Investigating the plastic deformation mechanisms of a twinning-induced plasticity steel using advanced transmission electron microscopy

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論 文 名　：Investigating the plastic deformation mechanisms of a twinning-induced plasticity steel using advanced transmission electron microscopy（先端透過電子顕微鏡法を用いた双晶誘起塑性鋼の塑性変形機構の解明）

Title

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Category

論 文 内 容 の 要 旨

Thesis Summary

The dissertation aims to enhance the current knowledge of plastic deformation mechanisms in an Fe-22Mn-0.6C (wt.%) twinning-induced plasticity (TWIP) steel using advanced transmission electron microscopy (TEM). The three main topics treated are 1) the microstructural factors dictating deformation mechanisms in this TWIP steel with ultrafine-grained (UFG) structures, 2) the effect of grain size on the dissociation behavior of dislocations, and 3) the seeking for a proof of dislocation pinning. A combination of ex-situ and in-situ TEM deformation techniques, along with post-mortem dislocation analysis was employed throughout the dissertation.

Structural defects in this TWIP steel with different average grain sizes are investigated using an ex-situ deformation approach (post-mortem) utilizing scanning-TEM (STEM) and TEM techniques to elucidate the microstructural factors influencing deformation mechanisms. The alternation of deformation mechanisms from dislocation gliding to deformation twinning when the grain size is smaller than 1 μm was observed. The nucleation of stacking faults and deformation twins in under 1 μm sized grains exhibited grain orientation (Schmid factor) dependence.

The effect of grain size on deformation twinning was further elucidated by looking into the dissociation behavior of dislocations using an in-situ TEM deformation technique. Wide stacking faults emitted from grain boundaries were observed in grains smaller than 1 μm. The influence of grain size on dislocation dissociation was quantitatively discussed based on the forces acting on Shockley partial dislocations, leading to a novel formula estimating the emission stress of a partial from a grain boundary. The emission stress exhibits Schmid factor dependence. The twin initiation stresses estimated from the Hall-Petch relationship and the emission stress are compared to explain twinning behavior in TWIP steels across all grain sizes.

To obtain a proof of dislocation pinning in the current TWIP steel, the kinetic behavior of dislocations under external tensile stress was investigated using the in-situ TEM deformation technique. A unique dislocation glide observed in the present alloy differs from the dislocation glide observed in other alloys, indicating the presence of dislocation pinning. The majority of pinned segments have a large edge character and are located near the specimen's foil surface, suggesting that the pinning is caused by a Cottrell atmosphere through dislocation pipe diffusion of interstitial C atoms. The potential mechanisms for plastic instabilities resulting from dislocation pinning are discussed.

The novelty of this work is the comprehensive demonstration of deformation mechanisms in UFG TWIP

steel using advanced TEM. The findings deepen the current knowledge of plastic deformation mechanisms in TWIP steel and have substantial implications for the development of high-strength materials with exceptional ductility.