2228
doi:10.1017/S1431927618011625

Microsc. Microanal. 24 (Suppl 1), 2018

Reversion to Ultrafine-Grained Austenite in a Medium-Mn AHSS

J T Benzing[1], J Bentley[2], A Kwiatkowski da Silva[3], L Morsdorf[3], J R McBride[4], D Ponge[3], B Gault[3], J Han[5], D Raabe[3], J E Wittig[1]

[1.] Interdisciplinary Materials Science, Vanderbilt University, Nashville TN, USA
[2.] Microscopy and Microanalytical Sciences, PO Box 7103, Oak Ridge, TN, USA
[3.] Max-Planck-Institut für Eisenforschung, Düsseldorf, Germany
[4.] Vanderbilt Institute of Nanoscale Science and Engineering, Vanderbilt University, Nashville, TN, USA
[5.] Materials Science and Engineering, Chungnam National University, Daejeon, Republic of Korea

Third generation advanced high-strength steels (AHSS) consist of alloying contents below 17 wt% and multi-phase microstructures of austenite, ferrite and martensite to respectively balance cost and tensile properties [1]. The types of third generation steels capable of achieving these desired properties are medium-Mn steels, lightweight steels and quenched-and-partitioned TRIP steels [2]. Medium-Mn steels generally exhibit a fully deformed martensitic (α') microstructure after hot and cold rolling. Intercritical annealing between Ac_1 and Ac_3 temperatures (the $\alpha+\gamma$ phase field) and above the α' recrystallization temperature produces austenite (γ) and ferrite (α), which are typically ultrafine-grained (UFG) in size. The intercritical annealing temperature determines composition and thus the austenite stacking fault energy (SFE). The SFE is important for controlling transformation- and twinning-induced plasticity (TRIP/TWIP) effects that further enhance the mechanical properties of steels by increasing the strain-hardening rate, even in ultrafine-grained austenite [3]. Recent work on a Fe-7Mn-0.1C-0.5Si (wt%) steel by Kwiatkowski da Silva *et al.* showed that austenite reversion sequentially depends on the co-segregation of C and Mn to dislocations and grain boundaries, the formation of face-centered-cubic (FCC) $M_{23}C_6$ transition carbides, and growth of the carbides controlled by C diffusion and local equilibrium at the interface, culminating in the nucleation of UFG FCC austenite [4]. The present study uses scanning transmission electron microscopy energy-dispersive X-ray spectroscopy (STEM-EDS) performed using a 200 kV FEI Tecnai Osiris equipped with a quad Super-X detector and atom probe tomography (APT) using a CAMECA LEAP 5000 XS in laser-pulse mode (70 K and 15% evaporation rate) to measure UFG phase compositions in a medium-Mn steel.

Intercritical annealing of a cold-rolled Fe-12Mn-3Al-0.05C (wt%) steel was performed at 585 °C. For this temperature, Thermo-Calc® simulations predict a RT austenite volume fraction of 44%, a RT austenitic SFE of 21 mJ/m^2, a RT austenite composition of Fe-20.8Mn-2.1Al-0.11C (wt%) and a RT ferrite composition of Fe-4.9Mn-3.7Al-0.001C (wt%). Samples were annealed for 0.5, 8 and 48 h at 585°C. Electron backscatter diffraction (EBSD) measurements (viewed in the normal direction) respectively yielded an austenite volume fraction of 35% after 8 h at 585°C. Samples annealed for 8 h (see Figure 1) revealed UFG austenite with compositions of ~21 wt% Mn, (thus matching equilibrium Thermo-Calc predictions). 3D APT offers improved spatial resolution for measurements of composition profiles across UFG austenite-ferrite boundaries (see Figure 2). APT results are consistent with STEM-EDS, but also reveal C-rich and C-poor boundaries. 3D FIB-EBSD measurements are underway and will be coupled with crystal plasticity finite-element modeling to investigate the effects of microstructure morphology on strain partitioning in this multi-phase medium-Mn TWIP-TRIP steel [5].

References:

[1] D K Matlock and J G Speer, pp. 185-205 in *Microstruct. Texture Steels*, ed A Halder, S Suwas and D Bhattacharjee (Springer, London), 2009.

[2] Y-K Lee and J Han, Mater. Sci. Technol. **31** (2015), p. 843.

[3] S Lee and B C De Cooman, Metall. Mater. Trans. *A* **44** (2013), p. 5018.

[4] A Kwiatkowski da Silva *et al*, Acta Mater. **147** (2018), p. 165.

[5] This work was funded by the US National Science Foundation, Division of Materials Research under grant DMR1309258, NSF EPS 1004083 and the Max-Planck-Institut für Eisenforschung in Düsseldorf, Germany.

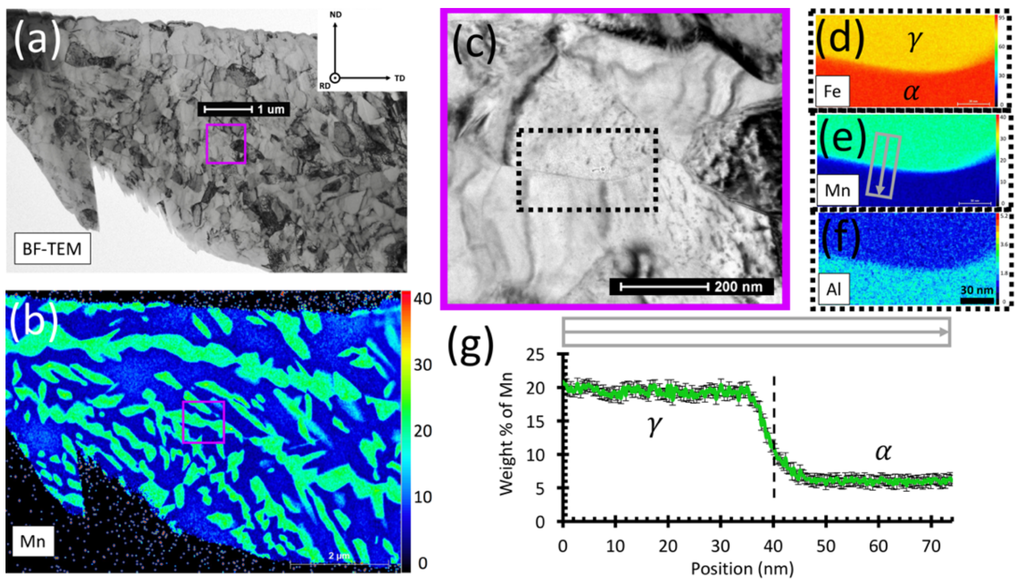

Figure 1. (a) BF-TEM image of a FIB lift-out from Fe-12Mn-3Al-0.05C (wt%) steel (cold-rolled and annealed 8 h at 585°C), viewed in the rolling direction (RD). (b) STEM-EDS hypermap of Mn content in wt%. (c) BF-TEM image shows a near edge-on boundary between UFG austenite (γ) and UFG ferrite (α). Hypermaps of the marked area are provided: (d) 0-95 wt% Fe, (e) 0-40 wt% Mn and (f) 0-5.2 wt% Al, as well as (g) a linescan across the γ-α boundary.

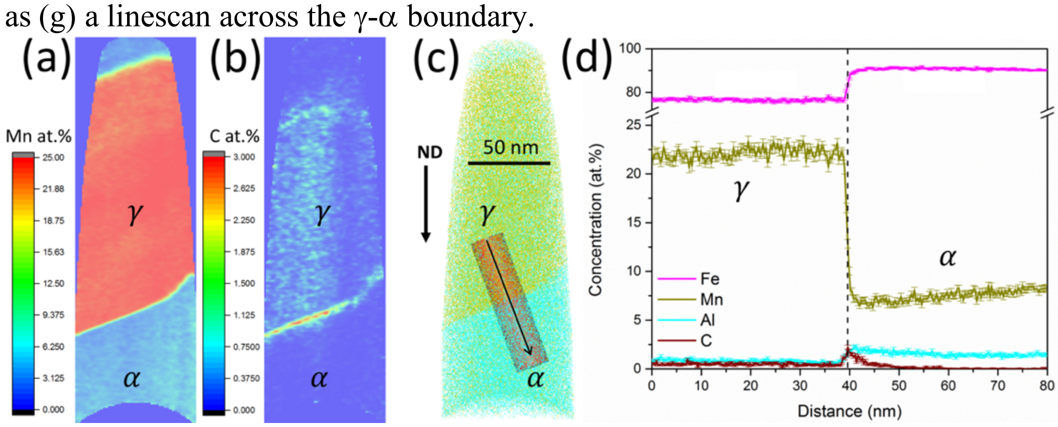

Figure 2. APT reconstruction of 150,000,000 ions measured from a FIB-prepared needle of Fe-12Mn-3Al-0.05C (wt%) steel (cold-rolled and annealed for 8 h at 585°C). The quantitative maps of (a) Mn and (b) C in at.% measure the composition across the entire width of UFG austenite (γ). (c) Image showing Mn and Al ions and position of the cylinder used to measure (d) a profile across the γ-α boundary.

https://doi.org/10.1017/S1431927618011625 Published online by Cambridge University Press