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EFFECT OF ADDITIONAL ELEMENTS ON DISLOCATION MULTIPLICATION DURING TENSILE DEFORMATION IN AL ALLOYS

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INTRODUCTION

Recently, dislocation density change during tensile deformation in pure Al has been investigated by *In-situ* XRD technique using synchrotron radiation. It was clarified that the dislocation density changed for stage I–IV. The stage I was elastic deformation stage, the dislocation density was almost constant. The stage II was the elastic and plastic deformation region with rapid dislocation multiplication. Deformation progressed almost only by plastic deformation with mild dislocation density change in the stage III dislocation density decreased by the break in the stage IV. 0.2% proof stress ($\sigma_{0.2}$) has been used as the yield stress, σ_{I} and σ_{II} were also suggested. Then, σ_{I} was the stress when dislocation starts to increase, σ_{II} was the stress when deformation began to progress almost only by plastic deformation. $\sigma_{0.2}$ is close to σ_{II} in pure Al with different grain sizes. When the dislocation density which corresponds to σ_{II} was defined as ρ_{II}, σ_{II} depended on the square root of ρ_{II}. Therefore, it was clarified that grain refinement hardening was dislocation hardening essentially. In this study, it is discussed the effect of additional elements on dislocation multiplication and hardening during tensile deformation in Al alloys.

EXPERIMENTAL PROCEDURES

Al-Si, Fe, Mg, Zn, Cu, Mn, Cr alloys were casted in each pure ingot and changed the solute element concentration in the range of 0.2–5.0 at.%. They were cold rolled to a thickness of 1 mm, and tensile test specimens were prepared by electric discharge machine. The change of dislocation density in Al alloys were measured during tensile deformation by *In-situ* XRD technique in SPring-8 synchrotron facility. The initial strain rate was 3.3×10^{-4} s^{-1}. The energy of incident X-ray was 25 keV, the beam size was 0.15×3 mm, and the time resolution was 2 s. The inhomogeneous strains were obtained by using Williamson-Hall equation from diffraction peaks.

RESULTS AND DISCUSSION

The lattice constants of each alloy increased or decreased linearly by the amounts of adding element in all alloys except for Al-Fe alloy. These slopes almost agreed with the reported values, therefore all alloys except for Al-Fe alloy were the solid solution state. By the *in-situ* XRD technique, the stage I–IV were also obtained as well as in pure Al, and σ_{I}, σ_{II}, $\sigma_{0.2}$ were depended on the square root of each solute amounts. $\sigma_{0.2}$ indicated the stress when deformation began to progress almost only by plastic deformation because $\sigma_{0.2}$ was almost equal to σ_{II} in all alloys. ρ_{II} (the dislocation density required for plastic deformation) increased almost proportional to solute amounts although the slopes were different by the kinds of the additional elements. This is because solute atoms and dislocation were obstacle of dislocation motion. σ_{II} and ρ_{II} were applied to the formula of dislocation hardening, shown in Figure 1.

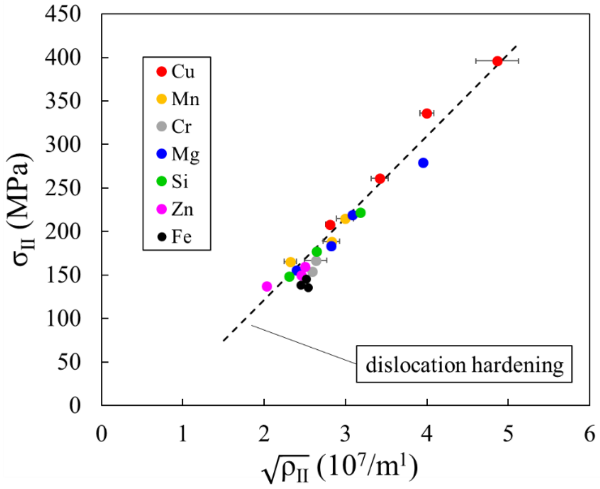

Figure 1. Relation of the dislocation density and yield stress in Al alloys

σ_{II} depended on the square root of ρ_{II} regardless of the kinds of additional atoms, these plots are good agree with the line of dislocation hardening in pure Al. This indicates that the yield stress was determined by the dislocation density and solid solution hardening is also dislocation hardening essentially in Al dilute alloys.

REFERENCES

Adachi, H., Miyajima, Y., Sato, M, &Tsuji, N. (2015). Evaluation of dislocation density for 1100 aluminum with different grain size during tensile deformation by using in-situ X-ray diffraction technique. *Materials Transactions, 56*, 671–678.

Bailey, J.E. & Hirsch, P.B. The dislocation distribution, flow stress, and stored energy in cold-worked polycrystalline silver. *Philosophical Magazine*, *5*, 485–497.

Williamson, G.K. & Smallman, R.E. (1956). Length of a free path of the screw dislocation segments in FCC-single crystals. *Philosophical Magazine, 1*, 34–36.

KEYWORDS

Al alloy, Dislocation density, Hardening mechanism, *In-situ* XRD, Solid solution hardening