EXPERIMENTAL STUDY ON TRITIUM RELEASE FROM LI_2TIO_3 PEBBLES AS TRITIUM BREEDER THROUGH INTERNATIONAL COLLABORATION BETWEEN KOREA AND CHINA

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1. INTRODUCTION

Lithium metatitanate (Li_2TiO_3) is a primary candidate material for tritium breeder in the solid type of breeding blanket concept, such as Helium-Cooled Ceramic Pebble (HCCP), Water-Cooled Ceramic Breeder (WCCB), Helium-Cooled Ceramic Reflector (HCCR), Helium-Cooled Ceramic Breeder (HCCB), and so on [1, 2]. The solid breeder is used as a pebble form in the breeding blanket due to packing phenomena, stress concentration, thermal conductance, purge gas flow, and so on [3]. The important properties of breeder pebbles are not only physical properties, such as diameter, sphericity, porosity, strength, and so on, but also tritium release property. The tritium is generated by nuclear reaction between a neutron from the fusion plasma and a lithium atom in the breeder pebbles. Therefore, the neutron source and tritium handling facility are essential infrastructure in order to investigate the tritium release property of breeder pebble. Korea Institute of Fusion Energy (KFE) in Korea has a source technology on the manufacturing of tritium breeder pebble. Meanwhile, Institute of Nuclear Energy Safety Technology (INEST) in China is operating the neutron source and tritium handling facility. Therefore, the international collaboration between Korea and China has been launched to investigate the tritium release property of the breeder pebbles for fusion energy. The preliminary experimental results of the Li_2TiO_3 pebble manufacturing, the neutron irradiation and the tritium release test from the irradiated pebbles are addressed in this study.

2. EXPERIMENTS

Li_2TiO_3 pebbles with 3.43 mm in diameter were manufactured by Powder Injection Molding (PIM) process which was first apply to pebble manufacturing by KFE. In addition, the specially designed rotating furnace system was utilized to avoid the adhered pebbles during sintering process. Average sphericity and grain size of the pebbles were less than 1.01 and 1.00 μm, respectively. The uniform microstructure with open pores in inside and outside of the sintered Li_2TiO_3 pebbles was observed. The porosity was about 39.7 % which was a relatively high as a breeder pebbles [4].

The High-Intensity D-T Fusion Neutron Source (HINEG-CAS) was employed at INEST to conduct the neutron irradiation experiment on the Li_2TiO_3 pebbles. Average neutron intensity during the irradiation was 5 x 10^{10} n/s. Total number of neutron with 14 MeV energy on the pebbles was reached to 1.104 x 10^{15} n. The neutron intensity and total number was measured by activated Nb foil. The irradiation test was conducted for about 6 hrs at room temperature [5].

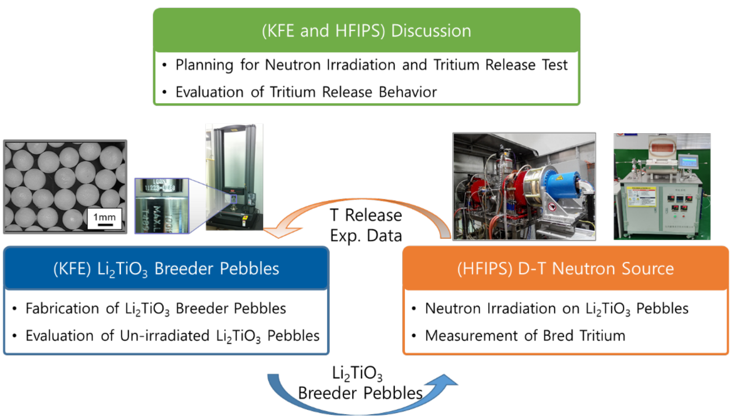

Fig.1 Structure of International Collaboration between Korea and China

Tritium release test from the irradiated pebbles was conducted by the tritium release system at INEST. The chemical composition of a purge gas was He + 1 % H_2. The flow rate and humidity of the gas were 100 ml/min and less than 15 ppm, respectively. The temperature of tritium release test was from room temperature to 800 ºC with 100 ºC / 1 h of heating rate. The temperature holding and the tritium collection by bubblers were conducted at every 100 ºC. The collected tritium was measured by ultra-low background liquid scintillation spectrometer [5].

3. RESULTS AND DISCUSSTION

During sintering process, the volumetric shrinkage ratio of Li_2TiO_3 pebbles was about 15 %. It can be used as a parameter to design the PIM mold in order to control the diameter of pebbles. In addition, the connected pebbles were not observed due to the pebble moving in the specially designed rotating furnace system. Therefore, the defects, such as crack, bump, flatted surface, and so on, were not formed at the surface of sintered pebbles. Also, the pebbles had an uniform microstructure with same particle size and open pores in the inside and outside of pebbles, and an extremely good sphericity. However, the amount of binder material has to be reduced during PIM process to decrease a porosity of the pebbles to improve the mechanical/thermal properties and increase the lithium density for high-performance of tritium breeder.

The total radioactivity of release tritium from the irradiated Li_2TiO_3 pebbles with 274.1 g in weight was about 1866.4 Bq. Tritium release behaviour including the ratio between HTO and HT from the bubblers at elevated temperature was preliminary investigated. Before heating, a certain amount of HTO and HT were about 54.4 Bq and 23.6 Bq, respectively. It was estimated that the tritium was bred at the surface during irradiation. The total amount of tritium released gradually increased until 400 ºC, and subsequently decreased at higher than 400 ºC. The ratio between HTO and HT at 400 ºC was about 79.3 % to 20.7 %. And then, the tritium radioactivity was decreased to background level after 4 hrs at 800 ºC.

4. SUMMARY

Li_2TiO_3 pebbles with 1 μm in grain size and high sphericity for tritium breeder material were successfully manufactured by using PIM process. The bred tritium from irradiated pebbles by 14 MeV fusion neutron source was successfully collected and measured. The preliminary test results are as follows;

- With increasing temperature, the total amount of HTO released gradually increased, reaching the main peak near 400 ºC and subsequently decreasing.
- The release pattern of HT exhibited similarity to that of HTO. However, there was almost no HT release below 300 ºC.
- The collected bred tritium was decreased to background levels, and indicating no residual tritium retention after 4 hrs at 800 ºC.

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