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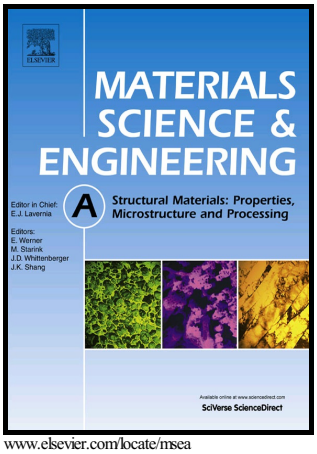

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Abstract

The ultrasonic surface rolling process (USRP) is a new technique employing a high strain rate and severe plastic deformation (SPD), and treated materials show high homogeneity, a large depth of strengthening and excellent surface integrity. In this work, USRP was used to treat 17-4 martensite precipitation-hardening (PH) stainless steels with a body-centered tetragonal (BCT) structure, and the deformation nanocrystallization mechanism was systematically investigated using microscopy and X-ray diffraction (XRD) analysis. The results indicated that a gradient nanocrystalline structure comprising thermal-mechanical coupled layer, elongated nanograin layer (long axis parallel to the treated surface), elongated ultrafine grain layer, refined grain layer and low-strain matrix layer was fabricated in 17-4PH stainless steels, reaching a thickness of 650 μm. The grain size presented a regular large-small-large variation, while the dislocation density showed a high-low-high variation with increasing depth. During the nanocrystallization process of 17-4PH stainless steel subjected to USRP, elongated ultrafine grains were formed first, and then grains were refined by dislocation tangles, dislocation bands, and dislocation walls through dislocation glide. In the near surface (approximately 10 μm below the processed surface), deformation twins presented in the nano-lath microstructure had a positive effect on the formation of nanocrystallites via an interaction between twinning and dislocations. Moreover, the disperse ε-Cu precipitated phase had a positive effect on the evolution of the nanocrystalline microstructure. The additivity of strengthening by dislocation density, grains and precipitates was prominently enhanced, and high compressive residual stress was