CONF
790125-- 32

SPUTTERING OF Be AND BeO BY LIGHT IONS*

J. Roth, J. Bohdanský, R. S. Blewer[†]), W. Ottenberger
Max-Planck-Institut für Plasmaphysik,
Association EURATOM-IPP, D-8046 Garching,
Fed. Rep. of Germany

and

J. A. Borders
Sandia Laboratories[†]
Albuquerque, New Mexico 87185

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately owned rights.

ABSTRACT

Sputtering yields of Be and BeO using 50 eV to 8keV H⁺, D⁺ and He⁺ ions are reported. The measurements were made by determining the weight loss of the samples using a microbalance with sub-microgram sensitivity. Zone melted Be and sintered BeO targets were used. For the oxide measurements, the surface charge was compensated by electrons emitted from a hot tungsten filament.

The energy dependence of the sputtering yield for both Be and BeO shows a maximum near 1 keV and a sharp decrease to lower energies. The results are discussed in terms of a scaling rule for low energy ion sputtering developed recently /1/.

+) Permanent address:
Sandia Laboratories,
Albuquerque, New Mexico 87185

*This work was supported by the U. S. Department of Energy under Contract AT(29-1)-789.

†A U. S. DOE Facility

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED 26

INTRODUCTION

Low Z coatings are receiving increased attention for use in magnetic fusion devices. Beryllium oxide layers are of special interest both because of their low Z constituents and because they can be formed and renewed in situ when Be is included in certain materials of interest /2/. However, few measurements have yet been made of the sputtering yield of Be and BeO under low energy particle irradiation /3,4/.

EXPERIMENTS

The measurements were performed at the 8 keV high current ion accelerator described previously /1/. The ion beam from a Duopigatron ion source is magnetically analyzed and enters the target chamber through a system of apertures. The pressure in the target chamber was below 10^{-7} Torr and rose to $\sim 10^{-6}$ Torr during bombardment due to the partial pressure of the bombarding ions. For energies below 2 keV, a 4 keV ion beam is extracted from the ion source and decelerated directly in front of the target. The ion fluence on the target was 2×10^{16} atoms/cm² sec. 2×10^{16} atoms/cm² sec.

The weight loss of the sample was determined using a micro-balance Mettler ME 22 with a sensitivity ~ 1 μ g. The effect of the added weight of the incident particles was accounted for in the data analysis. In no case could ion-induced oxide formation be observed as in /4/ leading to a net weight increase of a sample. The ratio of the rates of removed particles to impinging oxygen atoms is between 10 and 300 for H, D, and He in the energy range investigated. The targets were made

from single crystal Be of 99.44% purity and from sintered solid BeO /5/.

RESULTS

The energy dependences of the sputtering yields for Be and BeO with H, D, and He are shown in fig. 1 and 2. For both materials, the sputtering yield shows a maximum near 1 keV, the magnitude of the yields at the maximum being 2, 3.5 and 15×10^{-2} atoms per ion for H, D and He respectively. The yields decrease sharply at lower energies.

Recent values for the sputtering of BeO with D as taken from /3/ are introduced in fig. 2 (open points) and show good agreement with the present data.

DISCUSSION

For light ion low energy sputtering, systematics have been found for a large number of elements and compounds /1, 6, 7/. For all materials a universal energy dependence has been found, the magnitude of the sputtering yield as well as the threshold energy for sputtering following general scaling rules. The universal formula can be written as

$$S = 6.4 \times 10^{-3} \gamma^{5/3} M_2 \left(\frac{E}{E_{th}} \right)^{1/4} \left(1 - \frac{E_{th}}{E} \right)^{7/2} \quad (1)$$

where γ is the energy transfer factor $4M_1M_2/(M_1 + M_2)^2$ and the threshold of energy E_{th} is a fitting parameter. Eq. (1) describes all experimental data within a factor of 2. Also the present data for Be and BeO can be expressed by eq. (1). The threshold energies obtained from the best fit of eq. (1) to the data are given in Table 1.

For light ions on heavy materials the threshold energy E_{th} can be calculated using the expression /6,7/

$$E_{th} = \frac{E_B}{(1-\gamma)\gamma} \quad (2)$$

For the surface binding energy E_B , the energy of sublimation can be taken /8/. For light ions on a heavy material it can be assumed that the threshold energy is obtained in processes, where the light ion is reflected at a heavy target atom and ejects a surface atom in another close collision on its way out. This mechanism dominates up to mass ratios $M_1/M_2 = 0.4$. At larger mass ratios, as He on Be, reflected ions are not so important for sputtering since too much energy is lost in a close collision. At the threshold energy, sputtering is the result of a combination of different collision processes. Small cascades are necessary to reflect the momentum of the incoming ion. Therefore the threshold energy increases again at mass ratios larger than 0.4 /6/.

The threshold energy as well as the magnitude of the yields are similar for Be and BeO. This is surprising, as the smaller mass and the lower sublimation energy /8/ of Be should lead to a smaller threshold energy for sputtering. One explanation for this similarity is fast oxidation of the Be surface during sputtering due to oxygen atoms from the residual gas /4/. Preferential sputtering was not investigated.

CONCLUSION

The sputtering yields of Be and BeO by H, D and He at energies between 50 and 8000 eV has been measured using the

see p 2.9

weight loss method. The results agree well with a universal formula for sputtering by light ions described recently /6/. A higher threshold energy for He than for D and H could be found in agreement with this formalism.

In a previous paper /9/ it was found that graphite is superior to a number of carbon compounds, metals and alloys with respect to its sputtering yield (relative to the radiation loss it produces in the plasma). However, graphite is subject to chemical attack at elevated temperatures expected in a fusion reactor. In the present paper we find that the behavior of BeO (which is chemically stable in a hydrogen atmosphere) exceeds that even of graphite at sputtering energies below 200 eV.

REFERENCES

- /1/ H. L. Bay, J. Roth, J. Bohdansky, J. Appl. Phys. 48, 4722 (1977).
- /2/ J. Norem, D. A. Bowers, ANF/FPP/TM-108 (1978).
- /3/ J. A. Borders, R. A. Langley, K. L. Wilson, J. Nucl. Mat. 76 & 77, 168 (1978).
- /4/ R. A. Langley, this conference.
- /5/ Thanks are due to Sandia Labs, Albuquerque, USA, for providing the Be target and to the JET-Team, Culham, U.K., for providing the BeO targets.
- /6/ J. Roth, J. Bohdansky, A. P. Martinelli, Proc. of the Int. Conf. Ion Beam Mod. of Materials, Budapest, Hungaria (1978) to be publ. in Rad. Effects.
- /7/ J. Bohdansky, J. Roth, to be published.
- /8/ JANAF Thermo-chemical table, ed. D. R. Stull, H. Prophet NSRDS-NBS 37.
- /9/ J. Bohdansky, J. Roth, H. Vernickel, Proc. of the 10th Symp. on Fusion Technology, Padova, Italy (1978).

FIGURE CAPTIONS

- Figure 1. Energy dependence of the sputtering yield of Be with H, D and He.
- Figure 2. Energy dependence of the sputtering yield of BeO with H, D and He. The open symbols are the data of Borders, et al /3/.

Table 1

	H	D	He
Be	31	24	33
BeO	32	22	44

Experimental threshold energies for sputtering (eV).

The high threshold energy for He compared to H and D is unusual.