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Depth distribution of martensite in plasma nitrided AISI H13 steel and its correlation to hardness

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ABSTRACT

The depth distributions of hardness, nitrogen, and crystallographic phases in the diffusion zone of plasma nitrided AISI H13 steel were determined by microindentation, electron microprobe, grazing incidence X-ray diffraction, and conversion electron Mössbauer spectroscopy. For the phase analysis, successively new surfaces were exposed by means of controlled mechanical layer removal. In the diffusion zone, the nitrogen concentration decreases monotonously, while the hardness profile exhibits two distinct regions, one where hardness is roughly constant and another where it decreases to bulk values. Thus, in the case investigated here, the common sense of a linear dependence of hardness on the N concentration does not apply in both regions, but only in the second one. This behavior is discussed in terms of the above mentioned physico-chemical properties.

1. Introduction

Plasma nitriding is a surface engineering technology widely used to improve the tribological and mechanical properties of steel surfaces. In this process, the diffusion of nitrogen species from the plasma leads to the formation of nitrogenous phases in the near surface region [1–3].

The AISI H13 is a commonly used steel in hot working applications [4] and, next to other surface treatments [5], plasma nitriding is employed to increase its hardness and wear resistance. During this treatment, two different layers can be formed: the compound layer and the diffusion zone. The compound layer, which is the outermost one, usually consists of iron nitrides such as ε-$Fe_{2-3}N$, γ′-Fe_4N, or a mixture of these phases [6,7]. Below is the diffusion zone, described by some authors as a cubic ferrite structure (α-Fe) with dissolved nitrogen [8], while other authors refer to this region as containing tetragonal nitrogen-martensite, α′-Fe(N) [2,7]. The importance of the so called "excess" nitrogen in the diffusion zone has been reported, attributing its incorporation to the formation of nanoprecipitates of alloying element-nitrides, nitrogen absorption in the interfaces between the precipitates and the matrix, and interstitial nitrogen in the iron lattice [9–11].

Several authors have investigated the interdependence of hardness and nitrogen content in the compound layer and/or in the diffusion zone, and many describe a linear relationship between them [10–17], while others do not observe any correlation [18]. In the compound layer a linear dependence was observed [14,17] and was mostly attributed to the saturation with nitrogen, with the formation of ε-$Fe_{2-3}N$ and γ′-Fe_4N. The hardness in this case is determined by the proportion of these phases. In the diffusion zone a linear correlation between hardness and nitrogen concentration was reported [10, 11,15]. Hardness behavior at different depths was attributed partly to the formation of CrN precipitates [15], even if only a low fraction of this phase was formed.

Major attention has been dedicated to the role of nitride precipitates/nanoprecipitates on the improvement of the mechanical properties after nitriding. Few discussions are focused on the structural modification of the ferritic/martensitic matrix in the diffusion zone as a consequence of the excess of nitrogen observed in this region. Although nitrogen concentrations up to 12 at.% have been found in the diffusion zone of low temperature nitrided AISI H13 steel, the linear correlation between hardness and nitrogen concentration was only observed below 7 at.% nitrogen [11]. Another study in the same steel showed a constant behavior of the hardness along the diffusion zone and stated that no simple dependence on the content of precipitates of metallic nitrides can explain this observation [15]. These results point out the need to investigate the relation between phases and mechanical properties in the diffusion zone of nitrided steel.

We report here on the determination of the hardness depth profile in AISI H13 steel plasma nitrided in a specific condition, as well as on the depth distributions of nitrogen and crystallographic phases formed in the diffusion zone, investigating the relationships between these parameters. The nitrogen profile and the hardness, measured on the

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