MASLER

SPUTTERING AND CHEMICAL ATTACK OF 304 STAINLESS STEEL,
ALUMINUM, AND GOLD BY HYDROGEN IONS OF 100 eV ENERGY*

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Samples of polished and oxidized 304 stainless steel, aluminum, and gold have been subjected to bombardment by hydrogen ions in order to simulate effects expected in tokamak fusion devices. This paper reports on the sputtering and chemical effects of bombardment with 100 and 200 eV ions to fluence levels of 2×10^{21} ions/cm² and 4×10^{21} ions/cm², respectively. Under these conditions gold is badly blistered and eroded, aluminum is slightly blistered at 100 eV and substantially eroded at 200 eV but few changes are seen in the polished stainless steel. The oxide film (produced by a 1/2 hr exposure to air at 500°C) on the polished sample was, however, removed and only a very thin layer of substoichiometric oxide remained on the surface after exposure to either 100 or 200 eV hydrogen plasmas. Sample temperatures during bombardment were about 50°C for the 100 eV ions and 65°C for the 200 eV ions.

The apparatus used in these studies has been described elsewhere [1], and only its major characteristics will be described here. The plasma is a low temperature, partially ionized plasma supported by electron emission from a hot cathode. The plasma discharge is inside a 3.8 cm diam stainless steel tube and extends approximately 25.4 cm from the cathode to the main anode.

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Hydrogen ions are drawn from the plasma and accelerated through the sheath between the plasma and the wall to provide a high flux of hydrogen ions (1 mA/cm^2). An external power supply can be used to bias the plasma with respect to the wall and thereby provide ion bombardment at any energy between thirty and several hundred electron volts. The discharges normally operate at a pressure near 10^{-2} torr of hydrogen. For many experiments the sample surface includes the entire tube wall. However, small samples of wall material can be moved under ultra-high vacuum conditions from the discharge chamber to a separate chamber for surface analysis. The entire system is of ultra-high vacuum construction and is free of organic materials. Ion species accelerated from the plasma into the wall are estimated to be about 80% molecular ions and 20% atomic hydrogen ions.

Figure 1 shows the topography which developed on the aluminum, gold, and stainless steel examples exposed to 100 eV ions at 50°C to an integrated fluence of $2 \times 10^{21} \text{ ion/cm}^2$. The conditions of this exposure did not reduce the aluminum oxide. Figure 1A shows that the oxide film is blistered and torn by the irradiation. The top half of the frame showing the gold sample, Fig. 1B, was shadowed from the ions. The irradiated area below shows evidence of both erosion and blistering. The top half of Fig. 1C shows the appearance of the oxidized stainless steel in an area shadowed from the ions. The lower half shows that the oxide was reduced in the irradiated area leaving a roughened surface but no blisters or sharply defined features. Unoxidized, polished samples had no easily recognizable erosion or bombardment created features although macroscopic optical reflectivity changes made it easy to identify the irradiated area. Figure 2 shows the topography developed by 200 eV hydrogen ions incident on aluminum, gold, and stainless steel at 65°C to a fluence of $4 \times 10^{21} \text{ ions/cm}^2$. Figure 2A shows the aluminum topography to be mostly an erosion pattern. The gold sample, Fig. 2B, also

shows erosion and no blisters. The behavior of both the oxidized and unoxidized stainless steel samples, Fig. 2C, was similar to that observed in the 100 eV irradiation.

Auger analysis of the samples were made after each exposure. These analyses revealed that (1) The oxide on the stainless steel is partially reduced with relative atomic concentrations being given by Fe = 1.0, Cr = 0.6, Ni = 0.3, and O = 1.2. (2) The aluminum oxide was not significantly reduced in the 100 eV exposure (as indicated by the aluminum Auger line shape). (3) The sample of gold exposed to 100 eV ions had ~20 at. % of metal atoms from the stainless steel wall on its surface after the exposure. (4) The samples of gold and aluminum exposed to 200 eV ions were covered with sputter products. The Auger spectra showed no detectable gold signal from the gold sample.

Conclusions

1. The plasma-wall interaction simulator produces a useful measure of the ability of materials to resist attack by low-energy hydrogen ions.

2. Hydrogen ions of 100 eV and above produce significant surface damage in gold and aluminum under the conditions of this experiment but do little apparent microscopic damage to 304 stainless steel.

3. Hydrogen plasmas of the type used in this experiment can reduce the oxides on stainless steel to a thin substoichiometric layer of atomic dimensiona. (Other experiments in ISX-A have shown that higher purity plasmas can partially reduce Al_2O_3 and reduce the oxygen level on stainless steel to <1 at. %) [2].

References

- [1] L. C. Emerson, R. E. Clausing, and L. Heatherly, paper 32 this conference.
- [2] L. C. Emerson, R. E. Clausing and L. Heatherly, paper 7a this conference.

Figure Captions

Fig. 1. Topography developed on (a) aluminum, (b) gold, and (c) 304 stainless steel samples bombarded by 100 eV hydrogen ions at 50°C. Total fluence = 2×10^{21} ions/cm². Magnifications are 10,000×, 10,000×, and 30,000× respectively.

Fig. 2. Topography developed on (a) aluminum, (b) gold, and (c) 304 stainless steel samples bombarded by 200 eV hydrogen ions at 65°C. Total fluence = 4×10^{21} ions. Magnifications are 10,000×, 30,000×, and 30,000× respectively.

10K

2a

M 3797

10K

2B

M 3779

30K 2C

M 3950

M 3951

30K 2C
Bottom
half

30k

1b

10k

1a

M6040

M6042

30k

1c

bottom
half

M6275

30k

1c

top
half

M6279