研 究 速 報

UDC 539.375.5 : 539.431.2.014.11
669.384－172
620.186.4 . : 620.187

Propagation of Fatigue Cracks in Electrodeposited Copper Single Crystal Film

電着銅単結晶膜における疲れき裂の伝ぱ

Yoshiaki HAGIUDA* and Masahisa MATSUNAGA*

萩生田 善 明・松 永 正 久

1. Introduction

The authors reported propagation of fatigue cracks in electrodeposited copper polycrystal film[1], and stage I cracks in copper single crystal [2]. Present report will show the propagation of fatigue cracks in electrode－posited copper single crystal.

2. Experimental results

The method of experiment was the same as that of the previous report [2]. In this experiment, propaga－tion mode of fatigue cracks from point of stress con－centration in copper single crystal film will be com－pared with that of the polycrystal film. It was found that the stage I crack changed its direction after some stress repetitions. It was similar to the transition from stage I to stage II cracks in polycrystal films.

Fig. 1 shows a propagation mode of stage II cracks from a pit at [001] stress axis in $(1\bar{1}0)$ surface, at the stress amplitude of $\varepsilon_a = 1.38\times10^{-3}$ and repeti－tion of $n \approx 1.5\times10^{6}$. The stress direction had been found to be the most difficult one for slip in this case. Vertical direction to the stress axis corresponded to [110] direction, which had been imagined to be easy to slip from the viewpoint of Schmid factor but was to be difficult to slip because it corresponded to that of Cottrell's sessile dislocation. The cracks propagated from a pit similar to that of stage II. Fine slips from the cracks ran along [112] and $[11\bar{2}]$ di－rections. Although the slips were not formed on a specimen without pit, cracks and slip lines from these were formed if a pit existed. In comparing the cracks propagating from a pit in polycrystal copper film [1], the length of cracks was only about one third at the same stress amplitude and ten－fold re－petitions.

Fig. 2 shows cracks at [110] stress axis in (110) sur－face and at $\varepsilon_a = 0.96\times10^{-3}$ and $n = 6\times10^{5}$. Cracks

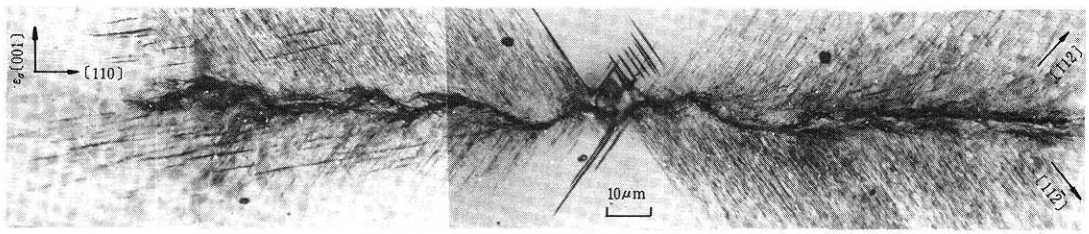

Fig. 1 Propagation of cracks from points of stress concentration in single crystal film, in a case that Cottrell's sessile dislocation worked. The cracks propagated perpendicular to the tensile stress.

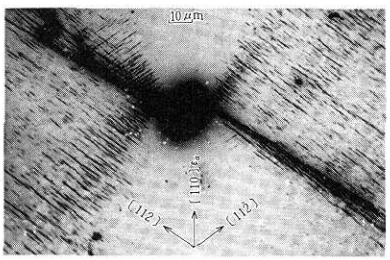

Fig. 2 Propagation of cracks from points of stress concentration, in a case that prominent orientation effect was found. Cracks formed along slip direction and gradually chan－ged its direction

from a pit propagated along a direction not perpendic－ular to the tensile axis but along [112], that is, slip direction. In this case, the slips occurred at first, the crack was formed along the slips at the next stage

* Dept. of Mechanical Engineering and Naval Archi－tecture, Institute of Industrial Science, Univ. of Tokyo

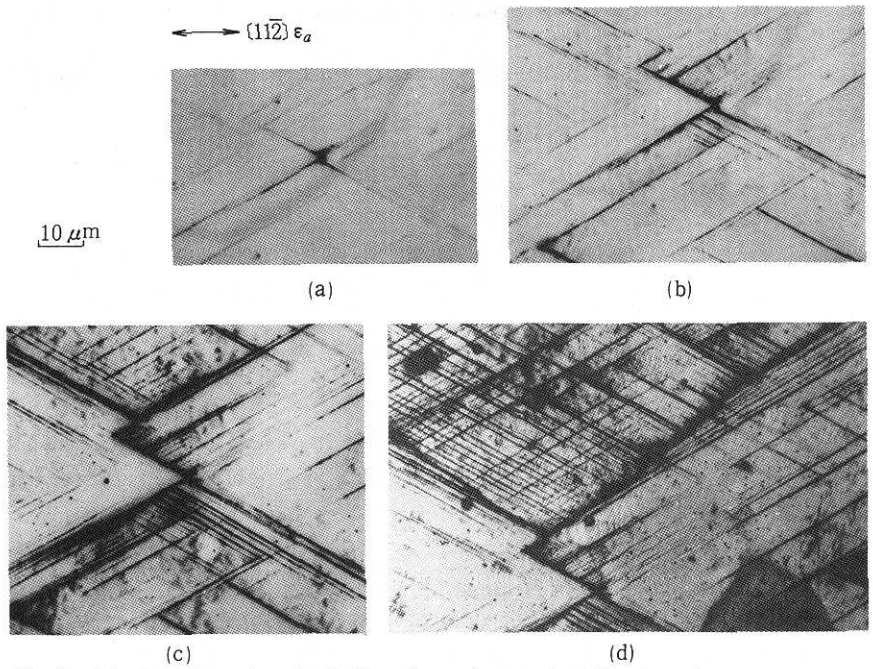

Fig. 3　The initiation of cracks indicated prominent orientation dependence. but gradually changed their direction and transferred to stage II cracks. $\varepsilon_a = 1.2 \times 10^{-3}$,
(a) $n = 1 \times 10^4$　(b) $n = 5 \times 10^4$,　(c) $n = 1.5 \times 10^5$　(d) $n = 1.8 \times 10^6$

and the crack changed its direction showing the transition to stage II cracks by connecting cross slips.

In the case of film having no stress concentrating pit, the similar propagating mode could be found. Fig. 3 shows a series of cracks from inititiation to rupture at [112] stress axis in (111) surface, at $\varepsilon_a = 1.2 \times 10^5$ and $n = 1.8 \times 10^6$. Some of the cracks changed their direction at about $n = 1.5 \times 10^5$.

Propagating rate of cracks formed by shearing slips was similar to that of stage I cracks. Fig.4 shows an example of propagating rates formed from a pit of 0.2 mm square at [210] stress axis in (001) surface. The rate at the straight line in which the interaction of cracks did not yet occur was 4Å/cycle and corresponded to that of stage I cracks.

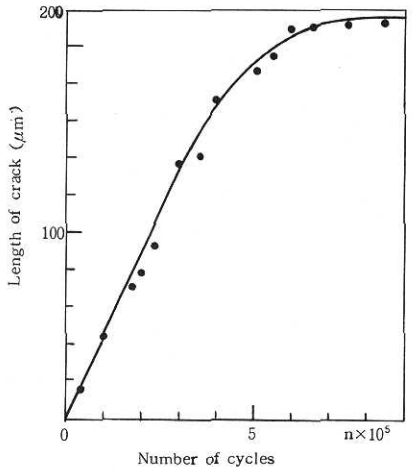

Fig. 4　Propagating rate of a crack in single crystal copper film. [210] stress axis in (001) surface. Size of notch was 0.2 mm square. Direction of crack was [110].

3. Conclusions

In single crystal film, propagation modes of the fatigue cracks from a point of stress concentration, for instance, from a pit, were different according to the stress axis and crystal orientations. One exhibited prominent dependence on orientation and the other did nearly the same behavior as polycrystal film. Cracks originated by slips in single crystal film changed their direction from the direction of slip lines to that perpendicular to tensile stress. It seemed to be a transition to stage II cracks.

(Manuscipt received August 23, 1977)

References

1) M. Matsunaga and Y. Hagiuda, Proc. 8th INTERFINISH, p.377, Forster-Verlag AG, Zürich, 1973
2) M. Matsunaga and Y. Hagiuda, This Journal 25.7. 300, 1973.