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Influence of the surface finishing of a stainless steel substrate on the hardness measurement of an oxide film deposited by electrochemical process

J.M.C. Vilela(1), C.R.O. Loureiro(1) M.S. Andrade(1), R.M.R. Junqueira (1) *

1 Fundação Centro Tecnológico de Minas Gerais – CETEC, Avenida José Cândido da Silveira, 2000, CEP 31170-000, Belo Horizonte, MG, Brazil
*Corresponding author: rosa.junqueira@cetec.br

Abstract – The hardness obtained by nanoindentation test of an oxide layer on austenitic stainless steel can be influenced by the substrate surface finishing. The contributions of the roughness and hardness of the substrate surface were analysed.

Stainless steels can be colored by growing an oxide layer on their surfaces [1]. A technique widely applied to obtain information on the mechanical properties of these layers is the nanoindentation [2]. Despite of the very low indentation depths used the measurement of their hardness and elastic modulus may be strongly influenced by the substrate. The investigation of the substrate surface finishing is necessary to interpret the nanoindentation results.

In this work an oxide film was grown by electrochemical process on two AISI 304 stainless steel sheets with different surface finishing: mirror finishing (MF - R_a= 0.8nm) and bright buffing (BB - R_a = 5.0 nm) [2]. Nanoindentation tests were performed at the two samples and substrates. Figure 1 shows load-displacement curves of the color film grown on the MF (1) and BB (2) substrates. The films presented a puzzling result concerning the hardness. When measured at the beginning of the load-displacement curves (low loads) the film deposited on the MF substrate was harder, while at higher loads the situation is inverted. This means that these curves cross at a load range between 1 and 2mN. Hardness measurements (not shown) performed at the substrates showed that the BB substrate was harder for all loads till 5mN. Aiming to interpret these results atomic and magnetic force microscopy, (AFM) and (MFM) respectively, were used to analyze the films and the substrates morphology and magnetic properties. Figure 2 shows AFM images of indentations on BB (a) and on MF (b) substrates. MFM images at BB and at MF substrates are presented in figures 2c and 2d, respectively. Besides the sizes of the indentations showing the different hardness of the substrates it is possible to observe the grooved (Ra=7.5nm) and flat (Ra=0.8nm) surfaces of the BB and of the MF steel sheets. MFM contrast images indicated that the BB surface is completely ferromagnetic (2c) and the MF surface has some ferromagnetic regions, but most of the surface does not present magnetic contrast (2d). These results show that the BB surface finishing transforms the austenite (paramagnetic) to martensite (ferromagnetic) while the MF finishing keeps most of the surface as austenite. The interpretation of the hardness measurements is that at low loads it is dominated by the surface topography of the substrate. The rougher surface of the BB substrate makes the film on it appear softer since the film follows the substrate topography. At higher loads, when indentations are deeper, the influence of the substrate dominates. The martensitic transformation induced by the BB finishing makes the film on it appear harder.

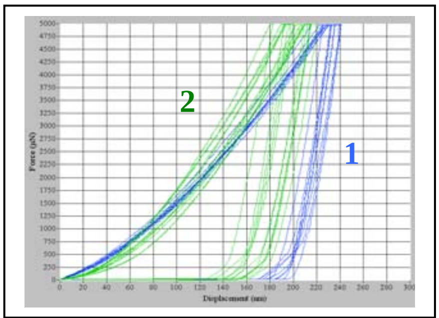

Figure 1: Load-displacement curves of oxide films deposited on MF (1) and BB (2) AISI 304 steel substrates.

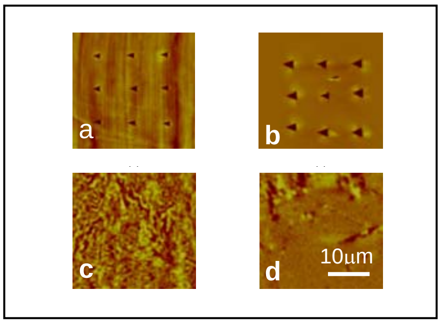

Figure 2: AFM images of indentations on BB (a) and MF (b) substrates. MFM images of BB (c) and MF (d) substrates.

References

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