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# Preliminary Study on Melting and Reaction with Liquid Metal Breeders for Developing the Korean Test Blanket Module in ITER

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## 1. Introduction

A liquid breeder blanket has been developed in parallel with the International Thermonuclear Experimental Reactor (ITER) Test Blanket Module (TBM) program in Korea. The Korea Atomic Energy Research Institute (KAERI) has developed the liquid TBM [1-6].

In the Korean liquid TBM and breeder blanket, liquid lithium (Li) and lead-lithium (PbLi) are considered as breeders. Related research has been performed: an Experimental Loop for a Liquid breeder (ELLI) constructed to develop an electromagnetic (EM) pump for circulating the liquid breeder, a magentohydrodynamic (MHD) experiment, and a flow corrosion test [7, 8]. In the ELLI, Pb-15.7Li, where Li is 15.7 at % (called PbLi hereafter), is used as the breeding material. It was purchased from Stachow Metall Company, Germany, and its impurities are shown in Table 1. An EM pump circulates the material in the loop with a maximum flow rate of 60 lpm. The operating pressure and temperature in the loop are 0.4 MPa and 300 $^{o}$C, respectively, and the maximum operating pressure and temperature are 0.5 MPa and 550 $^{o}$C.

Before the loop operation, the melting and solidifying temperatures of the PbLi were measured for ascertaining whether it will show a consistent value for the many cycles of heating and cooling at various conditions of the loop operation. We can also investigate the contamination of PbLi according to the cyclic use. Of the liquid type breeder materials, PbLi is much safer than Li itself, as liquid metal can be ignited when it meets with water or air. There is still a concern regarding the use of PbLi, and it has not been fully proven whether it will react with water or air when it is in a molten state, as it contains lithium. Therefore, reaction tests of Li and PbLi with air and water were performed for safety reasons using the prepared test chamber.

Table 1 Impurities of the used PbLi.

| Elements | Max. impurities [%] |
|---|---|
| Ag | < 0.001 |
| Bi | < 0.004 |
| Cu | < 0.0005 |
| Fe | < 0.00051 |
| Si | < 0.001 |
| Zn | < 0.0005 |

## 2. Preparation of the test chamber

A test chamber including a controlled heating system was prepared as shown in Fig. 1. Two windows were prepared for visual observation and several thermocouples were installed to measure the chamber wall and breeder temperatures. A water addition hole at the lid for a reaction test and an Ar gas supplying system for preventing an air and breeder reaction were prepared. The outer diameter of the chamber is 200 mmD and the wall thickness is 20 mm. To endure the reaction pressure, the cover thickness was designed to have a sufficient thickness of about 15 mm.

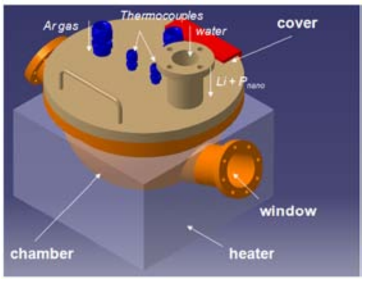


Fig. 1 Schematic of the reaction chamber.

## 3. PbLi melting and reaction experiments

Different phases of heating experiments were performed to obtain the characteristics of the PbLi:

(1) Ascertaining a consistent temperature for melting and cooling the PbLi sample considering cyclic use.
(2) Ascertaining a consistent temperature of melting and cooling of the PbLi after 1 day with an opening into the air after a contamination during loop operation.
(3) Effect of water addition on molten PbLi.

For phase (1), a sample of PbLi (373.62 g) was used to measure the melting and solidifying behavior in the reaction chamber, as shown in Fig. 2. The melting and solidifying temperatures of PbLi were about 235.0 $^{o}$C and 234.7 $^{o}$C, respectively, and there was no change even with the cyclic melting and solidifying conditions. To consider the contamination of PbLi, the PbLi in the chamber was opened to the atmosphere without an Ar gas supply for a day. The same experiment was then performed. The overall difference between the highest and lowest values was about 1.2 $^{o}$C, and it seems that the composition of the PbLi changed. This change in composition was evaluated based on a previous relationship. After a melting and solidifying test, water was added to the molten PbLi as the test of phase (3), and no reaction was observed. Even with added water in PbLi, the solidifying temperature was not changed. One conclusion is that the molten PbLi will not react when met with water. Rather, the molten PbLi will cool down when it meets the water. This is good news for the operation of ELLI, as we can be free of concern regarding the PbLi reactivity with water, which is contrary with the results of molten lithium, which reacts violently with an evolution of a large amount of heat. In addition, experiments on melting and cooling in certain cases of air-contact resulted in insignificant changes in the characteristics of PbLi. However, for a minimum change in the PbLi characteristics, it is advisable to conduct the PbLi experiments in an Ar atmosphere to prevent contamination.

### 4. Li melting and reaction experiments

In a similar way to the PbLi reaction test, a test with Li was performed. A few grams of natural Li were used in this experiment, and the microstructure of the used Li granule was observed before the test. The Li granules had different sizes, but there was no oxidation before the test. After melting of the Li, water was injected, and the reaction and wall/Li temperatures were then observed, as shown in Fig. 3. The reaction was very vigorous until all molten Li was burned. The Li and wall temperatures were measured during the test. The Li and chamber wall temperatures increased rapidly to over 700 $^{o}$C and 250 $^{o}$C, respectively.

To mitigate the Li reaction with water, nano-particles were used in this study: 1.1 g of Li and 2 ml of water with Ni nano-particles were used, the average sizes of which were 100 and 20 nm. With nano-paticles, the measured wall temperature was decreased, which indicates the possibility of a reaction mitigation using nano-particles.

### 5. Conclusion

Before operating an experimental loop, the melting and solidifying temperatures of the PbLi and its contamination were experimentally investigated considering a cyclic use with the prepared reaction chamber. The results confirmed that many cycles of safe melting and solidifying of PbLi were expected for ELLI operation without a significant change in PbLi composition. Due to contamination such as oxidation, however, the composition of the PbLi can be changed, which should be considered when operating the loop. From the reaction test of the PbLi and Li with air and water, it was found that water added to the PbLi did not result in an increase in temperature. Contrary to Li, which evolves a significant amount of heat when in contact with water, molten PbLi only cools when water was added. This is very good for the safe operation of ELLI. Moreover, the reaction mitigation of Li can be expected when nano-particles are used. Currently, progress is currently being achieved in terms of TBM development using PbLi as a breeding material. Completion of the test loop for PbLi circulation and the ensuing experiments will further furnish necessary knowledge for the completion of the TBM.

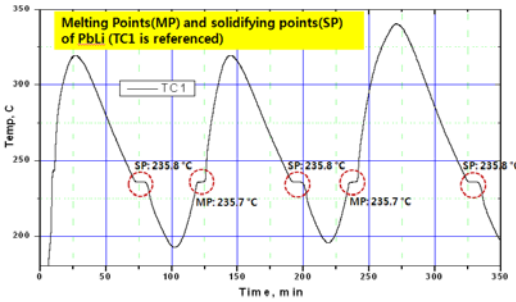

Fig. 2 Melting and solidifying temperature of PbLi.

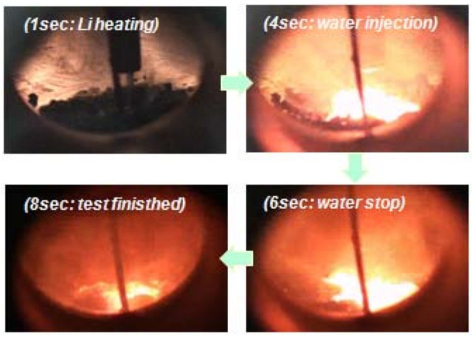

Fig. 3 Visual observation of the Li reaction.

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### References

[1] D.W. Lee, et. al., Current status and R&D plan on ITER TBMs of Korea, J. Korean Phys. Soc. 49 (2006) S340-S344.

[2] D.W. Lee, et. al., Preliminary Design of a Helium Cooled Molten Lithium Test Blanket Module for the ITER Test in Korea, Fusion Eng. Des. 82 (2007) 381-388.

[3] D.W. Lee, et. al., Helium Cooled Molten Lithium TBM for the ITER in Korea, Fusion Sci. and Tech. 52 (2007) 844-848.

[4] B.G. Hong et. al., Basic concepts of DEMO and a design of a helium cooled molten lithium blanket for testing in ITER, Fusion Eng. Des. 82 (2007) 2399-2405.

[5] D.W. Lee, et. al., Design and Preliminary Safety Analysis of a Helium Cooled Molten Lithium Test Blanket Module for the ITER in Korea, Fusion Eng. Des., 83 (2008) 1217-1221.

[6] D.W. Lee, et. al., Fabrication and High Heat Flux Test of the First Wall Mock-ups for the Korean He Cooled Test Blanket (KO HCML TBM), Fusion Eng. Des., 84 (2009) 1164-1169.

[7] J.S. Yoon et. al., Development of an experimental facility for a liquid breeder in Korea, Fusion Eng. Des. 86 (2011) 2212-2215.

[8] J.S. Yoon et. al., Performance test of the electromagnetic pump in an experimental liquid breeder loop for developing the KO test blanket module, Fusion Sci. and Tech. 60 (2011) 139-143.