Fusion Engineering and Design 107 (2016) 75–81

Contents lists available at ScienceDirect

Fusion Engineering and Design

journal homepage: www.elsevier.com/locate/fusengdes

Tritium release from advanced beryllium materials after loading by tritium/hydrogen gas mixture

Vladimir Chakin[a,*], Rolf Rolli[a], Anton Moeslang[a], Petr Kurinskiy[a], Pavel Vladimirov[a], Christopher Dorn[b], Igor Kupriyanov[c]

[a] Karlsruhe Institute of Technology, Institute for Applied Materials, Hermann-von-Helmholtz-Platz 1, 76344 Eggenstein-Leopoldshafen, Germany
[b] Materion Beryllium & Composites, 6070 Parkland Boulevard, Mayfield Heights, OH 44124-4191 USA
[c] Bochvar Russian Scientific Research Institute of Inorganic Materials, Rogova str., 5, 123098 Moscow, Russia

HIGHLIGHTS

- A major tritium release peak for beryllium samples occurs at temperatures higher than 1250 K.
- A beryllium grade with comparatively smaller grain size has a comparatively higher tritium release compared to the grade with larger grain size.
- The pebbles of irregular shape with the grain size of 10–30 μm produced by the crushing method demonstrate the highest tritium release rate.

ARTICLE INFO

Article history:
Received 1 December 2015
Received in revised form 11 March 2016
Accepted 10 April 2016
Available online 28 April 2016

Keywords:
Beryllium pebbles
Tritium release
Thermal desorption

ABSTRACT

Comparison of different beryllium samples on tritium release and retention properties after high-temperature loading by tritium/hydrogen gas mixture and following temperature-programmed desorption (TPD) tests has been performed. The I-220-H grade produced by hot isostatic pressing (HIP) having the smallest grain size, the pebbles of irregular shape with the smallest grain size (10–30 μm) produced by the crushing method (CM), and the pebbles with 1 mm diameter produced by the fluoride reduction method (FRM) having a highly developed inherent porosity show the highest release rate. Grain size and porosity are considered as key structural parameters for comparison and ranking of different beryllium materials on tritium release and retention properties.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

It is planned for beryllium to be used as the neutron multiplier material in the European Helium-Cooled Pebble Bed (HCPB) concept for a breeding blanket design for DEMO [1]. Tritium release and retention properties are the key issues for successful application of beryllium in the blanket. Under neutron irradiation, large amounts of tritium and helium are produced in beryllium. Clearly, the best possibility in current conditions to simulate fusion-relevant parameters is performing an irradiation test with investigated materials in a material testing nuclear reactor. There is, however, another method which allows the loading of beryllium samples by tritium without neutron irradiation [2]. It is a high-temperature loading of the samples in a tritium/hydrogen gas mixture. By using this method, it is possible to investigate and to rank advanced beryllium materials on tritium release and retention behavior without irradiation and, accordingly, with comparatively lower time costs. In this study, a wide range of beryllium materials is investigated by using the loading method and following temperature-programmed desorption (TPD) tests.

2. Experimental

In this study, several kinds of beryllium materials have been investigated. Beryllium grades I-220-H, O-30-H, and S-65-H have been consolidated by hot isostatic pressing (HIP) by Materion Beryllium & Composites (MBe&C), U.S.A. The samples were prepared as cylinders with dimensions of 4 mm in diameter and 2 mm in height. These beryllium grades differ from each other by grain size and beryllium oxide (BeO) content. The second kind of material is beryllium pebbles with irregular shape produced by Bochvar Institute, Russia by a crushing method (CM) from beryllium pieces with subsequent mechanical processing by an attritor. Three different types of pebbles were tested, with grain sizes of 10–30 μm, 30–60 μm, and >100 μm, respectively. The third kind of material is beryllium pebbles with a regular, round shape, differing by produc-

* Corresponding author.
E-mail addresses: vladimir.chakin@kit.edu, wladimir.tschakin@web.de (V. Chakin).

http://dx.doi.org/10.1016/j.fusengdes.2016.04.018
0920-3796/© 2016 Elsevier B.V. All rights reserved.

Table 1
List of beryllium materials/samples investigated.

Grade/kind of sample	Production method	Dimensions of sample, mm	Grain size, μm	Peak temperature, K	Total tritium release, Bq/g
I-220-H	HIP	Ø 4 × 2	5.5	1285	8.6×10^5
O-30-H			7.8	1275	6.2×10^5
S-65-H			8.8	1319	5.3×10^5
Pebbles with irregular shape	CM	1–2	10–30	1267	5.8×10^6
			30–60	1300	2.9×10^6
			>100	1280	2.3×10^6
Pebbles with round shape	REM	Ø 0.5	200–500	1302	5.7×10^5
		Ø 1/Ø 1 (pores)		1317/1308	$4.5 \times 10^5/7.4 \times 10^5$
		Ø 2		1342	3.4×10^5
	FRM	Ø 1	200–500	1228	8.0×10^5
		Ø 2		1232	8.1×10^5
Single crystal cube	Zone-Refining	5 × 5 × 5	no grains	1260	1.4×10^5

tion method and diameter. In particular, pebbles produced by the rotating electrode method (REM) with diameters of 0.5 mm, 1 mm, and 2 mm from NGK Insulators in Japan, and pebbles fabricated by the fluoride reduction method (FRM) with diameters of 1 mm and 2 mm from MBe&C were used. In addition, MBe&C supplied a piece of beryllium single crystal in the form of a 5 mm cube which was also investigated in this study. The main characteristics of the beryllium materials investigated are summarized in Table 1.

Currently, beryllium pebbles with a diameter of 1 mm produced by REM are considered as reference pebbles for the HCPB. However, there is a big problem of the production of these pebbles on an industrial scale. This point forces the fusion community to search for alternatives which can be different solutions such as other kinds of pebbles with easier scalability of production or even advanced beryllium grades having satisfactory relevant properties to be considered as a component of the neutron multiplier instead of the pebbles.

The tritium/hydrogen loading of the samples was performed in the $^1H_2$ + 500 appm $^3H_2$ gas mixture at 873 K for 15 h at 4 bar. By performance of the TPD tests, a permanent heating mode with a ramp rate of 0.117 K/s up to 1373 K followed by 3 h exposure at the maximum temperature was used [3]. The gas mixture of high-purity helium with a small addition of hydrogen (^{4}He + 0.1 vol.% $^1H_2$) was applied as a purge gas to transport the released species from the furnace with the beryllium samples to a proportional counter (PC). A Zn-bed was placed between the furnace and the PC. The Zn-bed was permanently heated up to 663 K which permitted the conversion of tritiated water to tritium gas to avoid the absorption of the tritiated water into the pipes and into the PC. For the same reason, all gas pipes in the manifold were heated up to 573 K during the TPD tests. So, the released tritium reaches the PC mainly in the form of $^1H^3H$ [3].

The loading method used in this study for beryllium materials allows simulating of irradiation with respect to radiation damage in fusion reactor environment. In particular, it gives a possibility to study tritium release behavior. However, the suggested method cannot fully reproduce the neutron irradiation impact in the beryllium microstructure. In particular, it is impossible to simulate with this method the radiation-induced cascade formation and the production of helium. Therefore, the loading method can be useful only for preliminary ranking of beryllium materials on tritium release and retention properties.

3. Results

3.1. Tritium release and retention

Fig. 1a shows the tritium release rate versus testing temperature for beryllium grades fabricated by HIP as well as for beryllium single crystal. All samples have quite a broad single peak at high temperatures with a long shoulder to lower temperatures. For all materials, the high-temperature peaks are located at 1260–1319 K (see Table 1), the shoulders begin around 500–600 K.

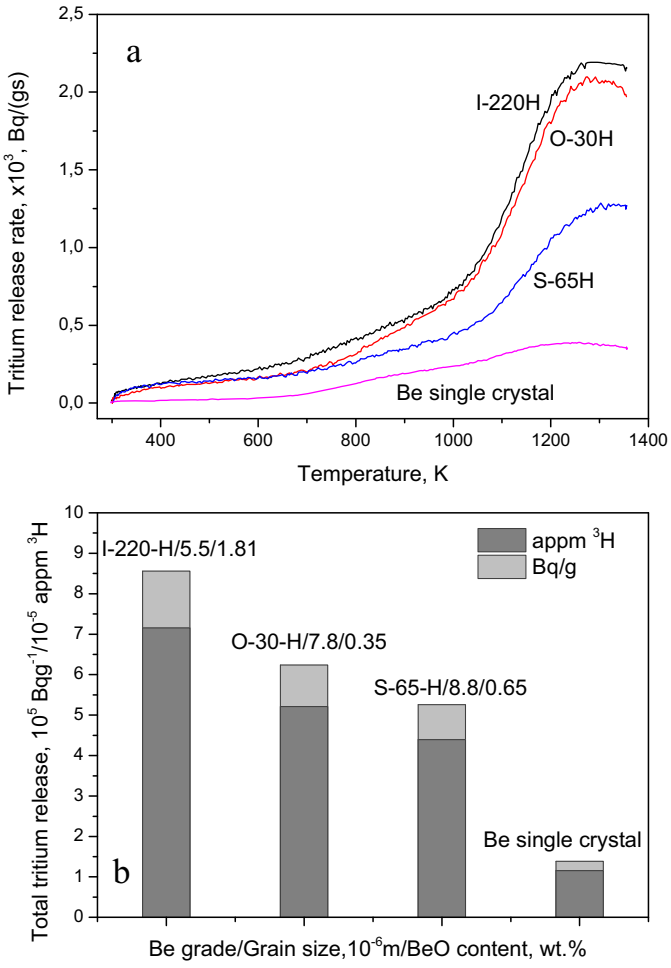

Fig. 1. Tritium release behavior for beryllium grades produced by HIP and for beryllium single crystal: a) tritium release rate versus temperature; b) total tritium release.

Fig. 1b shows the total tritium release for HIPed beryllium grades and for beryllium single crystal. I-220-H (the grade with the smallest grain size and highest BeO content) has the greatest amount of total release. Both O-30-H and S-65-H have comparatively lower total release values. S-65-H has the lowest total release and correspondingly, the largest grain size. This demonstrates, therefore, an

Download English Version:

https://daneshyari.com/en/article/270864

Download Persian Version:

https://daneshyari.com/article/270864

Daneshyari.com