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EBSP Analysis for Tensile Deformation Behavior of Martensitic Steel

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Abstract – The local deformation behavior of as-quenched low-carbon martensitic steel was characterized by electron backscattering diffraction pattern analysis. The crystal rotation behavior of each martensite block were traced up to 22% tensile strain, and compared to the predicted behavior, based on Sachs and Taylor models, in order to clarify actually operated slip systems. The result revealed that the slip systems with Burger's vectors lying on the invariant plane of martensite were preferentially activated than those with Burger's vectors pointing to out of the invariant plane. The evolution of operative slip systems during tensile loading was also discussed.

The martensite of ferrous material is well known as a metastable phase with supersaturating carbon. Since the phase generally exhibits high strength and hardness, it is widely utilized as a matrix of high-strength steels. For better application of the phase, many researchers has been investigated the deformation behavior of high-strength martensitic steels [1,2]. The present study intends to clarify the crystallographic features of martensite under tensile loading by EBSP analysis.

In this study, multi-layered composite consisting of high-strength and 304 austenitic stainless steels was used for achieving large uniform elongation of martensite phase under tensile loading. The composite was water-quenched after annealing at 1473 K for 120 s, and full martensitic structure was obtained in high-strength steel layer. The local deformation behavior of as-quenched martensite during tensile test was investigated using in situ SEM and EBSP analysis. In the evaluation of Schmid factor, (110)<111> and (112)<111> were employed as operable slip system of martensite [2].

The SEM images of martensite before and after 20% elongation were indicated in Fig. 1. The localized formation of slip bands on the surface was confirmed. The detailed EBSP analysis indicated that most of the slip bands were developed on martensite blocks having higher Schmid factor, in the slip system with Burger's vectors lying on the invariant plane. This suggests that the deformation behavior is strongly affected by geometrical anisotropy of martensitic microstructure. The actually operated slip systems during 22% elongation were evaluated from comparison between the crystal rotation captured by EBSP and that predicted by Sachs and Taylor models, and summarized in Fig. 2. In the models, two combination of operable slip system were considered, one has the Burger's vectors lying on the invariant plane of martensite lath (lath constraint), the other operates all four Burger's vectors. From 0% to 8% tensile strain, excluding the blocks with rotation behavior different from the prediction (blue), lath-constrained crystal rotation behavior (red) is confirmed in about three-quarters of all martensite blocks. This indicates that the slip systems with the Burger's vectors lying on the invariant plane are preferentially activated in the early stage of deformation. The gradual increment of the blocks deviating from the prediction with increase in tensile strain was regarded as the work-hardening of primal slip system and the transition to second one.

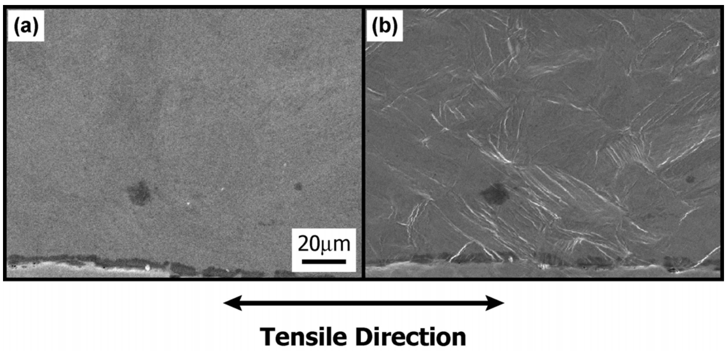

Figure 1: SEM images showing the surface morphology of as-quenched martensite (a) before and (b) after 20% elongation.

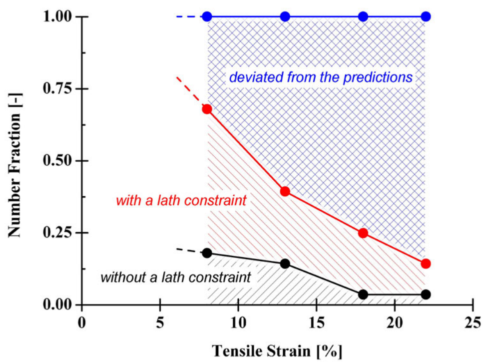

Figure 2: Evolution of operative slip systems during tensile test estimated from the prediction models.

References

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