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The Electrochemical Behavior of Ti and Ti Alloys Subjected to Pulsed Ion Beam Surface Treatment

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Introduction

Pulsed high energy ion beams have been used to thermally treat titanium and Ti alloy surfaces to alter the electrochemical response. Two general processing regimens have been explored: 1) rapid melt and resolidification (RMR) and 2) ion beam mixing (IBM). RMR uses the pulsed ion beam to melt and in some cases ablate the top most several microns of the Ti surface. Subsequent solidification is sufficiently fast (> 10^6 K/s) for nonequilibrium structures and compositions to be attained. IBM uses the ion beam to mix a previously applied metallic layer into the substrate to produce a compositionally and structurally distinct surface alloy. In this report, results from initial studies are presented exploring the effect of these two processing regimes on the electrochemical behavior of Ti and Ti alloys.

Experimental

The electrochemical behavior of ion beam treated surfaces was explored using potentiodynamic and potentiostatic techniques. Samples were masked with electroplater tape to define a small exposure area and mounted in a PAR flat cell. All tests were run on a PAR 273 potentiostat.

Electrochemical testing was conducted on Grade-2 Ti (commercially pure α Ti) and Grade 5 Ti (an α - ß alloy). Tests were run in 1.0 N NaBr, which provides a reducing environment to stimulate pitting at relatively low applied potentials.

Results

Figure 1 shows Rutherford backscattering spectra for Pt sputter deposited on to Grade 2 Ti before ion beam treatment and after ion beam treatment using 25 pulses at 4 to 5 J/cm^2. In the untreated sample, the Pt layer is evident as the large spike at 3.0 to 3.2 MeV. The Ti substrate is evident as the lower energy shelf. After ion beam treatment, a small shelf due to Pt-Ti mixing is observed. Analysis of the spectrum shows that most of the Pt present before ion beam treatment was missing. This was due to ablation and evaporation which is known to occur during ion beam processing. Nevertheless, 3 to 7 a/o Pt remained in the alloyed surface layer.

Figure 2 shows the substantial effect of ion beam surface treatment on the electrochemical behavior of Grade-2 Ti. The untreated sample undergoes pitting at about 1.7 V (SCE). It exhibits a wide stable passive region, and repassivates at fairly high potentials. The RMR treated sample exhibits a lower passive current density and is immune to pitting up to 2 V. The open circuit potential is almost identical to the untreated sample. It is probable that the improved passivation behavior and pitting resistance is the result of a modified passive oxide that forms during the treatment process. The third curve in Figure 2 is for a Pt plated, IBM sample. The beam treatment causes mixing of the Pt into the Ti and results in between 3% and 7% Pt in the alloy. Consistent with the presence of Pt in the alloy, the open circuit potential is shifted about 0.5 V in the noble direction to around 0 V. There is no distinct passive region, but from about 0.2 to 0.8 V(SCE), there is evidence of metastable pitting. The current increases rapidly above 0.8 V, and at 1.5 V is almost 2 orders of magnitude higher than for the untreated sample. However, the increased current density is not due to pitting, as both the reverse polarization behavior and visual examination of the surface following the experiment failed to indicate any pitting. The electrochemical behavior at potentials above 0.8 V is consistent with oxygen evolution, and indicate that the water oxidation reaction is catalyzed due to the presence of the Pt.

Figure 3 shows the results of similar experiments for Grade-5 Ti. Again, the passive current density is lower for the RMR treated alloy and the pitting resistance is improved substantially. In this case, pitting of the untreated material occurs at less than 1V (SCE), while no stable pitting is seen on the treated sample at potentials up to 2 V.

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Conclusion

Ion beam treatment has been shown to substantially improve the localized corrosion resistance of Grade-2 and Grade-5 Ti alloys.

Acknowledgment

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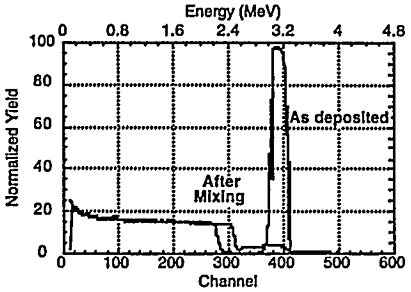

Figure 1. RBS data for Pt in Ti. Note that the ion treatment resulted in mixing of the Pt into the alloy.

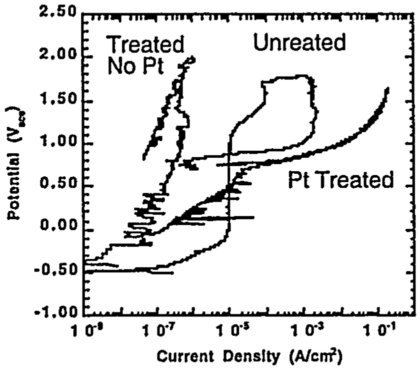

Figure 2. Potentiodynamic polarization behavior for Grade-2 Ti in 1.0N NaBr. The addition of Pt to the alloy substantially alters the electrochemical response.

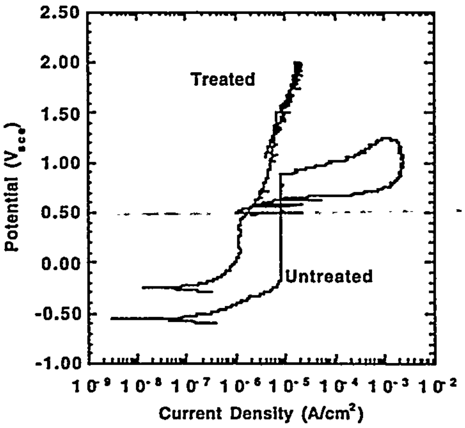

Figure 3. Potentiodynamic polarization behavior for Grade-5 Ti in 1.0N NaBr.