Characteristic features of expanded austenite layers formed on CoCrMo implant alloy by floating potential plasma nitriding

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Abstract

Moderate temperature nitriding of austenitic stainless steels (ASS) and CoCr alloy was shown to lead to hard and wear-resistant surface layers composed of expanded austenite phase γN. This work investigates the characteristics of the expanded layers produced by floating potential plasma assisted nitriding FPPAN of a medical grade CoCrMo alloy. Samples were nitrided at 400$\circ$C in N2-H2 atmosphere with a working pressure of 60 mTorr, for 1 to 20 hours. Other samples were nitrided at 350$\circ$C and 335$\circ$C. A combination of X-ray diffraction (both
$theta/2$
$theta$ and grazing incidence XRD), scanning electron microscopy, glow discharge optical emission spectroscopy, atomic and magnetic force microscopy were employed to reveal the phase structure, surface morphology, nitrogen composition/depth and magnetic properties of the expanded phase layers. The mechanical and wear behaviour of the expanded layers were investigated by nanoindentation on the cross-section, surface microhardness measurements and pin-on-disc wear tests. The experimental results clearly show the formation of the high-N-content expanded phase, γN, for all the treated specimens. At longer nitriding times at 400$\circ$C (6 h and 20 h), the decomposition of the expanded phase into CrN precipitates occurs. SEM imaging and GIXRD reveals the fine distribution of nanometer size CrN precipitates on the nitrided surface as well as across the γN matrix. [p1] As in ASS, nitrogen concentration-depth profiles can be interpreted by a thermally activated diffusion accelerated by the trapping-detrapping mechanism. The deduced nitrogen diffusivity at 400$\circ$C is then estimated to be D = 1.4 x 10-11 cm2/s. MFM imaging reveals ferromagnetic domain structures observed on all the surfaces and varying magnetic properties in the different surface grains. The surface microhardness is significantly increased at low load ; cross-section nanoindentations reveal that the hardness increase is homogeneous in the nitrided layer depth whereas the indentation elastic modulus is not modified. At lower processing times (1, 2, 4 h), the hardness increase is attributed to the formation of the expanded austenite phase/layer with a high residual compressive stress level. With longer treatment times, CrN precipitates distributed within the γN matrix are conributing to the enhancement of the

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mechanical properties. The wear resistance is significantly improved whatever the nitriding conditions but the corrosion protection is thought to be better preserved for the samples with lower processing times compared to the longer processed samples.

Keywords: Plasma nitriding, CoCrMo alloys, expanded austenite