Available online at www.sciencedirect.com
SCIENCE DIRECT
Fusion Engineering and Design 81 (2006) 993–998
Fusion Engineering and Design
www.elsevier.com/locate/fusengdes

Surface reaction of titanium beryllide with water vapor

K. Munakata [a,*], H. Kawamura [b], M. Uchida [c]

[a] *Kyushu University, Department of Advanced Energy Engineering Science, Interdisciplinary Graduate School of Engineering Science, Kasuga 816-8580, Japan*
[b] *Naka Research Establishment, Japan Atomic Energy Research Institute, Naka-machi, Naka-gun, Ibaraki 311-0193, Japan*
[c] *Engineering Department, New Metal Division, NGK INSULATORS, LTD., Maegata, Handa, Aichi 475-0825, Japan*

Received 6 February 2005; received in revised form 1 September 2005; accepted 1 September 2005
Available online 27 December 2005

Abstract

Beryllium is one of the candidate materials for the neutron multiplier in the tritium-breeding blanket. However, there are some problems related to the application of beryllium as a neutron multiplier, which include compatibility with structural materials, tritium inventory and reaction of beryllium with water vapor and oxygen in a LOCA accident. Titanium beryllides such as $Be_{12}Ti$ are known to have advantages over beryllium from the perspectives of higher melting point, lower chemical reactivity and lower swelling. Thus, these materials are promising alternatives of beryllium. The authors investigate here the reaction of titanium beryllides with water vapor at high temperatures, and it is found that $Be_{12}Ti$ is by far more tolerant to water vapor than beryllium. To clarify the high tolerance of $Be_{12}Ti$ to water vapor, the surface of $Be_{12}Ti$ used in the experiment was investigated by means of digital microscope, SEM, XRD and electron spectroscopy for chemical analysis (ESCA). These analyses suggest that some oxidized state of beryllium was formed on the surface of $Be_{12}Ti$ exposed to water vapor. In particular, the results of the ESCA analysis gave some clues to understanding the higher tolerance of $Be_{12}Ti$ to water vapor at high temperatures.

Keywords: Beryllium; Titanium beryllide; Water vapor; Surface; Blanket

1. Introduction

Beryllium is one of the candidate materials for the neutron multiplier in the tritium-breeding blanket. Beryllium in this capacity would be placed in the high neutron flux and temperature environment, which leads to problems related to compatibility with structural materials, tritium inventory and reaction of beryllium with water vapor and oxygen. Titanium beryllides such as $Be_{12}Ti$ have advantages over beryllium from the perspectives of higher melting point, lower chemical reactivity and lower swelling. Thus, these materials are promising alternatives of beryllium as a neutron multiplier. With regard to the reaction with water vapor, beryllium is highly reactive at high temperatures [1–3]. Here, the authors investigate the reaction of titanium

* Corresponding author. Tel.: +81 92 642 3784; fax: +81 92 642 3784.
E-mail address: kenzo@nucl.kyushu-u.ac.jp (K. Munakata).

0920-3796/$ – see front matter © 2005 Published by Elsevier B.V.
doi:10.1016/j.fusengdes.2005.09.041

beryllides with water vapor at high temperatures [4]. The experimental results reveal that $Be_{12}Ti$ is highly tolerant to water vapor. To clarify the mechanism leading to such high tolerance, the surface of $Be_{12}Ti$ used in the experiment was examined by means of digital microscope, scanning electron microscope (SEM), X-ray diffraction analysis (XRD), electron spectroscopy for chemical analysis (ESCA).

2. Experimental procedure

A sample disk of $Be_{12}Ti$ (7.9 mm in diameter and 1.4 mm in thickness) was prepared by NGK INSULATORS LTD. The sample disk was placed in the reactor made of quartz. Argon gas containing H_2O was introduced to the reactor. Water vapor was generated by introducing H_2/Ar gases into a CuO bed at 350 °C. The concentrations of H_2 and H_2O in outlet stream of the reactor were measured with a quadrupole mass spectrometer. More details of the experiment are given in literature [4]. After the experiments described above, the surface of the sample was observed using various techniques.

3. Results and discussion

The authors first tested the chemical stability of $Be_{12}Ti$ under argon gas flow containing 0.096% of H_2O. The reactor temperature was raised up to 940 °C at the constant rate of 10 °C/min. The result of the experiment reveals that a breakaway reaction, which takes place on Be metal ($Be + H_2O \rightarrow BeO + H_2$), did not take place on the surface of the $Be_{12}Ti$ disk. The sample was exposed to water vapor for 220 min. The authors next investigated the chemical stability of $Be_{12}Ti$ under water vapor of 1%. Fig. 1 shows changes in the concentration of H_2 in outlet stream of the reactor when the argon gas containing 1% of H_2O was introduced. The generation of H_2 started at a temperature near 600 °C. The concentration of H_2 in the outlet stream of the reactor reached a peak at 1000 °C and then began to decrease. The generation of H_2 terminated at 10 h. Again, more details of the experimental results have been reported in previous literature [4].

After exposure to 1% of H_2O, the color of the sample surface turned to white, indicating that the sample

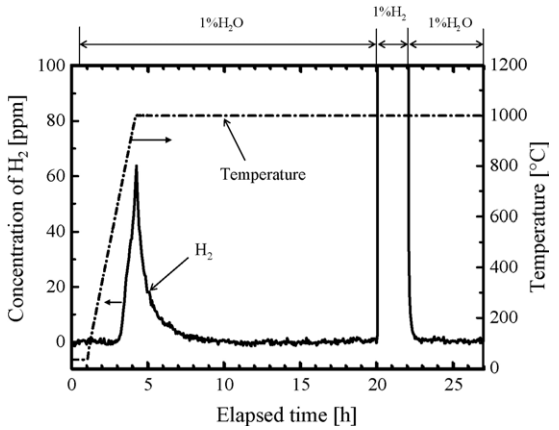

Fig. 1. Change in the concentration of H_2 in the outlet stream of reactor with a $Be_{12}Ti$ disk exposed to 1% H_2O/Ar gas (flow rate: 84.9 cm^3/min (standard temperature pressure)).

surface was oxidized. The surface roughness of the sample was measured using the digital microscope, which suggests that the roughness increased after exposure to water vapor. The sample surfaces were observed by SEM as well. The surface of the sample exposed to 0.096% is characterized by the presence of lots of white spots with the size of several tens of microns. Such spots are not observed on the surface of the sample exposed to 1% of H_2O. However, the photographs taken with higher resolution indicate that the surface of the sample exposed to 1% of H_2O is rougher. Once again, more details of the above observation have been reported in literature [5].

Questions remained as to why $Be_{12}Ti$ is so highly tolerant to oxidation by water vapor. Thus, the authors performed the XRD analysis using a X-ray diffractometer (RINT-1400 by RIGAKU Inc.). Fig. 2 shows X-ray diffraction patterns. The diffraction pattern of the sample as received (Fig. 2a) shows several diffraction peaks, most of which were attributed to $Be_{12}Ti$ using the JCPDS file. The other peaks were attributed to disproportionated phases such as $Be_{10+x}Ti$. Fig. 2(b) shows the diffraction pattern of the sample exposed to 0.096% of H_2O. Comparison of the results in Fig. 2(a and b) suggests a small difference in the patterns at 41°, which was attributed to beryllium oxide. Fig. 2(c) shows the diffraction pattern of the sample exposed to 1% of H_2O, indicating that one high peak arose at 41°. Additionally, new lower peaks arose. The new