Title

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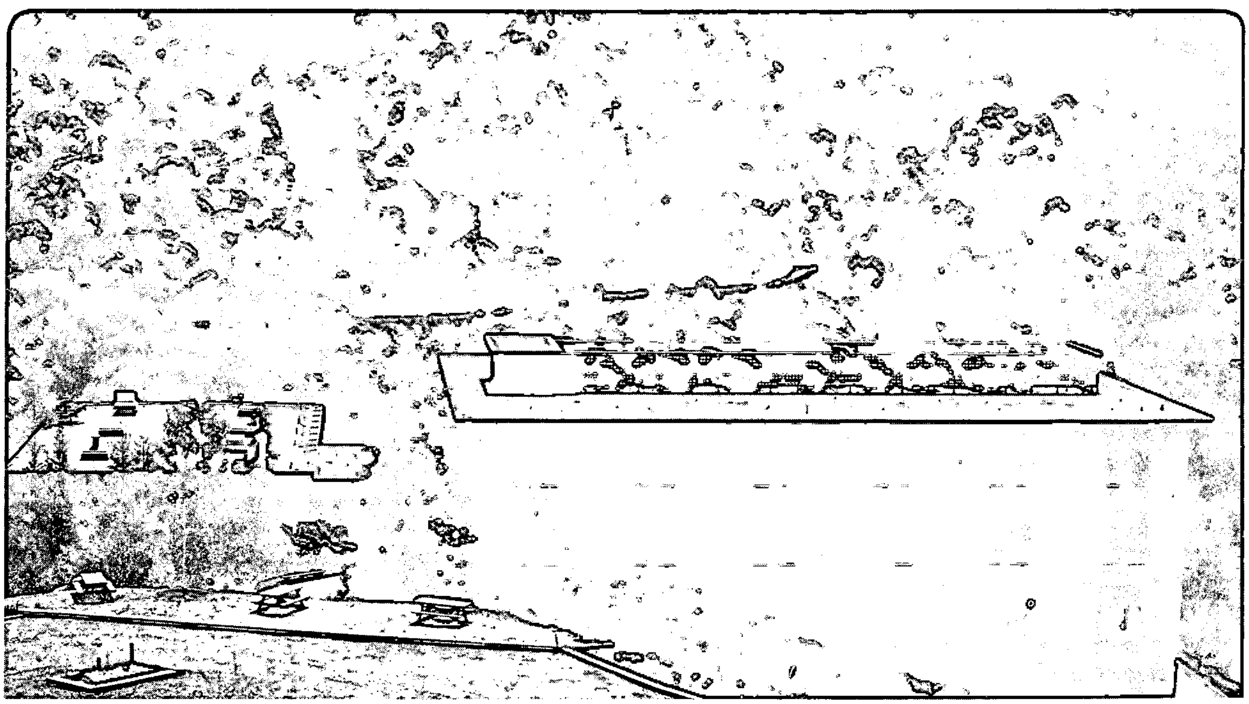

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DISCLAIMER

EFFECT OF ION IMPLANTATION ON THE CORROSION BEHAVIOR OF LEAD AND LEAD-ANTIMONY ALLOY

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Grid corrosion, particularly in the positive plate, is an important factor that limits the cycle life of lead-acid batteries. It has received considerable attention [1, 2].

In the present work, surface modification by ion implantation has been investigated to reduce the corrosion of grid materials. Titanium was primarily used for implantation; pure lead (99.99%) and a lead-4% antimony alloy were chosen as representative grid materials. The implantation of several other elements produced similar results. Ion implantation has been used before to modify surface properties of metals such as hardness and corrosion resistance [3, 4].

The ion implantation was performed with a new high-current, pulsed ion source that has been described elsewhere [5]. The purity of the Ti arc source was 99.999%. Typical beam current densities were 2.55 mA/cm^2, typical pulse durations 0.24 ms, and pulse frequencies 5-10 Hz. Ion beam energies of 30-120 keV, and implantation doses of $1x10^{15}$ to $5x10^{17}$ $atoms/cm^2$ were used.

Two methods were employed to determine the corrosion behavior of the grid materials: Corrosion rates were derived from the current response of the specimens in 5M H_2SO_4 to small anodic polarization (3-10 mV), extrapolated from short-term measurements to zero time (in order to represent the behavior of the original surface). Also, the morphology of the corroded surface after extended (60 h) open circuit immersion in the sulfuric acid was determined by SEM.

The dependence of corrosion currents for lead and lead-4% antimony on titanium ion dose and energy is illustrated in Figs. 1 and 2. Optimum implantation conditions are slightly different for the two specimens but lie in the vicinity of $5x10^{16}$ $atoms/cm^2$ and 60 keV. Compared to the untreated specimens, corrosion currents are reduced by the ion implantation up to 36-fold for the pure lead and up to 72-fold for the lead-antimony alloy.

The effect of the implantation of some other ions on corrosion currents is comparable to that of titanium and is illustrated in Table 1 for one set of implantation conditions.

Depth profiles of the implanted ions, obtained by Auger spectroscopy, are shown in Fig. 3. These profiles compare well with computed profiles and, together with anodic and cathodic polarization measurements, provide mechanistic information on the effect of ion implantation

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Table 1. Effect of the ion implantation of different atoms on the corrosion of lead and lead-4% antimony alloy in 5 molar sulfuric acid.

Implantation Conditions						Corrosion Current	
Ion	Energy keV	Dose atoms /cm^2	Peak Current Density mA/cm^2	Pulse Duration ms	Pulse Frequency Hz	mA /cm^2 Pb	Pb-4%Sb
Ti	60	$5x10^{16}$	2.55	0.24	5	0.15	0.040
V	60	$5x10^{16}$	2.55	0.24	10	0.20	0.053
Cr	60	$5x10^{16}$	2.55	0.24	10	0.27	0.093
Ni	60	$5x10^{16}$	2.55	0.24	10	0.18	0.085
W	180	$5x10^{16}$	2.55	0.24	~3	0.81	0.51
none	-	0	-	-	-	5.4	2.9

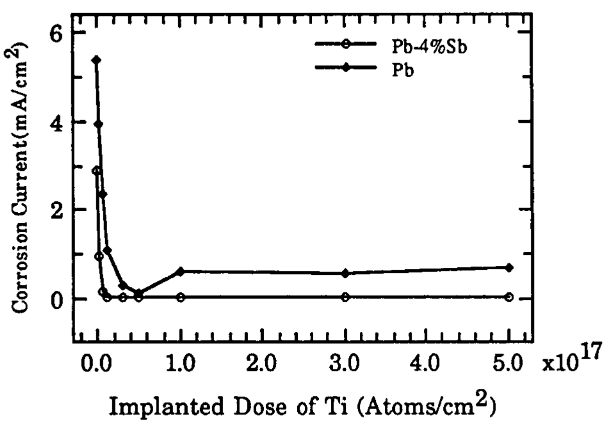

Fig.1 Dependence of corrosion current of Pb and Pb-Sb on dose of Ti implantation conducted at 60 keV.

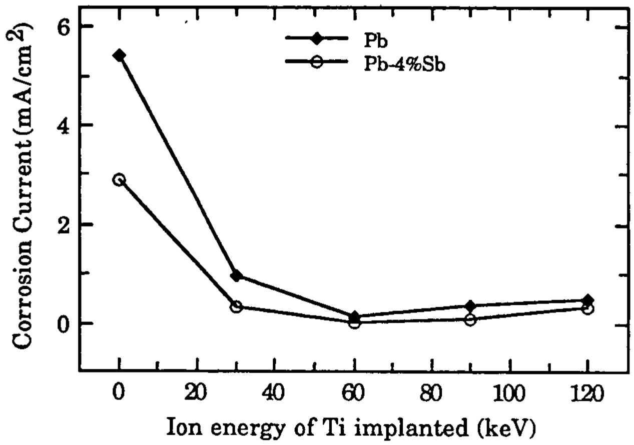

Fig.2 Dependence of corrosion current of Pb and Pb-Sb on Ti ion energy of implantation at $5x10^{16}$ atoms/cm^2.

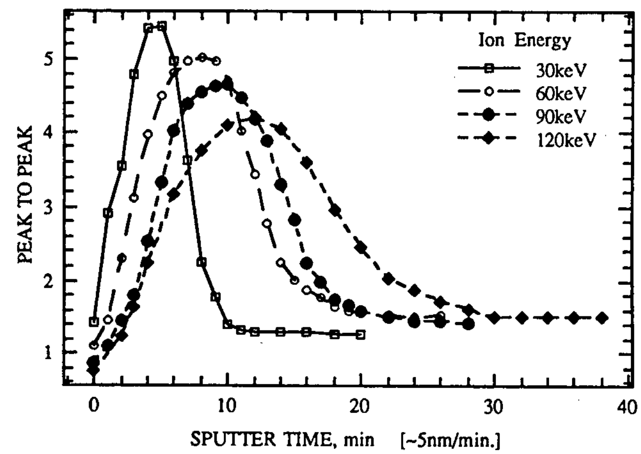

Fig.3 Measured depth profiles of Ti distribution in Pb for different implantation energies and a dose of $5x10^{16}$ atoms/cm^2.

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