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種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	機械 系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （ph. D ）
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要旨（英文 800 語程度）
Thesis Summary（approx.800 English Words ）

Thermomechanical control process is a key process applied to control the microstructure of metallic materials and thus modify the physical property. However, the mechanisms of microstructure evolution during plastic deforming and heat treatment are still largely unknown. The current research attempts to deliver a more comprehensive understanding about microstructure evolution in plastic deformation and heat treatment. Research objectives of current research are threefold: Predict texture evolution during plastic deforming with crystal plasticity finite element method (CP-FEM) and make detailed comparison with experimentally measured deformation characteristics; Based on measured nucleation sites, decide the most effective quantity and criterion for predictions of locations of newly formed grains in nucleation; Characterize boundary migration which realizes grain growth in different aspects, including overall growth kinetics, boundary migration velocity as well as grain boundary morphology change during heat treatment.

Single crystal pure iron specimens were fabricated for tensile tests and crystal plasticity finite element models were used to characterize the heterogeneity in deformation of single crystal pure iron specimens. The widely adopted phenomenological model was applied as user subroutine UMAT in the commercial finite element software package ABAQUS. The calculation results were compared with specimen deformation measured with SEM and EBSD in three aspects: macroscopic deformation, load-stroke relationship as well as collective deformed microstructure represented by inverse pole figures. The CP-FEM model used in this study was confirmed to be able to replicate deformation characteristics with a satisfying precision.

In-situ EBSD observation method was used to characterize the microstructure evolution of the specimens in static recrystallization. This method was compared with ex-situ EBSD and in-situ method outperformed ex-situ method in many prospects: precise temperature control on the specimen; Short observation interval; More consistent measurement on crystal orientation and grain growth kinetics. Based on the recorded microstructure changes, nucleation sites were approximated by the position where the grain first emerges to the observed surface under the assumption that grain growth is much faster along thickness direction. Two different quantities were used for the prediction of nucleation sites: energy input into the specimen and kernel average misorientation value. The former is shown to be largely dependent on geometrical constrains and cannot be used for the prediction of nucleation sites. KAM value calculated from CP-FEM delivers an effective mesoscale representation of local deformation and can qualitatively predict nucleation positions.

Grain growth kinetics were studied from different angles: recrystallization fraction, single grain kinetics and grain boundary migration velocity. Overall recrystallization kinetics represented by recrystallized fraction over annealing time differ from specimen to specimen, even for specimens which have the same initial crystal orientation and comparable deformation levels. For modelling the recrystallization kinetics, JMAK model was tested and surprisingly JMAK equation which is based on very simple isotropic nucleation and isotropic grain growth agrees well with the observed grain area expansion in single crystal pure iron specimens. Grain boundary migration velocity was modeled on derived datasets with in-situ EBSD observation. Based on this migration velocity model, a cellular automata algorithm was built and simulations of texture evolution were performed on experimentally derived data. It is confirmed that the CA model can reproduce both grain morphology and grain growth kinetics to a satisfying precision. The relative roles of curvature related energy and stored deformation energy were studied: curvature related energy takes effect in regularizing grain boundary shape to reduce boundary energy; stored deformation energy would generate protrusions toward highly deformed matrix and is the main driving force of boundary migration.