Fundamental research on structural materials based on the elementary processes of deformation and fracture

Research Project Outline for 2nd Phase（FY2016–2018）

Improvement of ductility of metallic structural materials by bulk nanostructuring and elucidation of its mechanisms

◎Elucidation of deformation mechanisms in steel, titanium and magnesium materials and acquisition of control guidelines.

⟶ Derivation of common principles and design guidelines, and establishment of common guiding principles.

Research Results (FY2015–2017)

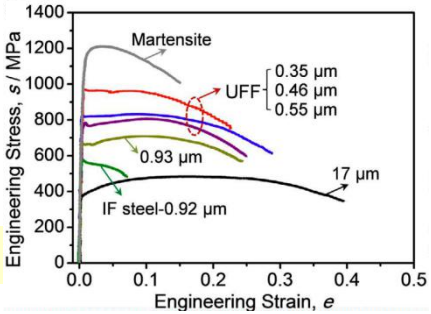
◆ New metallurgical technologies that may enable production of UFG steels

✓New strategies for ultra grain refinement can be developed by combining DT and DRX mechanisms, based on which fully ultrafine microstructures having a mean grain size as low as 0.35 microns and exhibiting superior mechanical properties can be obtained without high-strain deformation.

✓Obtained a significantly higher yield strength of 770–953 Mpa, a tensile strength of 810–973 MPa, and total elongation of 23–29%.

UFG steels by DT and DRX

L. Zhao, N. Park, Y. Tian, A. Shibata, N. Tsuji, Scientific Reports 6, Article number: 39127 (2016)



Stress-strain curve

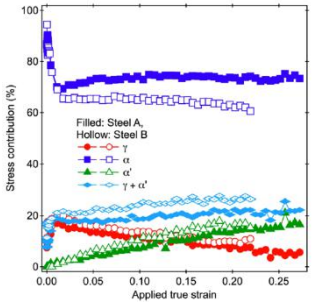
◆Martensite phase stress and the strengthening mechanism in TRIP steel by neutron diffraction

✓Stress contributions to the flow stress were evaluated by multiplying the phase stresses by their phase fractions.

✓The stress contribution from martensite was observed to increase during plastic deformation.

In-situ neutron diffraction study during tensile deformation in TRIP steel

S. Harjo, N. Tsuchida, J. Abe, W. Gong, Scientific Reports 7, Article number: 15149 (2017)



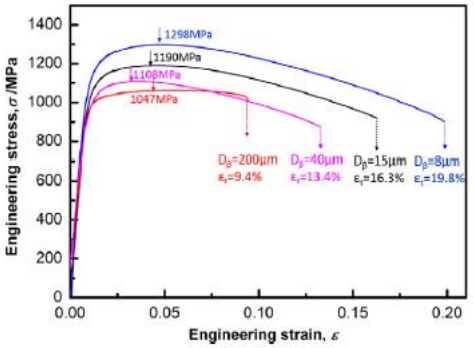
Stress contributions to the flow stress from three phases

◆Refined β grains and both strength and ductility improved in Ti-6Al-4V alloy

- ✓Fully martensite microstructures transformed from refined β grains were obtained in a Ti-6Al-4V alloy by rapid heat treatment (RHT)
- ✓By increasing the heating rate, the resulting β grain size was refined.
- ✓Both strength and ductility improved with the decrease in β grain size.

Both strength and ductility increased in Ti-6Al-4V alloy

Y. Chong, T. Bhattacharjee, J. Yi, A. Shibata, N. Tsuji, Scripta Mater. 138, 66-70 (2017)



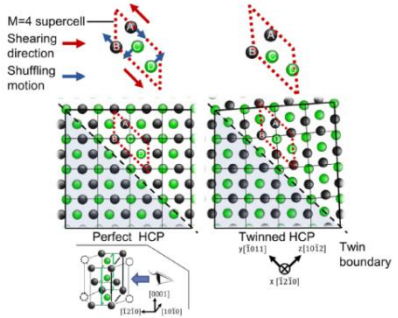
Engineering stress-strain curves of fully martensite microstructures with different β grain sizes

◆Shuffling-controlled versus strain-controlled deformation twinning: The case for HCP Mg twin nucleation

- ✓Shuffling-controlled deformation twinning is expected to have different temperature and strain-rate sensitivities from strain-controlled deformation twinning due to its relatively weaker strength of long-range elastic interactions, particularly at the twin nucleation stage.
- ✓By increasing the heating rate, the resulting β grain size was refined.

Shuffling of atoms in Mg twin nucleation

A. Ishii, J. Li, S. Ogata, Int. J. Plasticity 82, 32-43 (2016)



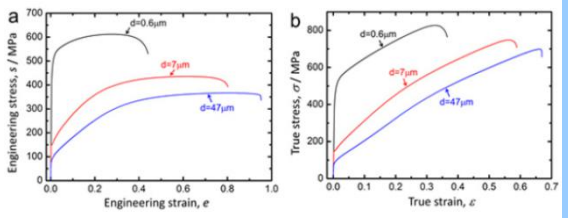
Atomic arrangements and four-atom supercell shape of perfect HCP and twinned HCP configurations

◆Significant contribution of stacking faults to strain hardening behavior

- ✓By decreasing the grain size from 47 μ m to 0.6 μ m, the yield strength greatly increases from 80 MPa to 450 MPa.
- ✓Instead of twinning, we detected a significant contribution from stacking faults (SFs) irrespective of the grain size, even in the initial stage of the tensile process.
- ✓Deformation twinning was sensitive to grain size, and the onset of twinning was postponed to a higher strain with an increase in the grain size.

Elucidation of plastic deformation process in ultrafine-grained Cu-15%Al alloy

Y. Z. Tian, L. J. Zhao, S. Chen, A. Shibata, Z. F. Zhang, N. Tsuji, Scientific Reports 5, Article number: 16707 (2015)



Mechanical properties of Cu-15Al specimens with different grain sizes