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Present status of beryllides for fusion and industrial applications in Japan

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Abstract

Beryllides have remarkable characteristics besides their low density, such as high radiation resistance, high chemical stability, low hydrogen isotope retention and good high temperature mechanical strength especially for fusion applications. In order to have a practical usage for industrial applications, it is important to compile a set of quantitative data on such properties. It is also important to develop fabrication and processing paths to assure the processing of inherently brittle beryllides.

The characterization and manufacturing technologies development have been carried out mainly on the $Be_{12}Ti$ interemetallic compounds at the Be-rich side of the Be–Ti binary system. In the present paper, up-dated results on several properties are described for the compound fabricated by hot isostatic pressing (HIP) and ingot metallurgy. Mechanical properties of the compounds having a duplex microstructure with neighboring phases are evaluated by compressive tests from room temperature to 1273 K. Radiation damage of the compound is preliminary studied by charged particle irradiation. Oxidation in air and the interaction with water vapor are evaluated. Thermal desorption of the deuterium is examined by using transmission electron microscopy (TEM) and thermal desorption spectrometry (TDS). Through these evaluations it seems that $Be_{12}Ti$ is superior as neutron multiplier with respect to pure Be metal.

Keywords: Beryllide; Neutron multiplier; Rotating electrode method

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1. Introduction

Beryllium metal is considered as the most promising candidate as neutron multiplier material for the tritium-breeding blanket of a fusion reactor. However, some problems are anticipated for the use of beryllium in the DEMO blanket that requires high neutron flux and high temperature. Beryllium metal could react with the in contact structural material in contact, it might accumulate a high tritium inventory, and it could react with water vapor in case of loss of coolant accident (LOCA) under such environment. It is felt that beryllium-based intermetallic compounds would have some advantages over beryllium metal because of their higher melting point, lower chemical reactivity, and lower swelling. Therefore, the compounds have gained an interest as an alternative material for neutron multiplier materials in Japan.

In the previous studies, $Be_{12}Ti$, $Be_{12}V$ and $Be_{12}Mo$ were pre-selected as candidate material from the viewpoints of low radio activation and high melting point, good oxidation resistance and high beryllium content. Since then $Be_{12}Ti$, which is considered to have the easiest fabrication technology has been mainly investigated. Phase equilibria of Be–Ti and Be–V systems were evaluated in their Be-rich portion in order to optimize the composition and microstructure of the pebbles based on these compounds. The tritium-breeding ratio (TBR) of the blanket with $Be_{12}Ti$ pebbles was found to be only 10% smaller than that with Be pebbles and it is considered that this value is within the design window. The pebbles consisting of the compound were successfully obtained by small scale rotating electrode method (REM). Characterizations concerning the compatibility with structural material and ceramic breeder, oxidation, steam reaction, tritium inventory, irradiation effects in Japan materials testing reactor (JMTR) and the structural evolution induced by charged particle irradiation have been carried out and the advantages were made clear. These results are summarized in a review paper by Kawamura et al. [1].

In the present work, in order to realize mass production of beryllide pebbles, fabrication of electrode for REM is attempted using the casting process. Moreover, the ductility improvement for the durability of the electrode through material design technique is carried out. Also, properties such as the compatibility with structural materials in contact, SUS316LN, the reactivity with air and with water vapor, and the tritium inventory of $Be_{12}Ti$ are studied to optimize the overall performance of the compound as neutron multiplier in the tritium-breeding blanket of a fusion reactor.

2. Alloy design and fabrication of pebbles

In order to impart some room temperature ductility to intrinsically brittle $Be_{12}X$ type intermetallic compounds, two-phase alloys involving Be solid solution, hereafter (Be), are prepared in Be–Ti and Be–V systems and the relationships between microstructure

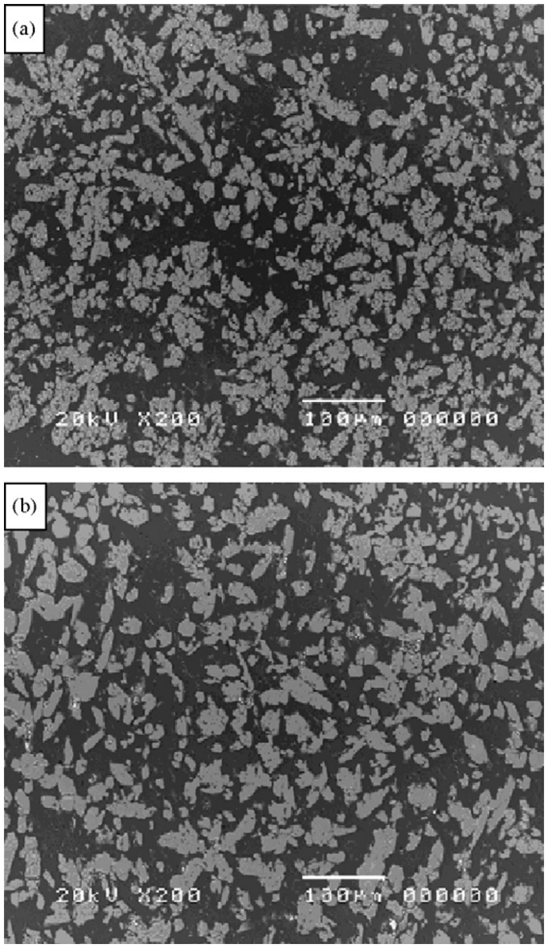

Fig. 1. Scanning electron micrographs and back scattered electron images (BEI), of a Be–3 at.%Ti alloy: (a) as-cast and (b) after hot-rolling to 50% reduction.