§15. Proposal of Flinabe Mixed with Metal Powders for Liquid Blanket

Sagara, A., Tanaka, T., Yagi, J., Watanabe, T.

A new concept of Flinabe mixed with metal powders is proposed for self-cooled breeding blanket to effectively increase hydrogen solubility and to increase thermal efficiency by the use of vanadium alloys as structure materials of blanket.

In FFHR design studies, the molten-salt Flibe ($LiF\text{-}BeF_2$) is the first candidate for a self-cooled liquid breeding blanket, due to its superior features on safety aspects such as a low MHD pressure loss, low reactivity with air, low-pressure operation and low hydrogen solubility [1]. In particular, low hydrogen solubility is advantageous to keep tritium inventory low and to simplify tritium recovery system. However, due to a high equilibrium pressure of tritium in the liquid (a few kPa at 600°C for 3GW fusion operation), the following two aspects have been big issues: (1) reduction of tritium permeation through a heat exchanger, (2) use of low radio-activation vanadium alloys which has high mechanical strength up to temperatures over 700°C [2] but high hydrogen solubility, namely a kind of hydrogen storage metals. In order to solve those two issues at the same time, it is newly proposed to mix hydrogen-absorption metal powders (such as Ti, Zr, V) in molten-salt to effectively increase hydrogen solubility.

Another issue in Flibe blanket is a narrow in-out operation temperature window limited by the melting temperature of Flibe at around 450°C and available temperature of ferritic steel up to 550°C. Recently the melting temperature of Flinabe ($LiF\text{-}NaF\text{-}BeF_2$) has been measured to be about 305°C [3]. Therefore, combining with the above proposal, the in-out temperature window of about 300°C might be possible with a temperature margin of 50°C for each lower and upper limit. Then the thermal efficiency of about 46% is hopefully achivable.

As schematically shown in Fig.1, the ratio of the total surface areas $S_p/S_w=1.5f_v(R/r)$, where f_v represents the volumetric occupancy of metal powders in the liquid. For instance, $S_p/S_w=10{,}000$ with R=10mm, r=10μm and $f_v=0.01$. Therefore, fairy large tritium trapping can be expected in the liquid, resulting in effective increase of hydrogen solubility. In this case, the MHD effect on metal powders is negligibly small. At a stage prior to heat exchange, tritium can be recovered by selectively heating the powders using micro-wave power.

As shown in Fig.2, neutronics performance of Flinabe is fairy good on TBR and nuclear shielding, comparing to Flibe.

[1] A. Sagara et al. Fusion Engi.Design 49–50 (2000) 661.
[2] T. Muroga et al. J. Nucl. Mater. 367–370 (2007) 780.
[3] R. Nygren, Fusion Sci. Technol. 47 (2005) 549.

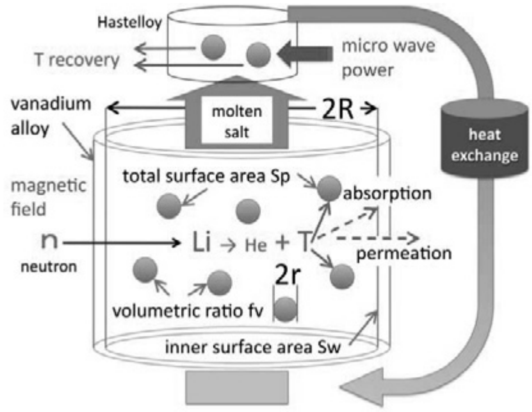

Fig.1 Illustration of a Flinabe blanket system with mixing metal powders.

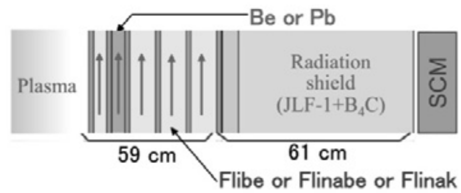

Fig.2 (a) The radial model of molten-salt blanket.

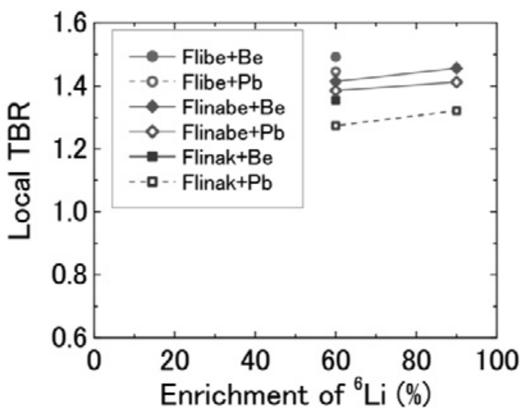

Fig.2 (b) Local TBR for Flibe, Flinabe or Flinak with neutron multiplier Be or Pb as a function of ^{6}Li enrichment.

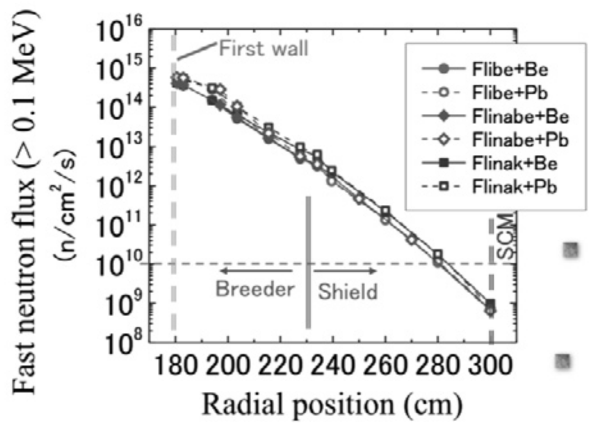

Fig2. (c) Shielding efficiency for fast neutron as a function of the radial position in the molten-salt blanket.