§37. Study on Design of Tritium Recovery System from Blanket of Falling Liquid Layer of Laser Fusion Reactor

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Introduction:

A lithium-lead eutectic alloy is the most promising liquid wall material for a laser fusion reactor that protects a plasma chamber disposed to a strong neutron flux. The advantages of Li-Pb eutectic alloy as the liquid wall material are comparatively large tritium breeding ratio, low Li vapor pressure, higher thermal conductivity and less corrosive action with solid walls. The largest disadvantages are large density and high electric conductivity. The last disadvantage is free from the laser fusion reactor. In the present study, we focus on tritium transfer in $Li_{17}Pb_{83}$ that has the lowest melting temperature. Solubility and diffusivity data are necessary for the designs of a blanket and a tritium recovery system. Previously, there were some experimental results for the solubility in $Li_{17}Pb_{83}$. However, there was large scattering in previous data of the solubility of H in $Li_{17}Pb_{83}$. In addition, there was no previous data on the isotopic difference in diffusivity and solubility among H, D and T in $Li_{17}Pb_{83}$. In this study, the solubility and diffusivity are determined by the permeation method. The isotopic difference is elucidated experimentally and analytically.

Experiment and Analysis:

The solubility, K_S, and diffusivity, D_{LiPb-H}, in $Li_{17}Pb_{83}$ are determined by an unsteady-state permeation method. A one-dimension Li-Pb layer with the thickness of 5cm was placed on a Fe plate. The lower surface is disposed to a constant partial pressure of H_2 or D_2 in Ar + H_2 (or D_2) mixture. The upper surface is disposed to an Ar flow. The flow rates of the upper surface and lower surface are maintained constant. The inlet and outlet concentrations of the lower and upper containers are detected by gas chromatography. The overall permeation rate of H_2 or D_2 in $Li_{17}Pb_{83}$ are determined by the following polynomial equation:

$$\frac{JL}{c_{LiPb}D_{LiPb-H}K_S\left(\sqrt{p_{H_2up}}-\sqrt{p_{H_2down}}\right)}=2\sqrt{\frac{L^2}{\pi D_{LiPb-H}t}}\left(e^{-\frac{L^2}{4Dt}}+e^{-\frac{9L^2}{4Dt}}+e^{-\frac{25L^2}{4Dt}}+\cdots\right)$$

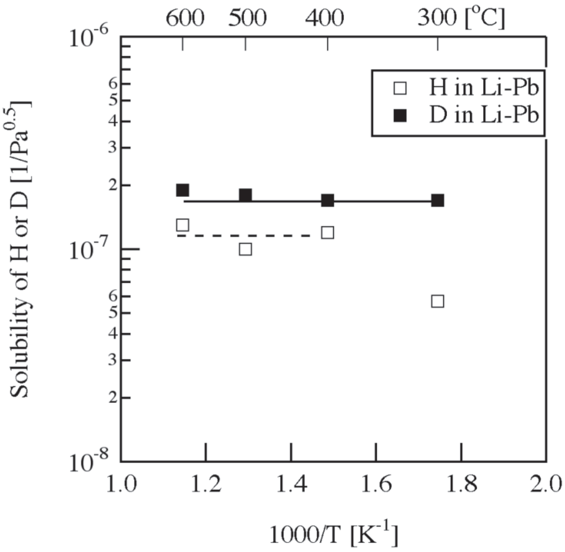

Fig. 1 Solubilities of H and D in $Li_{17}Pb_{83}$

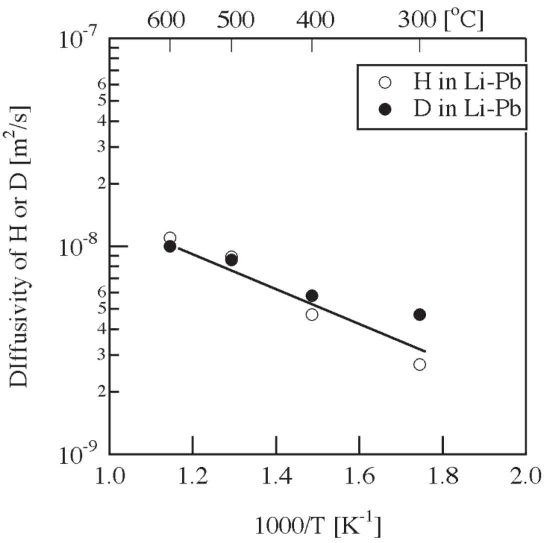

Fig. 2 Diffusivities of H and D in $Li_{17}Pb_{83}$

Results and Discussion:

Fig. 1 and Fig. 2 show solubility and diffusivity of H and D in $Li_{17}Pb_{83}$. There is appreciable isotope effect in solubility. The solubility of D in $Li_{17}Pb_{83}$ is larger than that of H. On the other hand, there is very small isotopic difference in diffusivity between H and D. The small isotopic difference can be explained by a small interaction between H with Li-Pb. The H atoms in Li-Pb are present as an neutral state because of small interaction of H atoms with Li-Pb atoms. The small interaction leads to a small enthalpy change in solubility. Judging from the phase diagram of the Li-Pb system, the present eutectic alloy is a mixture of LiPb intermetallic compound and Pb. The interaction between Li and H is small.

The isotopic difference in solubility between H and D (also T) was analyzed by the harmonic oscillation model:

$$\ln\left(\frac{K_H}{K_D}\right)=3\ln\left[\frac{\sinh\left(\frac{h\nu_{D,0}}{2k_BT}\right)}{\sinh\left(\frac{h\nu_{H,0}}{2k_BT}\right)}\right]+\frac{G_{H_2,0}-G_{D_2,0}}{2R_gT}$$

The zero-point interaction energy, $h\nu_{H,0}$, in H atoms in a mixture of LiPb and Pb is 22meV. This value can explain the reversal isotopic difference in solubility of H and D.

1. S. Fukada, *et al.* Proc. 4th IAEA-TM on Physics and Technology of IFE Targets and Chambers, Kobe (2007).