ANALYSIS OF TRITIUM KINETICS OF SIBELIUS BERYLLIUM

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INTRODUCTION

The EC/USA collaborative SIBELIUS experiment was performed at CEN Grenoble to obtain information on the compatibility between beryllium and steel, as well as beryllium and ceramics, in a low neutron fluence condition and to provide additional understanding of tritium behavior in irradiated beryllium[1]. The EC experimental data[2] has major uncertainty up to about 260% in the absolute values of the measured tritium release rate due to the uncertainty of the calibration of the ionization chamber. Recently, Baldwin[3] reexamined previously presented measured and calculated tritium inventories of USA experimental data and provided useful input data for tritium transport models and code development. Those reexamined experimental data has the uncertainty of ± 5%.

The purpose of the work is to analyze these USA experimental data, and to validate a developed model, BETTY, for tritium release from Be. In addition, to help interpret and plan future experimental data for fusion blanket applications, a parametric sensitivity analysis for the variance of surface activation energies is performed and the results of the analysis are discussed.

DESCRIPTION

The representative four SIBELIUS Be samples, 2-1, 3-1, 5-1, and 6-1, that are adjacent only to steel, were considered baseline specimens for investigation of tritium release characteristics and material properties of Be. The Be specimens, with high fabrication density (98% TD), were irradiated with low fluence (6×10^{20} n/cm^2) at relatively high temperature of 550 °C for 1690 h. Stepped isothermal anneal tritium release testing was performed, measuring tritium release rate over the temperature range from 550 °C to 850 °C, in 100 °C steps for about 24-h periods at each temperature. Among these four samples, two samples 2-1 and 5-1 were chosen in this analysis due to their small measured-to-calculated tritium ratios, and the tritium release curves are relatively well-behaved. The total amount of tritium released is 112 MBq for sample 2-1 and 130 MBq for sample 5-1. However, based on the tritium release experimental data given by Baldwin, the total tritium release of 198 MBq for sample 2-1 and 188 MBq for sample 5-1 were obtained. In order to be consistent for these two different tritium amount, the tritium release experimental data are modified and the adjusted experimental data are shown in Figure 1 and Figure 2 comparing with the modeling results.

A tritium transport model, BETTY, has been developed to describe and predict the kinetics of tritium transport in beryllium in fusion blanket application[4]. In the SIBELIUS experiments, the effects of tritium trapping in He bubbles (He < 60 wppm) and tritium retardation in the BeO layer (BeO < 300 wppm) on tritium release would be relatively less important than bulk diffusion and surface processes at the solid/gas surface. So, in this analysis only pure Be bulk diffusion and surface processes are considered. In this work, BETTY was applied to the tritium release experimental data of samples 2-1 and 5-1 and a comparison of the results for the SIBELIUS experimental data to those by the model is performed.

RESULTS

Based on the limited available data for activation energies and diffusion coefficients, the modeling results are compared to the SIBELIUS experimental data for sample 2-1 in Figure 1. When the surface is not considered, only desorption and adsorption to the bulk are included. When the surface is considered, four surface fluxes are included in the endothermic Be surface coverage[4]. The modeling results without surface coverage show that only

79% of the total tritium is released at the end of the annealing temperature. Therefore, the overall shape of the results is much below the experimental data. The modeling results considering surface coverage show that the amount of tritium released at 550 °C and 650 °C are closely matched to the experimental data and at the next two temperature the peak of the modeling results reaches that of the experimental data. The shape of the modeling results at 650 °C shows the reverse phenomena and the shape at 750 °C decreases more slowly than the experimental data. However, the shape at 850 °C follows the experimental data well at the first part and then decreases fast. Therefore, the modeling results reasonably reproduce the experimental data as the peak and the cumulative tritium release at each temperature as concerned.

Similarly, the modeling results are compared to the experimental data for sample 5-1 in Figure 2. When the surface coverage is not concerned, the modeling results show that only 80% of the total tritium is released. The shape of the modeling results at 850 °C only follows the experimental data at the rear part. The modeling results considering surface coverage show that the peak at 650 °C and 750 °C reaches that of the experimental data but the shape decreases slowly relatively to the experimental data. The modeling results for both samples 2-1 and 5-1 show similar phenomena with regard to the peak and the overall shape. The experimental data locates between two modeling results. Overall tritium releases fast when the surface coverage is considered and slowly when the surface is not considered. The retardation mechanism at relatively low temperature with surface coverage might be needed in the future work. Since the property data assumed in this analysis are not dominant values, a sensitivity analysis for the variation of surface activation energies are performed. The modeling results, however, have not changed in each case and show that the sensitivity of the activation energy is minimal.

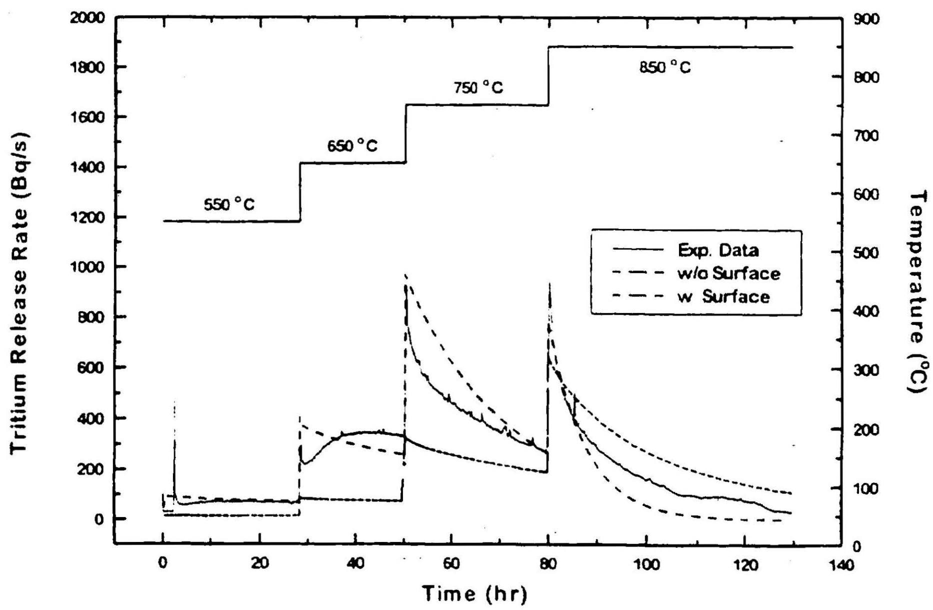

Figure 1 Comparison of BETTY Results with the Experimental Results for Tritium Release from SIBELIUS Sample 2-1 under Four Successive Temperature Anneals.

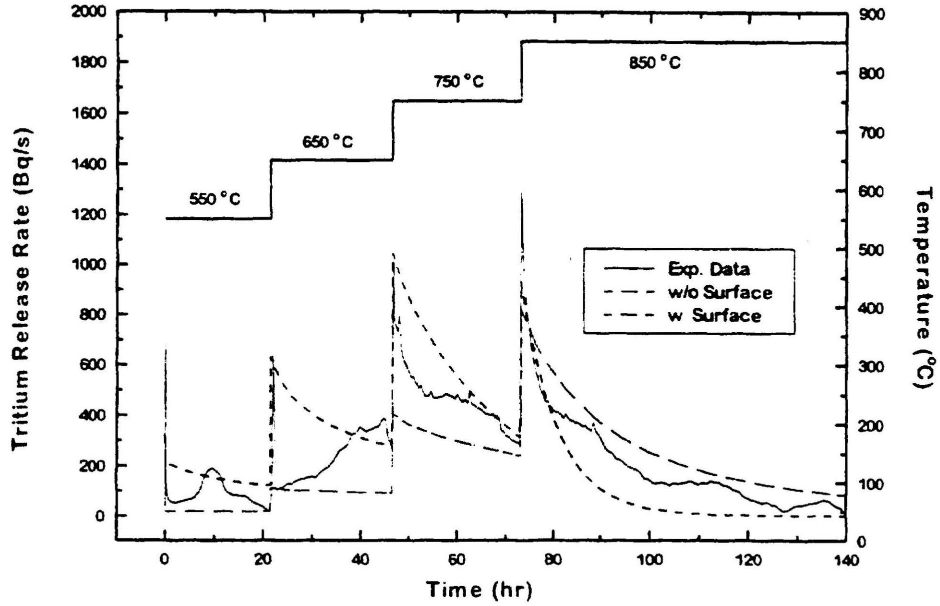

Figure 2 Comparison of BETTY Results with the Experimental Results for Tritium Release from SIBELIUS Sample 5-1 under Four Successive Temperature Anneals.

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3. D.L. Baldwin, "Tritium Release Behavior of SIBELIUS Beryllium", Proceedings of the International Workshops on Ceramic Breeder Blanket Interactions, Los Angeles, USA, June 1994, 307-323.
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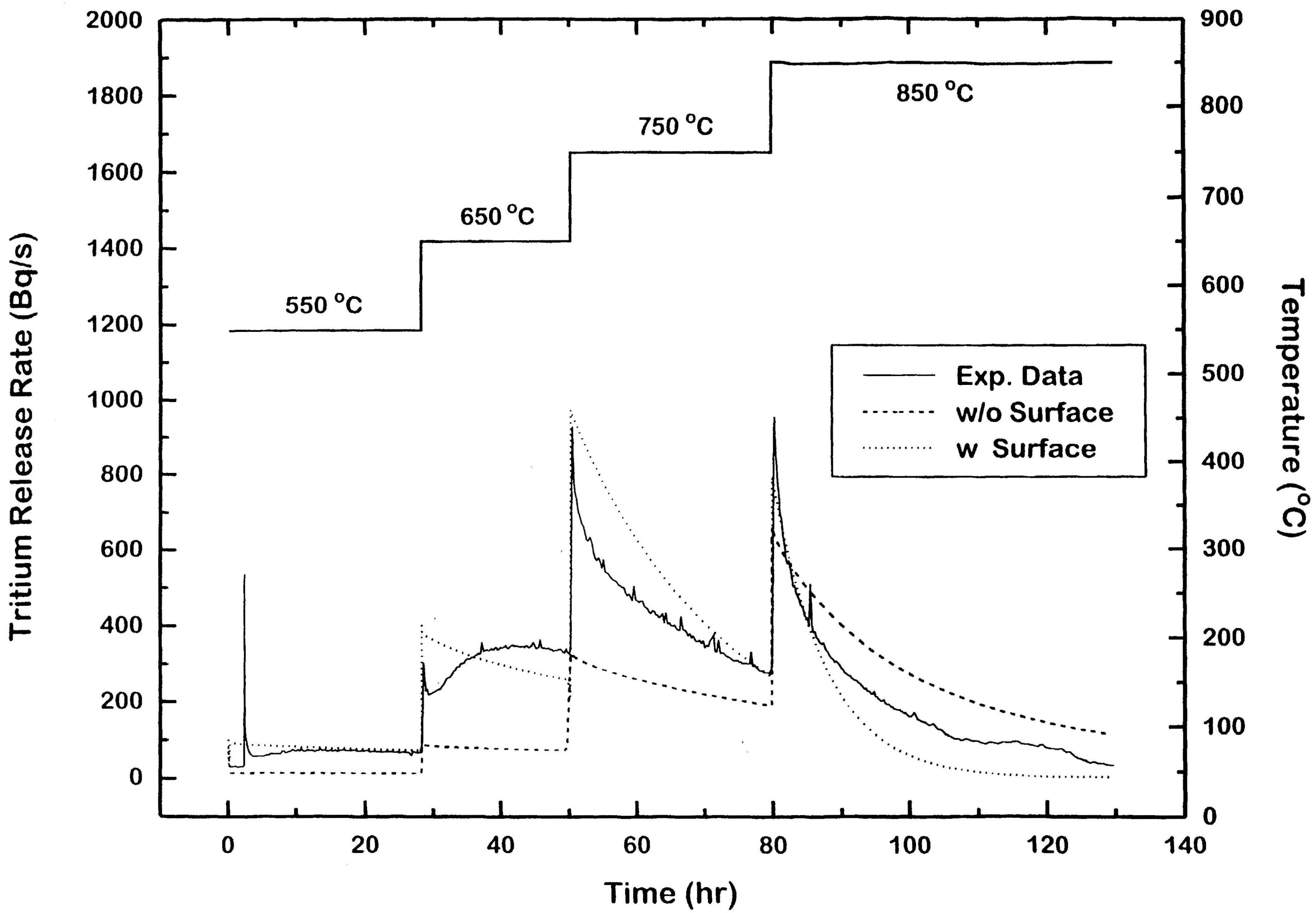

Figure 1
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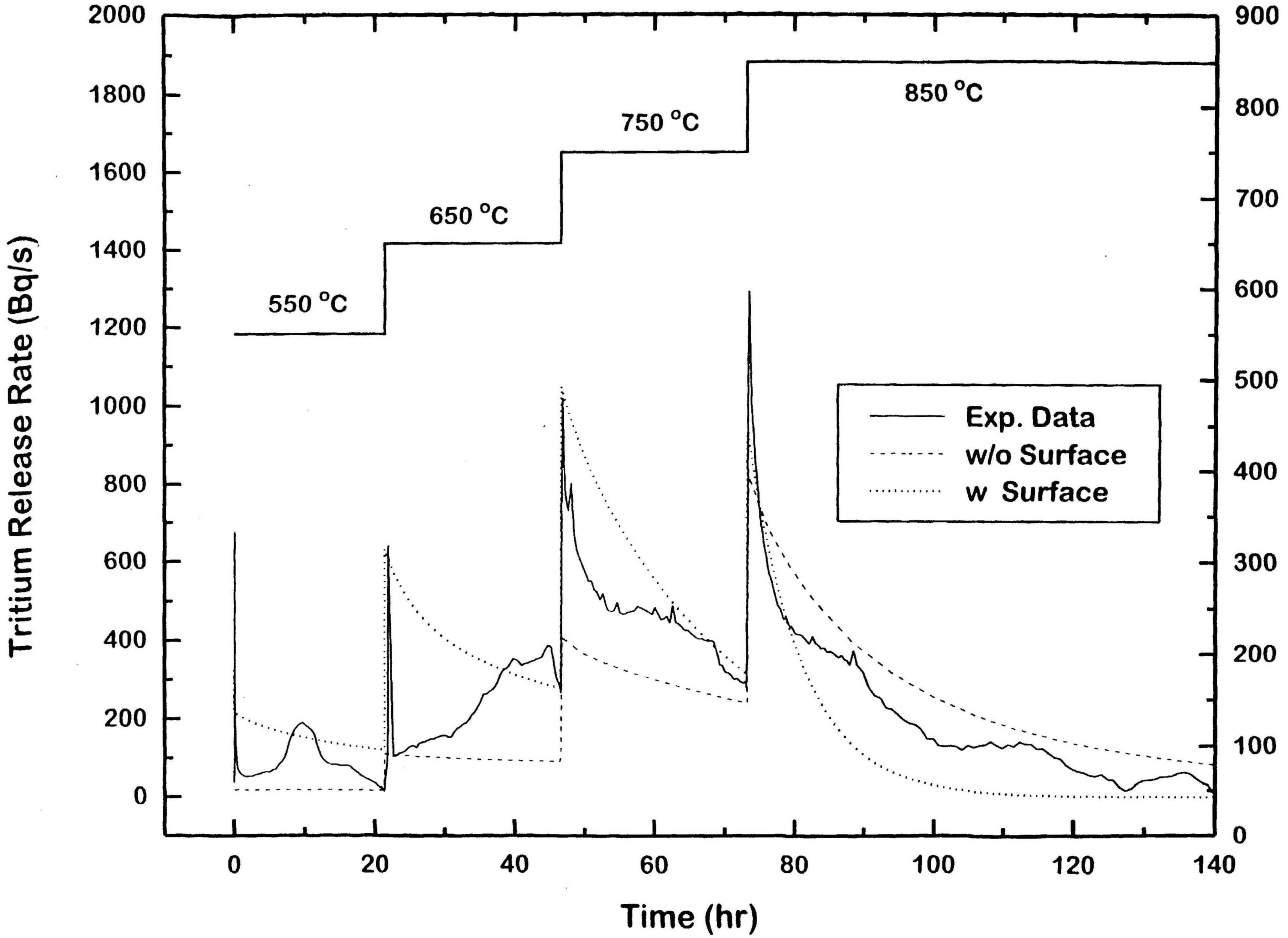

Tritium Release Rate (Bq/s)
Temperature (°C)
Time (hr)
550 °C
650 °C
750 °C
850 °C
Exp. Data
w/o Surface
w Surface
2000
1800
1600
1400
1200
1000
800
600
400
200
0
900
800
700
600
500
400
300
200
100
0
0
20
40
60
80
100
120
140