TEM study of twinning mechanism in Fe-Mn-C TWIP steels

H. Idrissi[1], L. Ryelandt[2], D. Schryvers[1], P.J. Jacques[2]

1 University of Antwerp, Department of Physics, EMAT, Groenenborgerlaan 171, 2020 Antwerp, Belgium.
2 Université catholique de Louvain, Département des Sciences des Matériaux et des Procédés, IMAP, Place Sainte Barbe 2, B-1348 Louvain-la-Neuve, Belgium.

nick.schryvers@ua.ac.be

Keywords: TWIP steels, twinning mechanism, EBSD, TEM, dislocations

Recently it was observed that twin boundaries have a higher efficiency than grain boundaries to achieve very high flow stresses sustaining good work-hardening in Fe-Mn-C TWIP steels [1]. In addition, many recent work on *fcc* metals indicate that the stress level is controlled by the twin spacing [2] and the work hardening is probably controlled by the twin thickness [3,4]. In the latter case, the authors expect an important contribution of the strength of twins of nanometric thickness (called “microtwins”) to the macroscopic strength of the twinned aggregate. However, no experimental evidences of the fundamental mechanism responsible of the small thickness and the high strength of microtwins were clearly studied in Fe-Mn-C steels. Several models for mechanical twinning in *fcc* materials were proposed in the literature [5-8] without obtaining the unanimity due to different kinds of observations resulting from different materials and different deformation conditions. However, although the twinning partials of all the models correspond to Shockley partial dislocations, the dissociation reactions controlling the twinning formation are composed of different components, i.e., Frank, another Shockley and stair-rod dislocations. The determination of the nature of the dislocations associated to the twins at the early stage of the deformation is the most important step to analyse the fundamental mechanism of twinning in Fe-Mn-C TWIP steels.

In the present study, mesoscopic behavior of mechanically deformed Fe-20Mn-1.2C TWIP steel is investigated at different deformation levels by Electron back scattered diffraction technique (EBSD), while transmission electron microscopy (TEM) was used to study the fundamental mechanism of twinning. Very thin microtwins were observed to develop at the early stage of the plastic deformation (2%). The twinning dislocations were identified to be $b = \frac{a}{6}[12\bar{1}]$ Shockley partial dislocations in the $(\bar{1}\bar{1}1)$ twinning plane, while high density of sessile Frank dislocations lying in the interface plane were observed (see figure 1). The origin of the Frank dislocations is discussed and compared to the models proposed in the literature.

In-situ TEM straining experiments were carried out in order to study the dynamics of the Shockley twinning dislocations. Figure 2 shows a dynamical sequence obtained during an in-situ TEM straining experiment. In figure 2a, a microtwin formed by the glide of a few Shockley partial dislocations can be observed. Three Shockley partial dislocations in the twinning plane are visible (G1, G2 and G3), while the SFs are out of contrast. Taken into account the curvature of the Shockley partial dislocation, we can deduce that the microtwin propagates from the lower left to the upper right part of figure 2a. The slip traces which correspond to the intersection of the twinning plane with the foil surfaces can be observed as two lines limiting the Shockley partial dislocations in figure 2a. Frank sessile dislocations

W. Grogger, F. Hofer, P. Pölt (Eds.): MC2009, Vol. 3: Materials Science,
DOI: 10.3217/978-3-85125-062-6-504 , © Verlag der TU Graz 2009

lying in the interface plane can also be observed in the same figure. In figure 2b, the Shockley twinning dislocation “G0” has glided very rapidly and interacted with the Frank sessile dislocation “S”. It is shown that the glide of Shockley dislocations in the twinning plane is highly affected by overcoming the sessile Frank dislocations. This mechanism certainly controls the growth of the twins and could explain the observed small thickness of these defects in the present work.

1. O. Bouaziz et al., Scripta mater. **60** (2009) 714.
2. O. Bouaziz et al., Scripta mater. **58** (2008) 484.
3. R.J. Asaro et al., Scripta mater. **58** (2008) 389.
4. J.G. Sevillano., Scripta mater. **60** (2009) 336.
5. J.A. Venables., Phil. Mag A. **30** (1974) 1165.
6. J.B. Cohen at al., Acta Metall. **11** (1963) 996 & 1368
7. T. Mori et al., Acta Metall. **28** (1980) 771.
8. S. Mahajan et al., Acta Metall. **21** (1973) 1353.
9. This work is supported by the Belgian IUAP P6/24 program.

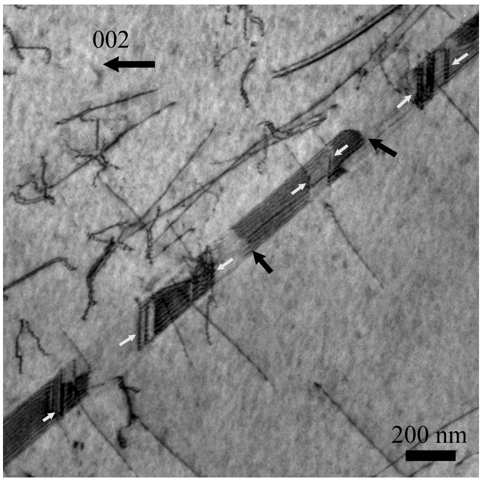

Figure 1. Micrograph obtained with $g = 002$. White arrows indicate Frank sessile dislocations. Two Shockley twinning dislocations are indicated by black arrows.

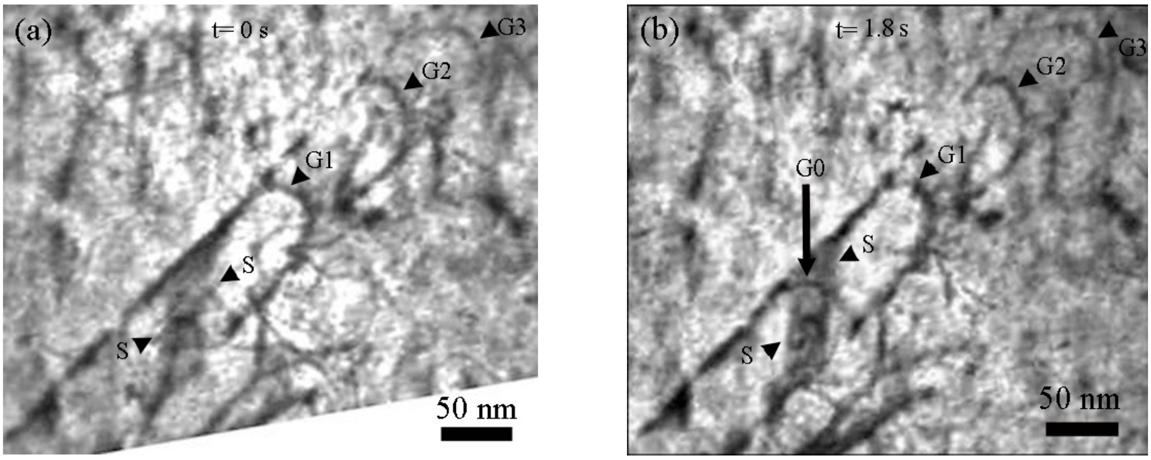

Figure 2. Dynamical sequence of the interaction between Shockley twinning partial dislocations “G0” and Frank sessile dislocations “S”.