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Crystallogeometric regularities of main crack origination and development in two-dimensional aluminum polycrystals

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Connection between crystallographic orientation of grains and arise and development of the main cracks in plastic deformated two-dimentional aluminium polycrystals with the average size of grains of about 10 mm is investigated. It is shown experimentally that macroscopic cracks arise in grains with crystallogeometric orientation [$\bar{1}$13] (411) or traverse them during failure. The features of crystallogeometry of dislocation sliding at the failure stage in such grains have been established.

Исследована связь между кристаллографической ориентацией зерен и возникновением и распространением магистральных трещин в пластически деформируемых двумерных поликристаллах алюминия со средним размером зерен, равным 10 мм. Экспериментально показано, что макроскопические трещины зарождаются в зернах с кристаллогеометрической ориентацией [$\bar{1}$13] (411) или проходят через них в процессе разрушения. Установлены особенности кристаллогеометрии дислокационного скольжения на стадии разрушения в таких зернах.

The main crack origination in a metal under mechanical stress is preceded by formation and growth of microdiscontinuities. In spite of the fact that there are numerous physical models of microscale failure mechanisms [1–3], the regularities of discontinuity areas occurrence in a loaded material and their transformation to a macroscopic crack remain unclear to date. At the same time, the interrelation between the strain processes and failure, in particular, the connection between motion and interaction of dislocations and formation of micro-cracks, is ascertained surely. That provides a basis for consideration of failure process from standpoint of the crystal geometry. So, crystallographic regularities of a micro-crack growth in strained thin foils of metals and alloys are ascertained thanks to experimental researches of failure in a high-voltage electronic microscope column [3]. The aim of this study is to investigate the relation between crystallographic orientation of grains and development of main cracks in plastically deformable two-dimensional ("parquet structure") aluminum polycrystals.

The research samples with the working part size of about 60×20×0.15 mm^3 were cut out from an aluminum foil (99.96 %). The necessary average grain size of about 10 mm was provided by selection of preliminary strain and of recrystallization annealing parameters. The grain structure was revealed by chemical etching. The specimens were strained under active tension conditions at a constant straining rate $\dot{\varepsilon} = 2 \cdot 10^{-5}$ s^{-1}. The main crack development was observed in situ using a digital camera at a shooting rate 30 pictures per second [4]. The crystallographic orientation of grains was determined using the Laue X-ray technique.

As the mechanical tests have shown, the failure of two-dimensional aluminum polycrystals with the average grain size of

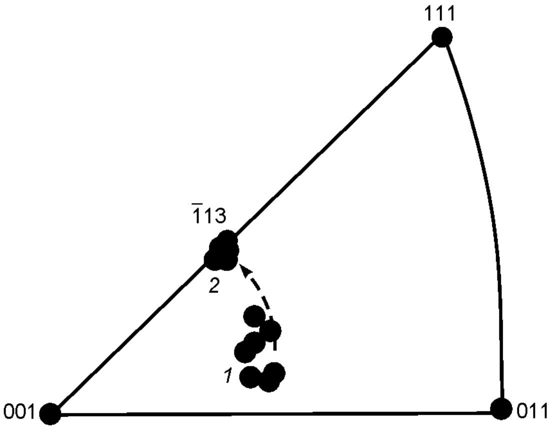

Fig. 1. Projections of tensile axis prior to straining (*1*) and after failure (*2*) and the approximate form of the grain reorientation trajectory.

about 10 mm is viscous and the failure character is trans-crystalline. The maximum plastic strain in such samples amounts to 30 %. It has been established that grains with crystal-geometric orientation $[\bar{1}13]$ (411) (tension axis and free grain surface are in close coincidence with crystallographic direction $[\bar{1}13]$ and crystallographic plane (411), respectively) are of a particular importance in the failure process. Macroscopic cracks arise in grains with such orientation or traverse them during the failure. The main crack changes its trajectory and rushes the grain with orientation $[\bar{1}13]$ (411) if such grain is away from the initial direction of crack development. The grains under consideration in this case initially have the $[\bar{1}13]$ (411) orientation or get this orientation during plastic straining. The approximate form of the reorientation trajectory in the second case is presented in a standard stereographic triangle in Fig. 1. The initial crystallographic orientation specifies that in such grains, the primary sliding system is the (111) $[\bar{1}01]$ one. The tightness of plastic straining caused by presence of grain boundaries entails the crystal lattice reorientation presenting a rotational plasticity act [2]. The grain rotation brings the tensile axis on the border of the stereographic triangle. This favors the activation of the conjugated sliding system $(\bar{1}\bar{1}1)$ [011]. The double sliding traces are observed on the surface of such grains (Fig. 2a).

The data of radiographic and metallographic studies enable to establish the features of crystal geometry of dislocation sliding at the failure stage (Fig. 2b). In the grains with initial $[\bar{1}13]$ (411) orientation, the plastic strain seems to take the character of double sliding at once. In the reoriented grains, the sequence of strain processes appears as follows: straining according to the primary sliding system – crystal lattice reorientation – activation of the conjugated sliding system – double sliding – failure. In both cases, the crystal-geometric orientation $[\bar{1}13]$ (411) is connected with double sliding. The interaction of dislocation in crossed sliding systems (111) $[\bar{1}01]$ and $(\bar{1}\bar{1}1)$ [011] seemingly makes this orientation unstable with respect to failure.

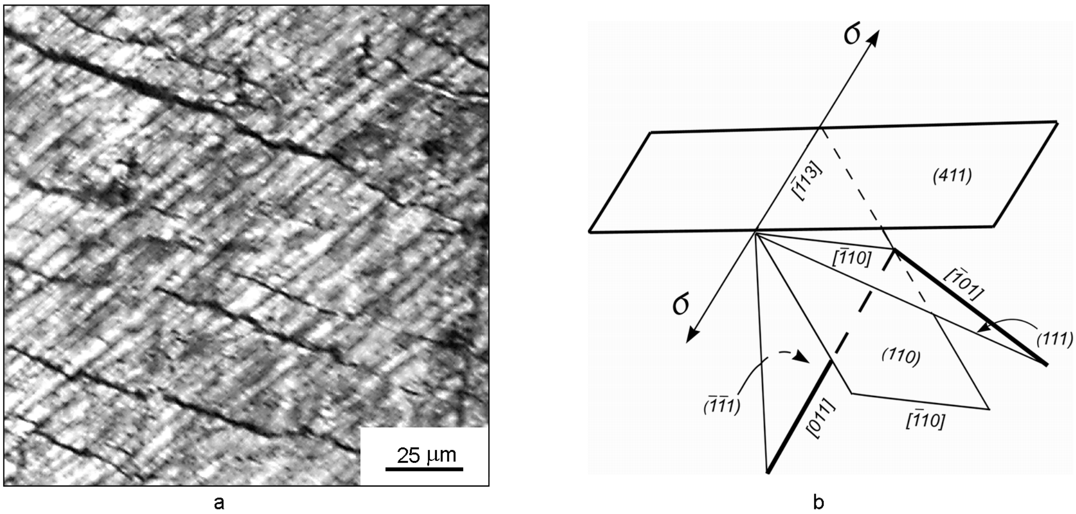

Fig. 2. Traces of double sliding (a) and its crystal-geometric scheme (b) in a grain with $[\bar{1}13]$ (411) orientation.

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Кристалогеометричні закономірності виникнення та поширення магістральних тріщин у двовимірних полікристалах алюмінію

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Досліджено зв'язок між кристалографічною орієнтацією зерен та виникненням і розвитком магістральних тріщин при пластичній деформації двовимірних полікристалів алюмінію із середнім розміром зерен, який дорівнює 10 мм. Експериментально показано, що макроскопічні тріщини зароджуються у зернах із кристалогеометричною орієнтацією $[\bar{1}13]$ (411) або проходять крізь них у процесі руйнування. Встановлено особливості кристалогеометрії дислокаційного ковзання на стадії руйнування у таких зернах.