1888
doi:10.1017/S1431927611010312
Microsc. Microanal. 17 (Suppl 2), 2011

Stacking-Fault Energy Measurements in Fe-Mn-Al-Si Austenitic TWIP Steels

D. T. Pierce*, J. Bentley**, J.A. Jimenez***, J.E. Wittig*
* Vanderbilt University, Interdisciplinary Materials Science, Nashville, TN 37232
** Formerly at Oak Ridge National Laboratory, Oak Ridge, TN 37831
*** Centro Nacional de Investigaciones Metalurgicas, Madrid, Spain

The stacking-fault energy (SFE) is a composition- and temperature-dependent materials property that can greatly influence the deformation mechanisms of austenitic steels. A low SFE increases partial dislocation spacing and leads to reduced dislocation mobility via an impedance to cross slip. This reduction in dislocation mobility will induce the formation of twins during deformation. These substructures will create further barriers to dislocation glide causing high strain-hardening rates that inhibit local necking and result in total elongation-to-failure of up to 80% [1]. The goal of this research is to determine the SFE experimentally for new Fe-Mn-Al-Si twinning-induced plasticity (TWIP) steels in order to gain a better understanding of the influence of this parameter on the relationship between structure and mechanical properties.

Three Fe–XMn-3Al-3Si (X = 22, 25 and 28 wt%) alloys were induction melted, thermo-mechanically processed by hot and cold rolling, and recrystallized at 900^{o}C for 30 min. After 1.5% tensile strain, electro-discharge machined 3-mm diameter disks were further annealed at 400°C, 650°C, and 700°C to induce equilibrium defect configurations. TEM samples, prepared by grinding the disks to 100 µm thickness and twin-jet electro-polishing in 30% HNO_3 and 70% methanol at -30^{o}C and 13.5 V, were analyzed using a Philips CM20T operating at 200 keV. Figure 1 shows the as-deformed microstructure for the 25% Mn alloy with wide non-uniform stacking faults and high-energy dislocation configurations. One method for measuring SFE is the analysis of extended dislocation nodes [2]. Node formation typically requires an annealing treatment to allow the partial dislocations to rearrange into equilibrium configurations determined by the SFE. Annealing at 400^{o}C had essentially no effect on the microstructure, and even after 70 h extended node formation was not observed, as shown in Fig. 2. Although annealing at temperatures of 650 or 700^{o}C for up to 70 h provided sufficient thermal activation energy to initiate dislocation movement and interaction, nodes were still rare, non-isolated and all displayed a certain degree of asymmetry, as shown in Fig. 3.

An alternative method for SFE measurements uses weak-beam dark-field (WBDF) imaging of extended dislocations to determine the separation of the individual partial dislocations [3]. Figure 4 provides an example of a WBDF image, with corresponding bright-field (BF) image, of a dissociated dislocation in the 22% Mn alloy after annealing for 70 h at 700^{o}C. An average separation distance of 6.6 nm +/- 0.9 nm was measured from this image. The sample was oriented with a beam direction **B** near [111] to simplify the partial separation measurements and Burgers vector analysis. With **B** near [111], a geometrical conversion of the observed separation to the actual separation due to inclination is unnecessary for dislocations that lie on the (111) glide plane. For a shear modulus and Poisson's ratio of 69.77 GPa and 0.3, respectively, a SFE of ~19 mJ/m^2 was determined, which is comparable to calculated values for a similar Fe-25Mn-1.6Al-0.24Si-0.08C alloy [4]. These first experimental results of SFE for Fe-Mn-Al-Si alloys provide some confidence in the assumed interfacial energy used for the theoretical calculations. However, the influence of pinning effects from interstitial solute atmospheres needs to be considered when observing partial dislocation separation post-annealing at room temperature or at elevated temperatures. In addition, the SFEs of these alloys are currently being measured as a function of temperature [5].

References:

[1] O. Grassel et al., *Int J Plasticity,* 16 (2000) 1391.
[2] A. W. Ruff, *Metall. Trans*. 1 (1970) 2391.
[3] D. J. H Cockayne, *J Phys-Paris*, 35 (1974) 141.
[4] S. Curtze, V.-T. Kuokkala, *Acta Mater*, 58 (2010) 5129.
[5] This work is sponsored by a grant from the National Science Foundation Division of Materials Research DMR0805295. The support of Prof. Dierk Raabe and the Max-Planck-Institut für Eisenforschung is also gratefully acknowledged.

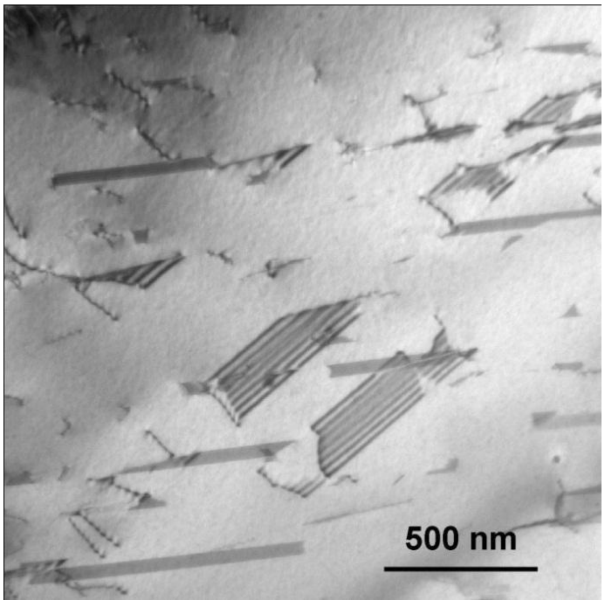

Fig. 1. BF image of Fe-25Mn-3Al-3Si after 1.5% strain.

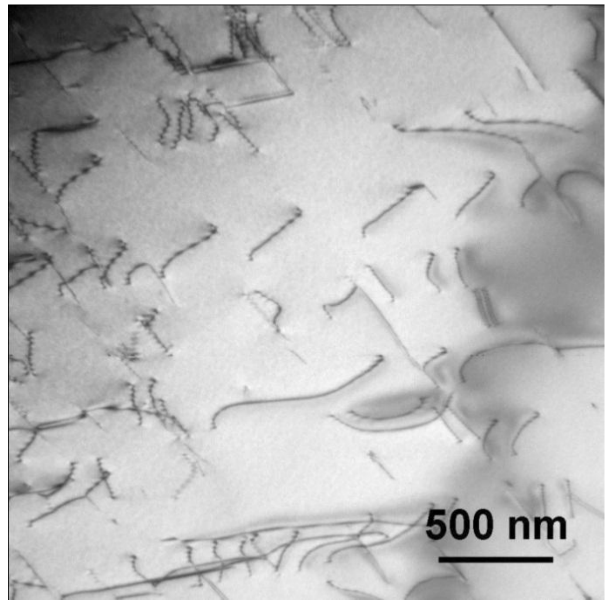

Fig. 2. BF image of Fe-25Mn-3Al-3Si after 1.5% strain and 70 h at 400^{o}C.

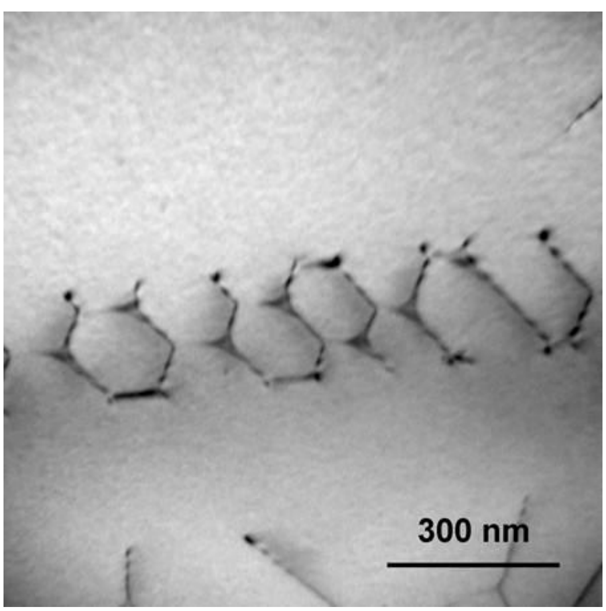

Fig. 3. BF image of Fe-25Mn-3Al-3Si after 1.5% strain and 70 h at 650^{o}C.

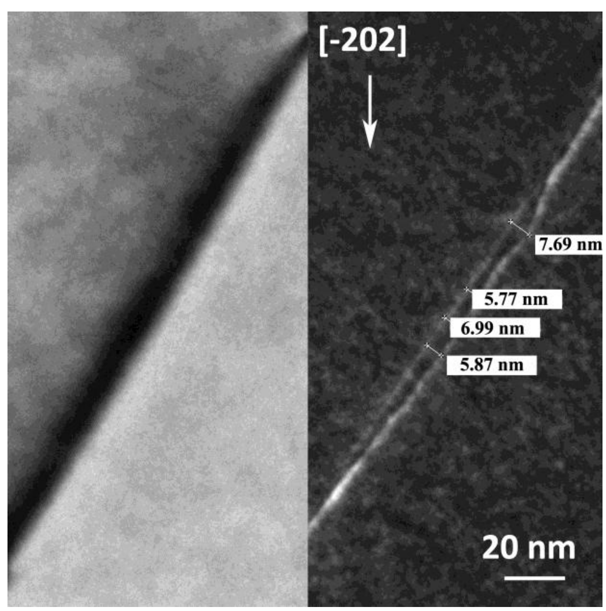

Fig. 4. BF (left) and WBDF (right) images of partial dislocation separation in Fe-22Mn-3Al-3Si.

https://doi.org/10.1017/S1431927611010312 Published online by Cambridge University Press