УДК 539.2

G. Gershteyn, T. Golosova, M. Schaper, D. Gerstein, D. Lychagin, Fr.-W. Bach

THE POSSIBLE MECHANISM OF SLIP BAND FORMATION

Annotation. An investigation of the deformation relief, which is an important characteristic of plastic deformation, is carried out. Despite of the large amounts of accumulated data published regarding the mechanisms of deformation relief there are still many open questions. This paper proposes some possible new mechanisms for the formation of slip bands. It is shown that the distribution of gliding in the parallel slip plane is possible as a result of the interaction of slipping dislocations with forest dislocations. Images of the deformation relief were taken. The proposed mechanism correlates with experimental data of the formation of the deformation relief.

Keywords: dislocation mechanism, deformation relief, dislocation interaction, slip line, double cross slip

Introduction

An important characteristic of plastic deformation is the deformation relief, whose study has a long history. Despite of the large amount of accumulated data [1, 2, 3, 4], there are still many questions in understanding the mechanisms of deformation relief.

It is known that at low dislocation densities in the crystal, dislocations are arranged in the form of Frank nets. The separate elements of Frank nets lie in different planes. Besides, there may be other dislocations in the crystal. When the strength, applied to the crystal, is higher than yield stress, the net elements located in the planes with maximum shear stress start to slide, to bend and to form dislocation loops by the mechanism of Frank-Read. If several loops were formed in the slip plane, their interaction results in a single dislocation loop which reaches the surface (Fig. 1). Several generated loops form a slip line on the surface.

Several closely placed slip lines form a slip band. Furthermore, several mechanisms of formation can be observed. The aim of this paper is to define the reason why the slip lines forming slip bands are grouped instead of spreading in regular intervals on the surface (Fig. 2).

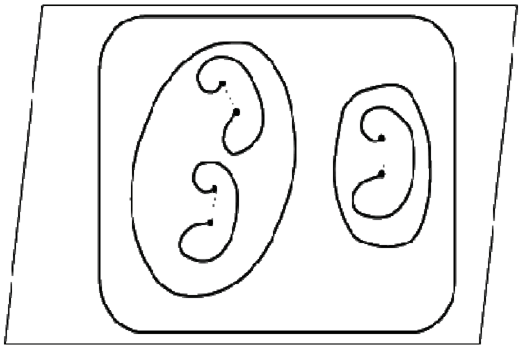


Fig. 1 - Several dislocation loops in the slip plane result in a single loop

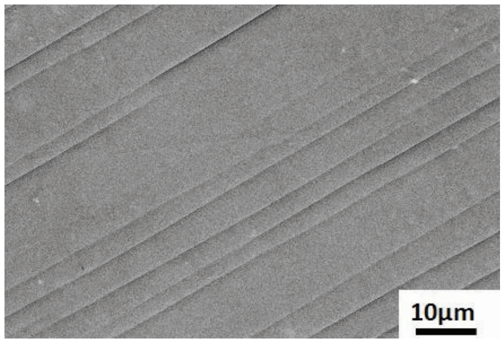
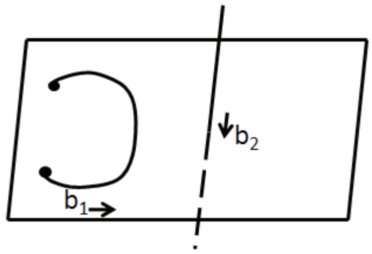


Fig. 2 - SEM image several closely spaced slip lines form slip bands, compression in aluminum single crystal at ε = 0.043, strain rate 4·10-3s-1

Proposed mechanism of the glide propagation into parallel slipping planes

The known mechanism of glide propagation into parallel slipping planes is a double cross slip. Also, other mechanisms are possible. The slip plane of dislocation loops crosses the dislocations located in other slip systems, which are of different types and Burger's vectors. Typically, that kind of dislocation is called forest dislocation. These may be mobile or less-mobile for an applied strength. The slipping dislocation loops interact with these dislocations. These dislocations are interacting with dislocation loops, forming thresholds and bands depending on the direction of their Burger's vector [5]. The bends are located in the plane of dislocation glide and might annihilate. The creation of thresholds is accompanied by a shift of a part of the dislocation loop into the parallel slip plane. This shift is equal to the Burger's vector of the forest dislocation (Fig.3).



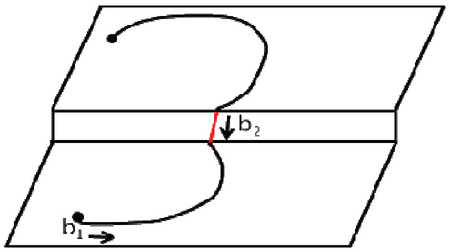


Fig. 3 - Formation of a threshold on the sliding dislocation segment, resulting in a share of one part of the segment into parallel slipping plane; left: a segment before its interaction with the forest dislocation; right: a segment after interaction with the forest dislocation

Since the threshold is located in a plane different from the slip plane of the loop, its speed is much lower than the speed of the loop. This results in a well-coordinated movement of dislocations, similar in type and Burger's vector, which move in parallel planes at distances between these planes that are equal to the Burger's vector of the forest dislocation. Thus, a new source of dislocations is created in a new slip plane. This source generates a further dislocation loop under the influence of the applied strength. This loop crosses the same forest dislocations, interacting with them, and again a part of the loop is shifted into a parallel plane. This way the sliding spreads within the closely placed parallel planes. Presumably, the dislocations follow each other within the parallel planes. Moreover a system of well-coordinated dislocation sources is created in parallel planes. This system leads to the formation of new closely spaced slip bands. If a Frank-Read source emits about 10 to 80 loops, the slip band width formed should be in the range of 4 nm to 80 nm.

ISSN 1562-9945

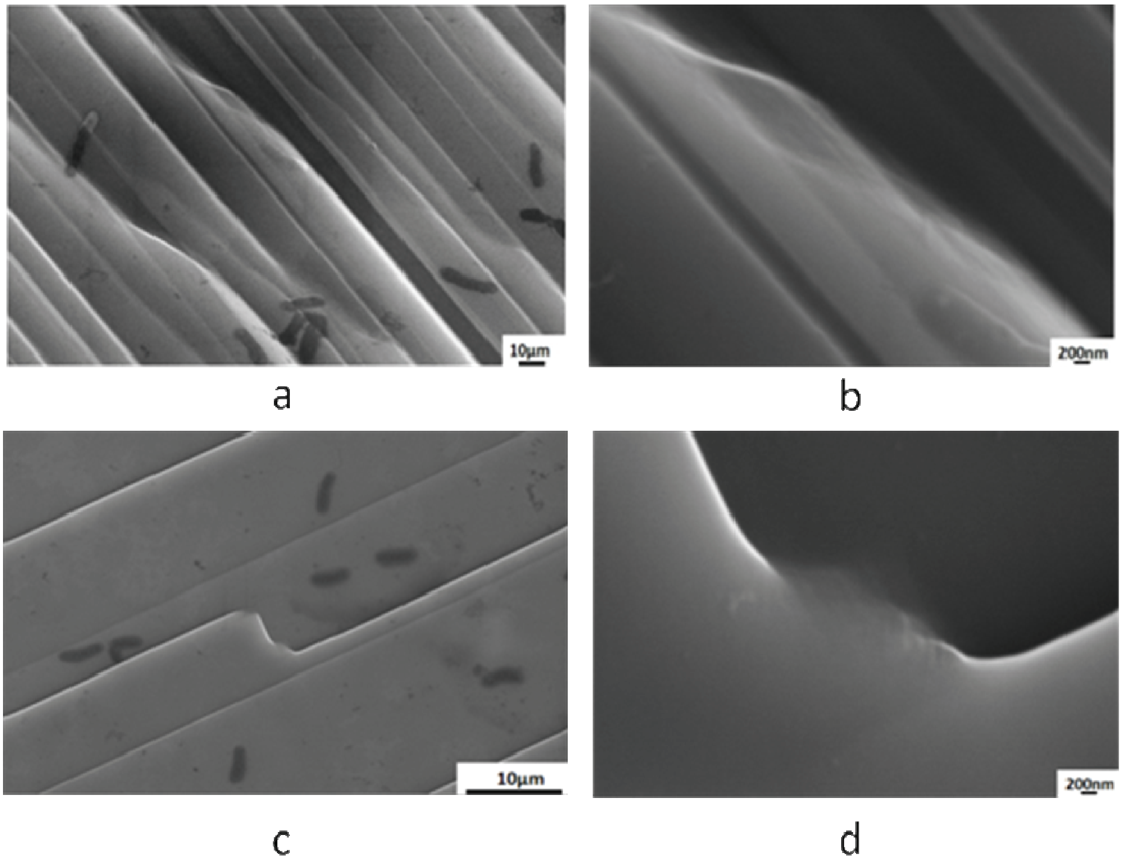


Fig. 4 – SEM image of deformed relief on the sample surface after uniaxial compression in aluminum single crystal at 5 = 0.05, strain rate 4·10-3s-1; a, c - the overall picture of the slip; b, d - slip microstructure elements

The comparison of offered mechanism with mechanism of double cross slip

The higher the deformation, the higher is the amount of the secondary slip planes. The forest dislocation density increases. The density of forest dislocations might positively influence the width of the slip band. Experiments show that the gliding lines occur in groups parallel to each other. These lines occur in a lamellar formation. The dislocation segment that glided into the parallel plane by the threshold creation is much longer than in the case of a cross slip. The longer the dislocation segment, the less stress is needed for this segment to form loops according to the Frank-Reed mechanism. Therefore, the dislocation segments, placed into the parallel planes during the formation of the threshold, need less time to create dislocation loops and slip lines under the applied stress then in case of double cross slip.

Experimental observations

The figure 4 shows that two different kinds of gliding occurred. The first one is a clear transaction of the slip line in a new plane. This transaction might be caused by a cross slip. The second one is a smooth, gradual transaction of a slip line in a new plane. This process described above might enable this transaction. The proofs for this process can only be provided by high resolution transmission electron microscopy.

Conclusions

Presumably, both the mechanism of double sliding and the offered mechanism take place at plastic deformation. Additional researches are necessary to define relevance and localization of the offered mechanism and the mechanism of cross-section sliding.

Acknowledgements

The results presented here were determined within the framework of the project cluster (PAK250) "Identification and modeling of material characteristics for the Finite Element Analysis of sheet forming processes" in the sub project TP5 supported by German Research Foundation (DFG).

LITERATURE

1. Mader, S. Electronenmikroskopische Untersuchung der Gleitlinienbildung auf Kupfereinkristallen, Zeitschrift fьr Physik, 149(1977), pp. 73-102
2. Neuhauser, H. Dislocation in Solids, Ed. By F.R.N. Nabarro, Nort-Holland Publ., 6(1983), pp. 319
3. Kuhlmann-Wilsdorf, D. Theory plastic deformation: properties of low energy dislocation structure, Mater. Sci. and Eng, A113(1989), pp. 1–41
4. Lychagin, D.V.; Starenchenko, V.A.; Solov'eva, Yu.V. Classification and the scale hierarchy of structural elements of the deformation of bcc monokristall, Physical mesomechanic, 8(2005), 6, pp. 67-77
5. Novikov, I.I.: Defects in the crystal structure metallov, Moskva, Metallurgy, 197

Received 29.10.2010г.

 ISSN 1562-9945