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POSITRON ANNIHILATION IN POLY- AND MONOCRYSTALLINE SILVER DEFORMED BY UNIAXIAL TENSION

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ABSTRACT

Angular distributions of the positron annihilation quanta was measured for polycrystalline and monocrystalline silver samples oriented in (111) and (100) direction, deformed by uniaxial tension up to different deformation degrees. The S parameter as a function of deformation degree and the S parameter as a function of the W parameter has been determined. The data obtained for monocrystalline samples was found that the dynamics of the dislocation and vacancy generation, during the sliding of some crystallographic planes, depends on the crystallographic direction. The data obtained for polycrystalline silver samples elongated up to different elongation degrees indicate that in the proportionality and limited proportionality regions the changes in the physical properties of silver are governed mainly by generation of vacancies and formation and kinetics of transformations of vacancy clusters occurring first of all on the grain boundaries of monocrystallites. In the region of plastic deformations the dominant defects are dislocations and vacancies and their aggregates generated due to the formation and movement of the dislocation of the primary and secondary slip.

INTRODUCTION

It is well known that metals under action of external load causing a slow uniaxial elongation of the sample up to its rupture, the metals are deformed, first elastically and, after exceeding the elasticity limit, the deformation starts to be plastic [1].

The behaviour of polycrystalline samples in the process of plastic deformation by uniaxial tension differ from that of monocrystalline samples. In the monocrystalline metal samples, during the elastic deformation, the ordering of the crystal lattice remains unchanged, only the interatomic distances are changing, which leads to a change in the volume of elementary lattice cell. If the value of external forces exceeds the extremum of interatomic forces, metals start to deform plastically. Plastic deformation requires the dislocation movement by gliding in the slip plane or climbing [2]. During the climbing process the edge (or mixed) dislocations are moving by adjoining or realizing vacancies to or from the extra half plane. This way the edge and mixed dislocations are the sinks (or source) for vacancies. The slip starts when the tangential stress in the easy slip plane and easy slip direction (close – packed planes and directions) caused by external forces, reaches minimum value – so-called critical stress. In the case of the silver, the easy slip planes are {111} planes and easy slip directions are (110) directions.

It is well known that polycrystalline material is an ansamble of microcrystallites with randomly oriented crystal axes. They have no defined elasticity limit. Even in the equilibrium state, the grain boundaries are strongly defected. After exceeding some crystal strain the defects accumulated at the grain boundaries penetrate through the grain boundaries. In the macroscopic scale this results in appearance of the low and upper limits of elasticity. In this intervals the strain oscillates around some value proportional to the energy required for penetration of the grain boundary by the defect. In this interval some ordering of the intergrain regions is observed.

After equalization of the concentration of dislocations is all the grains, their penetration through the grain boundaries becomes unimportant. At this moment the plasticity arrest ends and the plastic range starts. The dislocations (especially the edge dislocations) strongly interact among themselves and the hardening of the sample starts. Although the cross section area of the sample decreases uniformly along the sample length, the strain increases rapidly because of the hardening of the sample. In this range the mutual displacements of the grains, their coalescence because of joining of small grains and decomposition of great grains into small pieces is observed.

The dislocation movement in polycrystalline materials is blocked by grain boundaries and therefore the easy slip stage, observed in monocrystals, does not occur in the case of polycrystals. This blocking effect of grain boundaries is the reason for simultaneous initiation of plastic deformation in various slip planes. Therefore, the elasticity limit for polycrystalline materials is much higher than that for monocrystals, the increases in the value of elasticity limit being the larger the smaller are the grain dimensions. The obstacles for the dislocation movement are mainly the broad–angle grain boundaries, whereas the low–angle grain boundaries are permeable for the mobile vacancies.

The present paper is a continuation of our previous works [3–8] aimed at the application of the positron annihilation method for explanation what are the physical; reasons for nonuniform course of the deformation of mono- and polycrystalline silver samples.

EXPERIMENT

Monocrystalline samples, oriented in the (111) and (110) directions, with dimentions at $15\times10\times1\ \lfloor mm^3 \rfloor$ and polycrystalline samples with dimensions $25\times10\times1\ \lfloor mm^3 \rfloor$, of the 4N purity used in this experiment, were annealed for four hours at 980 K and slowly cooled to room temperature. After that, one of the samples was placed in a specially prepared set–up, by means of which the sample was elongated to different relative elongations. For each elongation value the (ACAR) curve was measured using the standard correlation spectrometer with a long slit geometry. The positron source (^{22}Na) of the activity about 150MBq. All the measurements were performed at room temperature.

RESULTS AND DISCUSSION

The detailed explanation of the procedure for evaluation of the S- and W-parameter value can be found in our previous papers [3–8] as well in [9].
Figure 1 represents the correlations between the S- and W- parameter values determined for each of the relative elongation values.

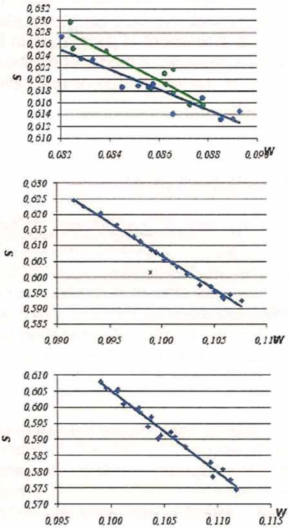

Figure 1. Correlation between the S- and W- parameter values for polycrystalline and monocrystalline silver samples oriented in the (110) and (111) directions.

It is well known from the literature [9] that the $\Delta S/\Delta W$ ratio is constant if the positrons are trapped only in one type of defects. The value of $\Delta S/\Delta W$ ratio, named R_D parameter, determines the dimensions of the defect. A detailed description of this conjecture may be found in [9]. In such a case the experimental points on the S – W curve are located along one straight line. When the positrons are trapped in defects of different type (vacancies, dislocations, grain boundaries) the R_D parameter value gives the dimension of defects, averaged over all the positron trapping centers present in the investigated sample.
In the case of investigated polycrystalline silver sample, the experimental data are located along two straight lines. One of these straight lines fits the points corresponding to the interval $0 < \varepsilon < 3\%$. The remaining points lie in the close vicinity of the second straight line. In the range elasto – plastic deformation (first

straight line) the dominant role play the vacancies and their agregates generated mainly in the grain boundary regions. In the remaining ranges of the strain-stress curve the dominant role belongs to the vacancy type defects formed due to the generation and movement of dislocations in the primary secondary slip.
In the case of monocrystalline silver samples we have obtained, for both samples one straight line sloped under some angle to the W coordinate. In this case, mast probably, dominant role belongs to the vacancy type defects formed due to the generation and movement of dislocation in the primary secondary slip, what might corraborates a dislocation model of plastic deformation.
Such measurements are in the final stage of realization and their results will be published in nearest future.

CONCLUSIONS

From the investigations performed in the frames of the present study it follows out that:

- measurements of the angular correlations of positron annihilation quanta can be applied as a method supporting the static tensile tests;
- changes in the positron annihilation parameters caused by uniaxial static elongation permit to reveal and to describe the microscopic changes in the structure of investigated material;
- it is possible to follow the kinetics of generation of defects with conjecture to the particular ranges of the strain – stress curve;

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