論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Cyclic deformation behavior and dislocation structures of multiple-slip-oriented copper single crystals
著者(和文)	MA Tianchang
Author(English)	Tianchang Ma
出典(和文)	学位:博士(工学), 学位授与機関:東京工業大学, 報告番号:甲第12197号, 授与年月日:2022年9月22日, 学位の種別:課程博士, 審査員:藤居 俊之,竹山 雅夫,小林 郁夫,村石 信二,小林 覚
Citation(English)	Degree:Doctor (Engineering), Conferring organization: Tokyo Institute of Technology, Report number:甲第12197号, Conferred date:2022/9/22, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
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	材料 系 材料 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of （ 工学 ）
学生氏名： Student's Name	MA Tianchang	指導教員（主）： Academic Supervisor(main)	藤居 俊之
		指導教員（副）： Academic Supervisor(sub)	村石 信二

要旨（英文800語程度）
Thesis Summary（approx.800 English Words ）

Metal fatigue occurs in various key engineering components and is known to be regarded as the main factors responsible for the fracture in engineering structures during the cyclic deformation. Therefore, the basic understanding of fatigue behavior of metals is the most important aspect to study the fatigue of metals. This work was dedicated to investigating the cyclic deformation behavior and dislocation structures of multiple-slip-oriented copper single crystals. Especially, the relationship between the combination of activated slip systems and the corresponding dislocation structures is systematically studied, in order to prevent occurrence of the fatigue cracks and improve the fatigue performance of metals.

The content of this thesis consists of five parts: Chapter 1: General introduction. Chapter 2: Crystallographic features of deformation-kink bands in coplanar double-slip-oriented copper single crystals. Chapter 3: Analysis of deformation bands and cell structure in cyclically deformed near-$[\bar{1}11]$ multiple-slip-oriented copper single crystals. Chapter 4: Formation of dislocation structures during cyclic deformation in near-[001] multiple-slip-oriented copper single crystals. Chapter 5: General conclusions.

First of all, in Chapter 1, the basic knowledge of the fatigue behavior of fcc single crystals was introduced, including the cyclic stress-strain (CSS) curve, surface slip morphologies and microscopic dislocation structures. The intrinsic relationship between dislocation structures and crystal orientations in a cyclically deformed fcc single crystal was also introduced in this chapter.

In Chapter 2, deformation bands (DBs) formed in a coplanar-double-slip oriented copper single crystals during the monotonic deformation was investigated as a preliminary study for the following study on the cyclic deformation behavior. The characteristics of DBs with kink bands features are studied via multiple-plane observation by scanning electron microscopy (SEM), and electron back-scattered diffraction (EBSD). The inhomogeneous deformation during the compression test causes DBs to form at comparatively low plastic strain, i.e., less than 1%. When the coplanar-double slip system is activated as the secondary slip system, the formation plane of DB is perpendicular to both the coplanar-slip plane and the sum of the Burgers vectors for the activated primary and coplanar slip systems (i.e., the {211} plane) under the coordinates in the DB. From the EBSD results, it can be recognized that the DB regions are rotated approximately 10 degrees with respect to the matrix after the inhomogeneous deformation. By observing the dislocation structures using SEM, a cell-like dislocation structure is observed in the DB. The relationship between the deformation behavior and

the activated slip systems is well explained by studying the crystallographic features of the DB, which improves our basic understanding of cyclic deformation in copper single crystals.

Chapter 3 focused on the DBs and dislocation structures in the near-[$\bar{1}$11]-multiple-slip-oriented copper single crystals during cyclic deformation. The DBs, including DBI and DBII, and corresponding dislocation structures was carefully investigated using SEM. Experimental results show that at lower plastic strain amplitudes ($\gamma_{pl} = 5 \times 10^{-4}$ and $\gamma_{pl} = 1 \times 10^{-3}$), the dislocation structures are mainly characterized by vein-like and wall structures while the cell structure can be regarded as the main dislocation structure at higher γ_{pl} ($\gamma_{pl} = 1 \times 10^{-2}$). Based on the experimental results and crystallographic geometry, three different types each of DBIs [(111), ($\bar{1}\bar{1}$1), and ($\bar{1}1\bar{1}$)] and DBIIs [($\bar{2}$11), ($\bar{1}$21), and ($\bar{1}$12)] can be summarized as the primarily activated slip plane and the combination of activated primary and coplanar slip systems, respectively. In addition, the formation planes of cell bands (CBs) [(121), ($\bar{1}\bar{1}$2), and ($\bar{2}1\bar{1}$)] formed in the DBs can be regarded as the plane which is perpendicular to the cross-slip plane and parallel to the primary slip direction. Furthermore, due to the highly symmetrical characteristics of [$\bar{1}$11] multiple-slip-oriented single crystals, the inconsistent correspondences between DBs and CBs can also be detected based on the numerous observations of the cyclically deformed copper single crystals. In addition, from the EBSD results, it can also be found that there is a weak rotation between the two neighboring CB formed in the DB, which induced the formation of the (111) twist boundary.

In Chapter 4, the evolution of dislocation structure during the cyclic deformation in the near-[001]-oriented copper single crystals is investigated across a wide range of plastic strain amplitude $\gamma_{pl} = 1.7 \times 10^{-4}$-$1.7 \times 10^{-2}$ using SEM. When $\gamma_{pl} < 1.5 \times 10^{-2}$, the dislocation structure comprised a labyrinth with a set of parallel (100) and (001) walls, which is highly correlated to the activation of primary and critical slip systems. However, when γ_{pl} increased to 1.5×10^{-2}, the labyrinth structure is decomposed with the formation of cell structures to accommodate the higher plastic strain. The formation of cell structures formed on the (111) [or ($\bar{1}$11)] plane, owing to the local activation of the primary and primary coplanar [or critical and critical coplanar] slip systems. The formation plane of the cell boundary depends on which slip system is activated as the primary slip system. In addition, a slight misorientation in the dislocation cell structures formed at higher γ_{pl} can also be detected by EBSD with approximately 3° misorientation angle. The rotation axis can be regarded as [010], which is simultaneously perpendicular to the primary and critical slip direction due to the formation mechanism of dislocation cell structures.

Finally, in Chapter 5, the conclusion of this work is summarized.

Overall, this study proposes the relationship between the activated slip systems and the formation of DBs and related dislocation structures during the cyclic deformation, which deepens our understanding of the fatigue of metals.