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Polonium evaporation and adhesion experiments for the development of polonium filter in lead–bismuth cooled reactors

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Abstract

Fundamental experiments were performed to determine the adhesion characteristics of polonium to different metals and to develop a filter for polonium evaporated from neutron-irradiated LBE. The results of the first experiments suggested that adhesion characteristics are almost the same for stainless steel and nickel metal. The results of the preliminary experiments for a polonium filter suggested that stainless steel mesh with thin wires could effectively collect polonium evaporated from neutron-irradiated LBE. In the experiments, stainless steel wire mesh was used, but from the results of adhesion experiment, it is expected that the same effect can be obtained with wire mesh made of other kinds of metal.

Keywords: Polonium; Lead–Bismuth Eutectic; Contamination; Adhesion; Filter

1. Introduction

Lead–Bismuth Eutectic (LBE) has good characteristics including a low melting temperature, a high boiling temperature and chemical inertia with air and water. It is expected to be utilized as a coolant in innovative fast reactors, and as a coolant and target of accelerator-driven subcritical systems. One of the problems to be solved for practical use is erosion/corrosion with steel. Another problem may be the production of polonium-210. Neutron capture of bismuth-209 in LBE produces polonium-210, a radioactive nuclide that emits alpha particles of 5.3 MeV with a half-life of 138.4 days. In the maintenance of reactors and coolant leakage accidents, there is a possibility that polonium will be released to the air, and hence, that radioactive polonium will be inhaled by workers.

For the practical use of LBE in nuclear systems, it is necessary to establish effective protection technologies for the polonium contamination issue. For that purpose, it is important to know the characteristics of the adhesion of polonium to metals. Adhesive phenomena can be an effective device to collect polonium in the gas phase. In a previous work by Obara et al. (2005), the characteristics of polonium adhesion and its removal were experimentally studied; it was shown that evaporated polonium from neutron-irradiated LBE adhered to quartz glass and that polonium contamination could be removed by heating the glass in a vacuum condition. Miura et al. (2006) experimentally studied polonium's adhesion to and removal from stainless steel and showed that polonium contamination by polonium evaporated from LBE could be removed by heating at 500 °C in a vacuum of 0.4 Pa. In the present study, experiments to compare the characteristics of polonium adhesion to different metals were performed. After that, some preliminary experiments were performed to investigate the possibility of developing a filter to collect polonium in the gas phase using stainless steal wire mesh.

2. Polonium adhesion and evaporation experiment

The purpose of this experiment is to determine differences in polonium adhesion characteristics between stainless steel and nickel metal. Stainless steel was chosen because it is a typical material for nuclear reactors. Nickel plate was chosen because an erosion/corrosion study of LBE published by Kondo et al. (2005) showed that nickel is easy to melt into the LBE.

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For the experiments, LBE samples of 5 g were prepared. Thermal neutron irradiation was performed upon the samples. For the irradiation, the thermal neutron beam facility of a research reactor JRR-4 in Japan Atomic Energy Agency was used. Irradiated thermal neutron fluence ranged from 9.8×10^{12} to 6.5×10^{13} n/cm^2 depending on the location of the sample. The estimated specific radioactivity of polonium in the samples in the adhesion experiments ranged from 12 to 63 Bq/g.

A schematic view of the experimental apparatus for the adhesion experiment is shown in Fig. 1. Irradiated LBE samples were heated in a SiO_2 glass tube in a furnace. A nickel plate or SS316 stainless steel plate was set above the LBE sample. The diameter of the plates was 28 mm and the thickness was 0.2 mm. The temperature of the plate was changed between 230 and 605 °C using a water cooling loop. The maximum temperature of the LBE samples was either 550 or 630 °C. The pressure in the furnace was kept at 0.6 Pa using a vacuum pump. The heating time, which means the time at the maximum temperature during the heating, was 1 h. The heating caused the evaporated polonium to adhere to the plate. After the heating, alpha particles from the plate were measured for 20 h using an alpha particle spectrometer, and the number of the alpha particles was counted.

Fig. 2 shows the relationship between the metal plate temperature and the 20-h alpha particle counts obtained by the measurement. This figure shows that if the LBE temperature is 630 °C, a remarkable increase in the alpha particle count is observed when the metal temperature is below 280 °C and if the LBE temperature is 550 °C, a remarkable increase in the alpha particle count is observed when the metal temperature is below 240 °C. There is no difference in the tendencies of the nickel and stainless steel plates. The alpha particle count shows the amount of polonium adhered to the plate. The experimental results suggest there is no significant difference in the adhesion characteristics of polonium to the two metals.

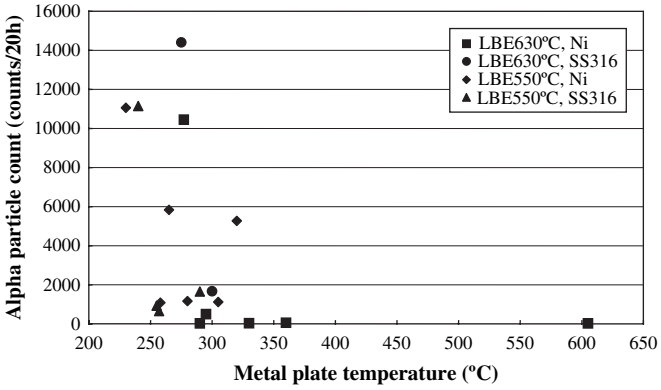

Fig. 2. Alpha particle counts from metal plates after neutron-irradiated LBE heating.

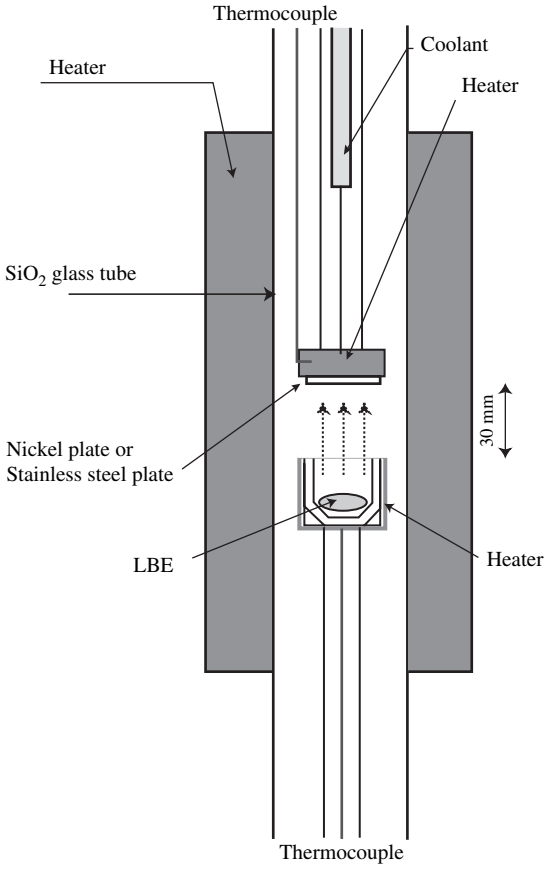

Fig. 1. Experimental apparatus for polonium evaporation and adhesion experiment.

3. Preliminary experiment for polonium filter in gas phase

The purpose of this experiment is to show the possibility of a filter collecting polonium in gas phase using stainless steel wire mesh. As shown in the previous experiment, it is possible to capture polonium evaporated from neutron-irradiated LBE by adhesion using stainless steel. So it is expected that polonium can be effectively collected using the filter. In addition, stainless steel is a popular material and can be used at various temperatures.

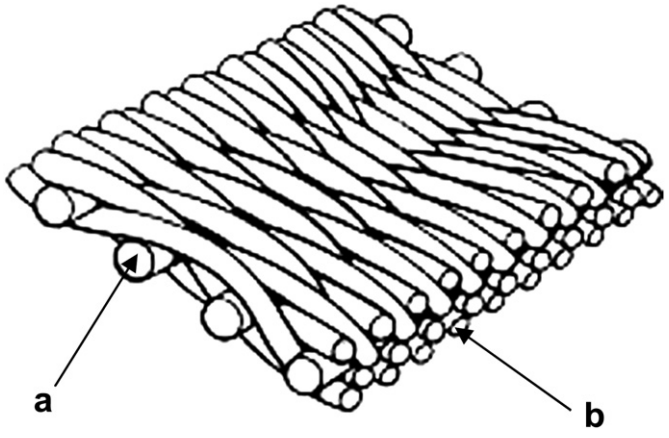

Fig. 3. Stainless steel wire mesh for polonium filter experiment.