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The Influence of Stacking Fault Energy on the Temperature Dependent Deformation Mechanisms in High Mn-N Austenitic Stainless Steel

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Austenitic stainless steels are widely used as structural materials owing to a combination of excellent corrosion resistance from the Cr content (16-18 %), and low temperature toughness from a face centered cubic (FCC) austenitic microstructure stabilized by Ni (8–12 wt.%) [1]. However, the production of low-Ni austenitic steels is possible by the addition of elements such as Mn and interstitial elements like carbon or nitrogen [2]. Compared to 300 series 18Cr-8Ni stainless steels, the deformation induced martensitic phase transformations of these low-Ni austenitic steels occurs over a larger range of temperature and strain rates, which can be attributed to the steel chemical composition controlling the relative stability of austenite (γ) and martensite (ε and α′), and the influence of composition on the stacking fault energy (SFE) [3]. Reduced SFE promotes dissociation of perfect dislocation into partials, which inhibits dislocation glide. Under specific combinations of strain rate and temperature, a decrease in the SFE in austenitic steels allows for transformation induced plasticity (TRIP) from martensitic transformations or twinning induced plasticity (TWIP) during deformation. In both cases, a large elongation to failure and high-strain hardening can be associated with the effectiveness of the transformation product in preventing localized necking during tensile deformation.

A high Mn-N austenitic stainless steel with composition (mass %) Fe-16.5Cr-8Mn-3Ni-2Si-1Cu-0.25N-0.08Ti ($C \leq 0.05$) was prepared by induction melting. This material was hot rolled at 1100 ºC, cold rolled to 1.5 mm in thickness, and recrystallized by annealing at 1050 ºC. Samples tested in tension at −75, 20, 50 and 200^{o}C with a strain rate of 4 x 10^{-4} s^{-1} were analyzed using transmission electron microscopy (TEM) in order to characterize their deformation mechanisms after 5% deformation and elongation to failure. In addition, X-ray diffraction (XRD) was used to determine the volume percent of the deformation induced transformation products. Fig. 1 (a) and (b) show the early stages of the stress-induced martensitic transformation after deformation of 5% at -75^{o}C. The ε martensite forms with $(111)\gamma//(0001)\varepsilon$ and $[\bar{1}01]\gamma//[1\bar{2}10]\varepsilon$, while the α′ martensite nucleates at the intersections of ε platelets with the Kurdjumow-Sachs relationship $(111)\gamma//(110)\alpha$ and $[\bar{1}01]\gamma //[1\bar{1}1]\alpha$. The samples tested at -75^{o}C failed with ~ 70% elongation and XRD data indicate that the microstructure consists mainly of α′ martensite with 8% γ. Tensile testing at 20^{o}C produced over 75% elongation where the deformation mechanisms include ε martensite that transforms into α′ martensite, highly deformed γ grains from slip, and mechanical twinning as shown in Fig. 1 (c). Elevating the testing temperature to 50^{o}C increased the tendency for twinning. The sample tested at 200^{o}C in Fig. 1 (d) deformed by slip and fractured at ~ 50% elongation with a high-dislocation density austenitic microstructure. An improved understanding of the deformation mechanisms as a function of temperature will permit the development of structure-property relationships, which are critical for continued improvement of Cr-Mn-N austenitic stainless steel alloys [4].

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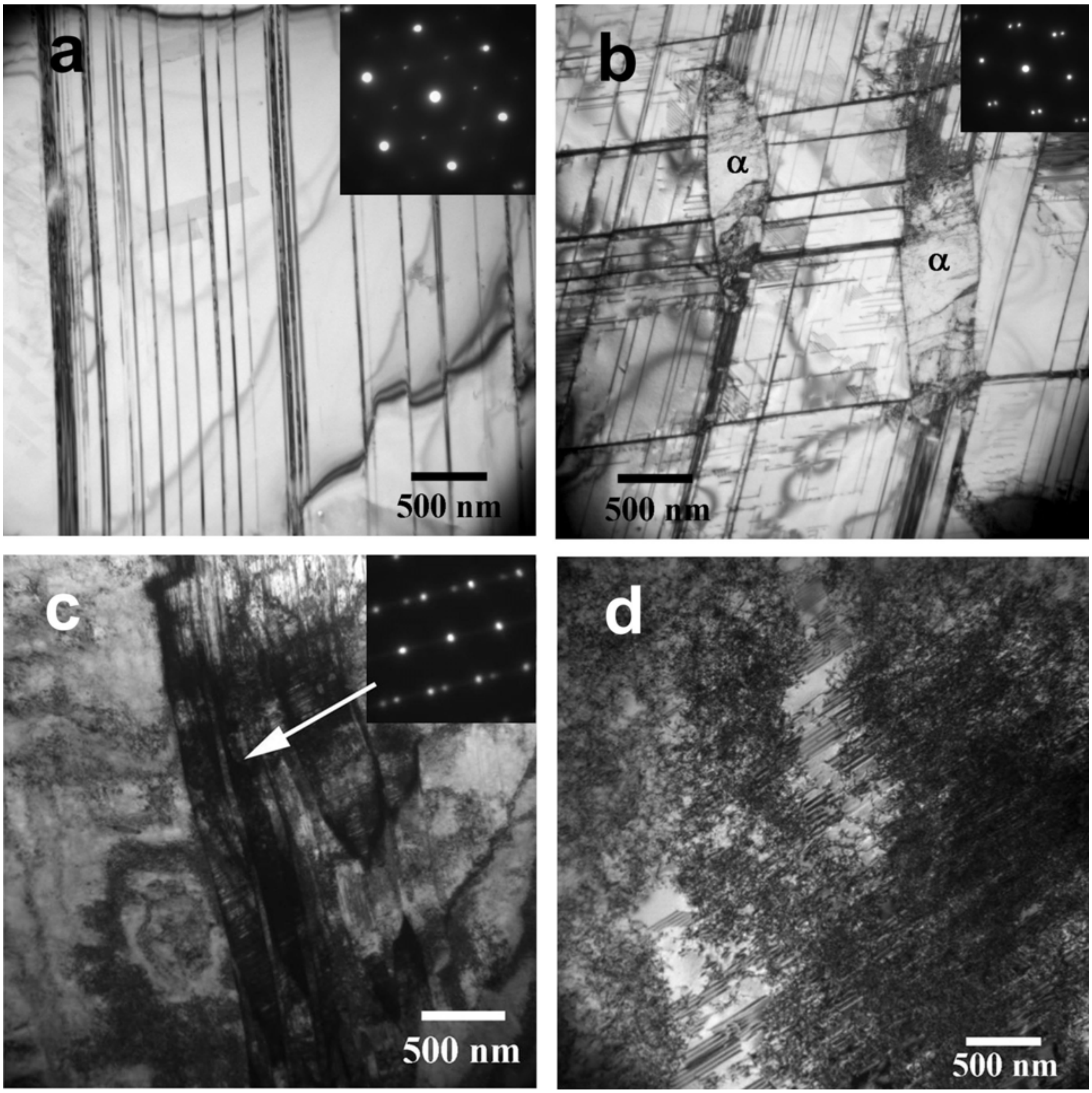

Fig. 1 - After deformation of 5% at -75°C, (a) the ε martensite forms with $(111)\gamma//(0001)\varepsilon$ and $[\bar{1}01]\gamma//[1\bar{2}10]\varepsilon$ while (b) the α′ martensite nucleates at the intersections of ε platelets with the Kurdjumow-Sachs relationship $(111)\gamma//(110)\alpha$ and $[\bar{1}01]\gamma//[1\bar{1}1]\alpha$. (c) Deformation at intermediate temperatures (20-50°C) exhibited martensite, slip, and mechanical twinning. (d) Deformation from tensile testing at 200°C occurred by slip with a high-dislocation density austenitic microstructure.

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