Technical University of Denmark

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Alimadadi, Hossein; Villa, Matteo; Somers, Marcel A. J.

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An electron microscopy study of spontaneous and FIB-induced martensite formation in metastable stainless steel

HOSSEIN ALIMADADI[1], MATTEO VILLA[2], MARCEL A.J. SOMERS[2].

[1]Technical University of Denmark, Center for Electron Nanoscopy, Fysikvej b. 307, DK – 2800 Kgs. Lyngby, Denmark.

[2]Technical University of Denmark, Department of Mechanical Engineering, Produktionstorvet b. 425, DK – 2800 Kgs. Lyngby, Denmark.

The transformation of f.c.c. austenite into b.c.c. martensite is of high importance for metastable stainless steels. Lath martensite is of large technological interest, especially for structural applications where a combination of high strength and reliable toughness is required. Thus, understanding various kinetic aspects of martensite formation, i.e. nucleation and growth, is key to successful tailoring of the austenite microstructure and obtain the desired martensite microstructure after transformation. To this end, two approaches were applied on a steel containing 17wt%Cr-7wt%Ni-1wt%Al. In both approaches electron backscatter diffraction (EBSD) at room temperature was used to characterize the same location before and after transformation. In the first approach the evolution of the microstructure was monitored in-situ using secondary electrons in an SEM operated at 255 K. In the second approach, room temperature focused-ion beam (FIB) was applied to locally induce the nucleation of martensite at preselected locations.

Monitoring microstructure evolution at 255 K, it was observed that martensite formation in an austenite grain induces transformation in neighboring grains and transformation is rate determined by autocatalytic nucleation. Furthermore, austenite twin boundaries appear as preferential sites for the nucleation of martensite. The orientation relation (OR) between the austenite (γ) and lath martensite (α′) is generally approximated as $\{111\}_\gamma \parallel \{011\}_{\alpha'}$ $\langle 01\bar{1}\rangle_\gamma \parallel \langle \bar{1}1\bar{1}\rangle_{\alpha'}$, the Kurdjumov-Sachs (K−S) OR. This OR covers 24 possible variants for a certain austenite grain. EBSD results show that twin boundaries promote the formation of variant(s) that are common for the twinned parts of an austenite grain.

FIB-induced nucleation is an interesting technique to study nucleation of martensite at the neighboring grains. The results obtained in this study, show that neighboring grains may influence variant selection and that twin boundaries in austenite play a role as an easy nucleation site for martensite. It was found out that there are at least two different morphologies of martenite in relation with twin boundary plane (TBP) (i) elongated crystal(s) parallel to the TBP (ii) equi-axed crystal growing also perpendicular to the TBP. This hints potentially two different mechanisms of formation.