Chromium Recoil Implantation Into SAE 1020 Steel By Nitrogen Ion Bombardment

G. F. Gomes[a], M. Ueda[a], H. Reuther[b], E. Richter[b], and A. F. Beloto[c]

[a] *Laboratório Associado de Plasma, LAP-INPE, São José dos Campos-SP, Brazil*

[b] *Forschungszentrum Rossendorf, FZR, Dresden, Germany*

[c] *Laboratório Associado de Materiais e Sensores, LAS-INPE, São José dos Campos*

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SAE 1020 is a widely used plain carbon steel, as mortar reinforcement in buildings and small machine parts. But aside from good mechanical properties, its surface suffer from severe corrosion and high wear rate, due to modest hardness. Chromium (Cr) in excess of 12% in Fe alloys renders them resistant to several corrosive attacks. So we tried to introduce Cr in such amounts into the surface of that steel. Cr films were deposited by electron beam on SAE 1020 steel. Bombarding the Cr film either by nitrogen Plasma Immersion Ion Implantation (PIII) or nitrogen ion beam (IB), Cr atoms were recoil introduced into the Fe matrix. Normally, in the recoil process, heavy atoms are used, but in this set of experiments we used a relatively lighter atom, viz. nitrogen. SRIM simulation was used to show Cr atoms range in the steel matrix after being hit by nitrogen atoms. AES analysis showed ranges far beyond the calculated figures and in percentages above 13at. %, enough to the purposes of these works. Preliminary corrosion results showed remarkable enhancement under corrosive attack.

1 Introduction

SAE 1020 construction steel is used frequently as mortar reinforcement and small machine parts[1-3]. But aside good surface properties as ductility, hardness and wear resistance, it is prone to severe corrosion. As the presence of Chromium (Cr) in excess of 12-13 % in Fe alloys, renders them resistance to several corrosive attacks, we tried to introduce such amount of Cr into the surface of this steel. Cr films were deposited by electron beam on SAE 1020 surface and then bombarding either by nitrogen Plasma Immersion Ion Implantation (PIII) or ion beam (IB) Cr atoms are recoil introduced into the steel matrix [4,5].

Numerical simulations were carried out using 2000.40 version of SRIM,[6] code, showing the range of Cr and N atoms in Cr/Fe region, where the presence of Cr film was taken into account. These simulations showed that Cr atoms can be introduced in the steel surface by nitrogen ion recoil, confirmed by AES analysis. Preliminary corrosion analysis results showed great enhancement after such surface hybrid treatment.

2 Experimental

Before ion bombardment SAE 1020 steel samples were polished to 1μm with alumina powder and then covered with chromium film of several thicknesses, Fig. 1, in a 5 keV electron beam device. Ion bombardment were performed using a 100 keV N^+ beam to doses of $2 \times 10^{17} N/cm^2$ and $5 \times 10^{17} N/cm^2$. In the case of nitrogen Plasma Immersion Ion Implantation, PIII, samples were bombarded using high voltage pulses at 40 kV and pressure of 8×10^{-2} mbar in a nitrogen plasma, to doses about $3 \times 10^{17} N/cm^2$. Plasma Immersion Ion Implantation is a novel technique, used as a means to improve surface properties of materials like metals, semiconductors and insulators. In this process, a sample is immersed in suitable plasma and then repetitively bombarded with high negative voltage pulses. Under the negative pulses, positive ions are extracted from plasma and then implanted in the surface of the sample. As in other plasma immersion treatment, all the exposed sample surfaces are simultaneously treated [7-9]. Ion implantation introduces beneficial effects into the treated surface. Among these effects, are enhancements in hardness, corrosion resistance, wear and in fatigue life. Some of these effects are due to formation of compounds of implanted ion and surface components and other due to lattice damage.

SRIM simulation showed Cr atoms introduced into steel surface after N recoil, at several ion energies. Auger Electron Spectroscopy (AES) measurements were applied to elemental profiling.

3 Results

SRIM simulation of nitrogen ion bombardment on Cr film, showing that the latter can be introduced into the iron matrix, as can be seen in the Fig. 2, were confirmed by AES results. The energy of nitrogen ion beam at 100 keV seems to be large enough to make the ion N^+ to cross the Cr film, and despite of a 30% Cr content measured in the region just beneath the interface between the Cr film and the steel, Cr atoms lie in a very thin layer, less than 9 nm, as can be seen

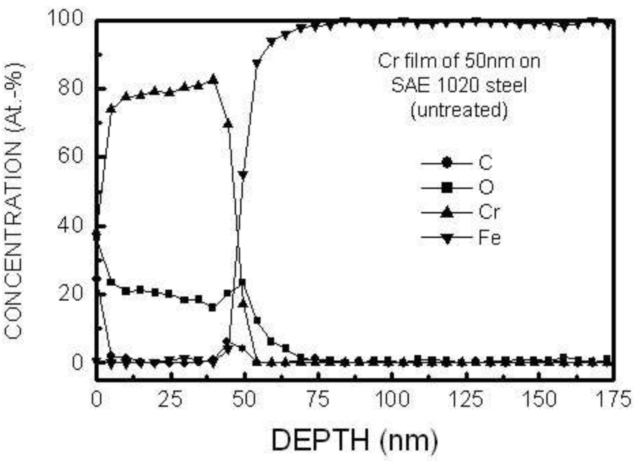

Figure 1. AES profile of a 50 nm Cr film on SAE 1020, deposited by a 5 keV electron beam.

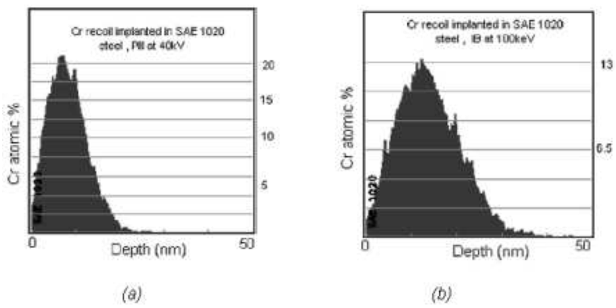

Figure 2. Theoretical depth profile of Cr atoms in SAE 1020, after Nitrogen recoil at (a) 40 kV (PIII) and (b) 100 keV (IB), beyond the 50 nm original Cr film.

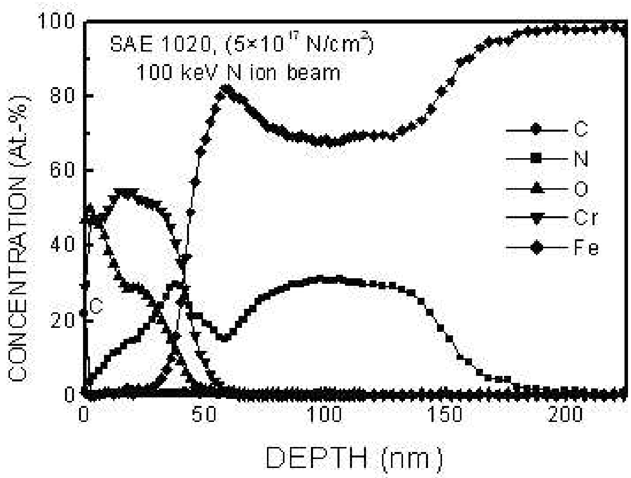

Figure 3. AES depth profile of the Cr into SAE 1020 matrix, after Ion Beam bombardment by N^+ at 100 keV energy.

in the Fig. 3. The best Cr implantation was attained using Cr film of 50 nm and PIII at 40 kV, with percentages over 13 % Cr at the surface in a layer ranging over more than 90 nm, as seen in Fig. 4. Oxygen appears as impurity in the modified layer, probably coming from the pumping system. Preliminary corrosion tests indicated remarkable increase in the SAE 1020 resistance under corrosive medium attack, even in the case of IB, that produced a modest Cr enriched layer in the treated samples and great amount of Cr remaining in the original film.

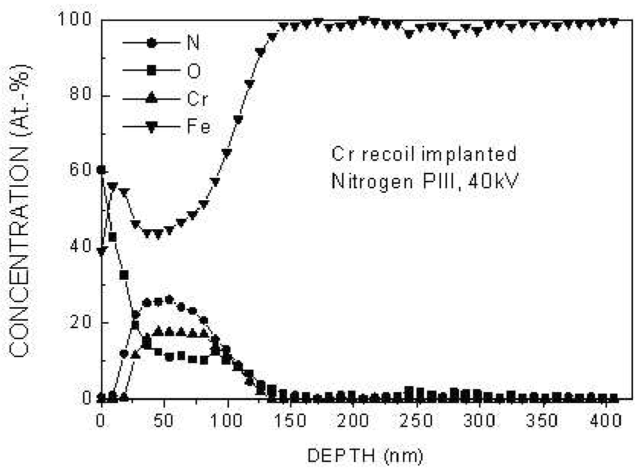

Figure 4. AES depth profile of the Cr into SAE matrix, after N Plasma Immersion Ion Implantation bombardment at 40 kV.

In the case of PIII, the modified layer showed good uniformity, with a maximum of 17 % at., ranging to about 90 nm. Almost all the Cr film was implanted in the steel surface. By another side, IB implantation presented an irregular profile, with a maximum of 30 % at., going into the surface for about only 10nm, with a large part of the original film remaining on the steel surface.

Corrosion test showed good performance of the PIII treated sample. The IB treated sample showed some enhancement over the reference and the only Cr film treated sample showed no modification on the corrosion character as compared to the non-treated reference.

4 Conclusion

To produce a Cr-rich layer on the surface of construction steel, aiming to enhance its corrosion resistance, we deposited Cr films of several thicknesses on SAE 1020 steel surface. Then, we bombarded the film either by Nitrogen Plasma Immersion Ion Implantation, at 40 kV or by Ion Beam, at 50 and 100 keV. Nitrogen hitting on Cr atoms caused them to penetrate the iron matrix.

Computer simulations showed that by bombarding a Cr film with energetic nitrogen ions, it is possible to implant some Cr atoms by recoil process.

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