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Mechanical and atomic attrition effects on low temperature plasma nitriding of ferrous alloys

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Abstract – In this work, we report a comparative study between mechanical and atomic attrition pre-treatments focusing on their effects in the posterior plasma nitriding treatment of AISI 316 stainless steel at low temperature. The results show that the pre-treatment influences the crystalline structure after the plasma nitriding process. Moreover, the nitrided layer thickness shows a contradictory behavior where either the thickness increases or diminishes due to atomic or mechanical attrition, respectively. Finally, the surface hardness is enhanced as a function of pre-treatment time.

Plasma nitriding of metal alloys is an important area of surface engineering and the effects of this thermochemical process on steel surfaces are intensively studied. Surface pre-treatments are usually used previously to plasma nitriding for cleaning purposes. Each pre-treatment produces specific effects on the base material modifying its structural and mechanical properties. In this work, we report a comparative study between mechanical and atomic attrition pre-treatments focusing on their effects in the posterior plasma nitriding treatment of AISI 316 stainless steel at low temperature.

Four groups of samples (AISI 316 stainless steel) were prepared. The first sample group was defined as atomic attrition (nanoscopic) and involves the argon ion bombardment on steel surfaces by argon DC plasma for different times[1]. The second sample group was defined as mechanical attrition (macroscopic) and involves a ball milling treatment for different times[2]. The third sample group was performed by plasma nitriding for 7 hr at 300°C of the first sample group. The fourth sample group was performed by plasma nitriding for 7 hr at 300°C of the second sample group.

The samples were characterized by X-ray diffraction (XRD), nanohardness and scanning electron microscopy (SEM). The results show that the pre-treatment yields different crystalline structures after plasma nitriding process (Figures 1 and 2). The nanoindentation experiments show that the surface hardness before and after plasma nitriding is enhanced (Figure 3). The nitrided layer thickness was measured directly from the scanning electron microscopy images. On one hand, the nitrided layer thickness of samples pretreated by atomic attrition increases as a function of pre-treatment time. On the other hand, the nitrided layer thickness of samples pretreated by mechanical attrition diminishes as a function of pre-treatment time. The last could be associated with the oxidation of the steel surface during the ball milling process avoiding the posterior nitrogen diffusion/incorporation into the material.

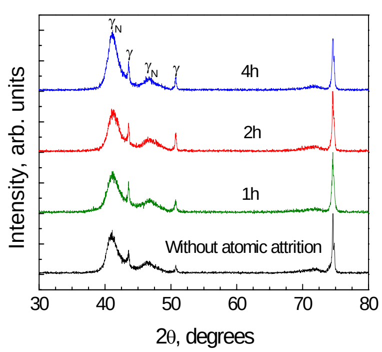

Figure 1: XRD patterns show the influence of atomic attrition time in nitrided AISI 316.

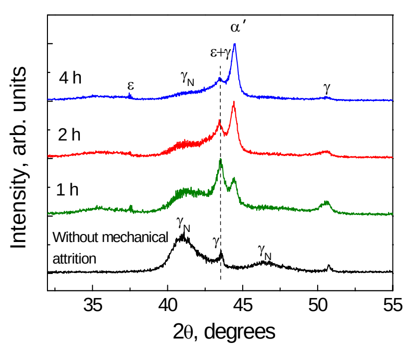

Figure 2: XRD patterns show the influence of mechanical attrition in nitrided AISI 316.

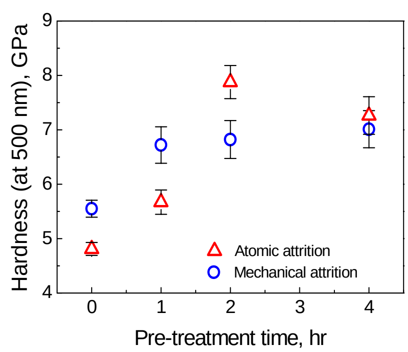

Figure 3: Hardness behavior of nitrided samples as a function of pre-treatment time (groups 3 and 4). Pristine sample hardness = 2.7 GPa.

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[2] K. Lu, J. Lu, J. Mater. Sci. Technol. 15, 193 (1999).