the purge gas can give profound effect on the system effect in the piping part, the memory effect in the monitoring part and tritium recovering efficiency in the recovery part. It goes without saying that effort to analyze the tritium transport phenomena in the breeding part without paying attention to the effect of water or chemical form of bred tritium in the piping system or the monitoring system may give erroneous results in estimation of the tritium behavior in the blanket system.

The water management is important in understanding of tritium transfer phenomena in the solid breeder blanket system.

References
(1) Tritium in the breeding part
(2) System effect in the piping system


(3) Tritium in the monitoring part


(4) Tritium in the recovery system


Figure 1  Block diagram for development of Fusion Reactor Tritium System Complex.

Figure 2  Research steps for designing of solid breeder blanket system.

Figure 3  Issues to understand tritium behavior in solid breeder blanket system.
Figure 4-a Solid breeder grain and tritium which is given from gas flow.

Figure 4-b Behavior of bred tritium in solid breeder grain.

Figure 4-c Model to check effect of surface water on solid breeder grain.
Figure 5  Model for release behavior of bred tritium from solid breeders.

Figure 6  Estimated tritium release curves (purge gas: humid gas)

Figure 7  Tritium release curve observed for as-received Li$_2$TiO$_3$ sample.
Figure 8  Tritium release curve observed for as-received Li$_2$TiO$_3$ sample.

Figure 9-a  Release curve of bred tritium from Li$_2$TiO$_3$ (CEA) which is dried only at the room temperature

Figure 9-b  Release curve of bred tritium from Li$_2$TiO$_3$ (CEA) which is dried only at the room temperature
Figure 10  Water release curve from Li₂TiO₃ sample.

Figure 11  Water release curve from Li₄SiO₄ sample.

(purge gas: dry gas and dry gas with hydrogen)

Table 1  Temperature giving peeks at tritium release and water release.

<table>
<thead>
<tr>
<th></th>
<th>Tritium release</th>
<th>Water release</th>
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<tbody>
<tr>
<td>Li₄SiO₄</td>
<td>503K</td>
<td>383K, 553K, 663K</td>
</tr>
<tr>
<td>Li₂TiO₃</td>
<td>623</td>
<td>533</td>
</tr>
<tr>
<td>Li₂TiO₃(b)</td>
<td>668</td>
<td>523, 793, 900</td>
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<tr>
<td>Li₂ZrO₃</td>
<td>733</td>
<td>393, 473, 603</td>
</tr>
<tr>
<td>LiAlO₂</td>
<td>813</td>
<td>443, 533, 743</td>
</tr>
</tbody>
</table>

Temperature rising rate : 5 degree/min
Table 2 Assumptions made in estimation of release curve of bred tritium having a large amount of surface water

1. Temperature of the grain exceeds 573K during irradiation.
2. Surface water (chemically adsorbed water) is released to the capsule atmosphere.
3. Some tritium is released to the capsule atmosphere to form HTO.
4. Tritium in the capsule atmosphere returns to the grain surface as physically adsorbed water and chemically adsorbed water when grains are cooled after irradiation.
5. Some tritium is released from the grain surface with desorption of physically adsorbed water at the room temperature.
6. Some tritium is released from the grain surface with desorption of chemically adsorbed water at the elevated temperature.
7. Tritium left in the bulk of grain at irradiation is released via diffusion and surface reactions.

Fig. 12 Estimated tritium release curve (dry gas or hydrogen purge).

Fig. 13 Estimated tritium release curve for humid purge gas condition.
Temperature [°C]

Li$_2$TiO$_3$ (CEA) (black color)
(Dried by 10,000ppmH$_2$/N$_2$ gas at 900 °C. Then, placed in room air for 48 hours)

0.2 [g] L=8 [mm]
10,000ppmH$_2$/N$_2$ gas 400 [cc/min]

Fig. 14 Water release from blackened Li$_2$TiO$_3$ placed in room air for 48 hours.

Fig. 15 Bred tritium recovery system in tritium safety confinement system.

Fig. 16 Tritium and information transfer path in the blanket system.