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Study of the effect of γ-irradiation on copper single crystals by etching technique

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Abstract : The effect of γ-irradiation with low energies on samples of copper single crystals with oriented surfaces of (111), (100) and (621) was studied by etching technique. The etch pits show a formation of glide bands, polygonized walls and Blisters as result to irradiation.

Keywords : Copper single crystal, effect of γ-irradiation, etching technique.

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1. Introduction

It is of great interest in the field of materials science to answer the question how long can the surface of the materials resist the bombardment of light ions (such as H or He) or the radiation (neutron, electron or γ-rays) without occurrence of any deformation. Many authors (Makin and Blewitt 1962, Yoshitawa *et al* 1974, Keefer and Sosin 1964 and Mifune *et al* 1967) had found that electron irradiation increases the yield stress of copper, aluminium and their alloys. This effect was explained on the basis of movement of dislocations. The effect of neutron irradiation between 200 and 400°C on the decoration of dislocations in copper single crystals was studied (Jackson *et al* 1977). Their results show inhomogeneous clusters of damage. The dislocation velocity at temperatures below 100°K was studied (Wada *et al* 1980). The long range migration of self interstitial takes place above 30°K and small interstitial clusters and/or interstitial impurity complexes are thought to be formed in the specimen. The displaced atoms and vacancies from irradiated copper crystals that do not recombine may diffuse through the lattice and condense as aggregates depending upon the temperature or irradiation. A tendency for formation of clusters is associated with the grown-in dislocations (Jackson *et al* 1974). The purpose of this work is to study the effect of γ-irradiation with low energy on the surface deformation of copper crystals with specific orientations.

2. Experimental

Oriented samples of the plane surface (111), (110) and (621) from cylindrical copper single crystals were obtained, using X-ray back reflection technique and acid cut. The Cu-single crystals were obtained from Department of Physics, Tu-Dresden, Germany. The samples were chemically polished and flattened using a saturated solution of cupric chloride in HCl

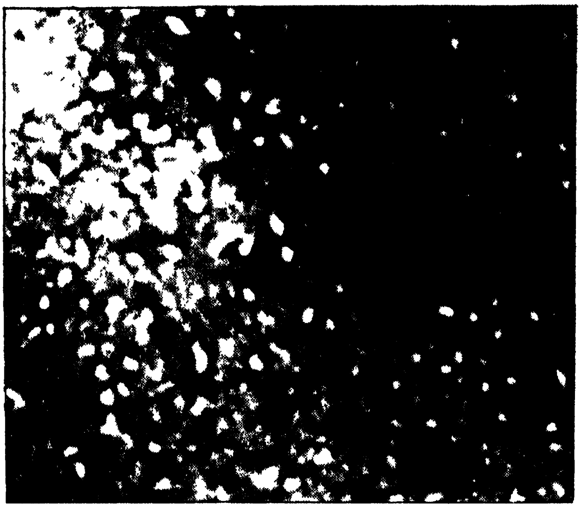

Figure 1. Dislocation configuration in as grawn copper single crystal for surface (621).

(Mitchell *et al* 1967). The samples are immersed in a nitric acid to remove a damaged layer near the plane surfaces, and then electrolytically etched using etching solution of 25 ml HCl + 90 ml H_2O + 15 ml CH_3COOH + 1 ml Br_2 (Marukawa 1967) before and after irradiation

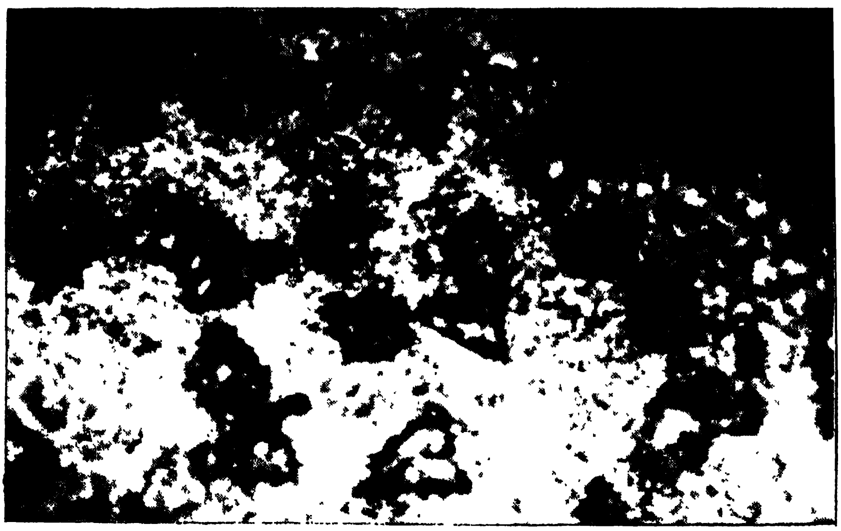

Figure 2. Dislocation configuration in as grawn copper single crystal for the surface (111).

by γ-rays using ^{60}Co-source of activity 453.1 KBq and of photon-energy 1173.238 KeV (the source was obtained from the IAEA-Vienna). The samples were subjected to exposure for continuous 144 hours. The etched surfaces were investigated using metallurgical optical microscope of the type Union ME-3007.

3. Results and discussion

Figures 1 and 2 show the dislocation configuration in as grown copper single crystals of surfaces (621) and (111).

Figure 3. The formation of polygonized walls on (621) surface by irradiation.

It is shown that the dominating defect type in copper single crystals are individual dislocations and small angle grain boundaries.

Figure 4. Glide bands formation on the surface (621) after irradiation.

On irradiated (621) surfaces, etch pits appear as lines which may be due to glide bands and polygonized walls, as shown in Figures 3 and 4. These Figures, show regions free from dislocations which could be due to migration of vacancies and dislocations to create clusters in other regions. These results are in agreement with those obtained on neutron irradiatied surfaces (111) (Jackson 1977).

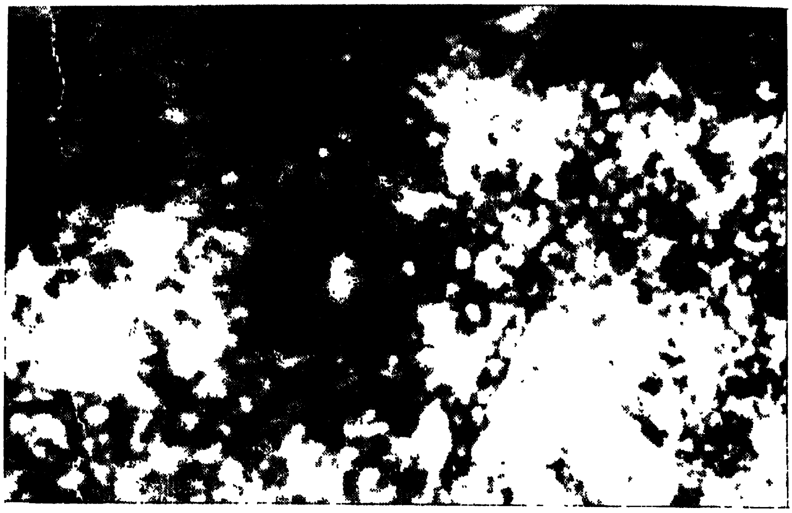

Figure 5. Glide bands and polygonized walls formation on the surface (111) after irradiation.

The observed glide bands and polygonized walls in Figure 4 may be due to slip and climb motion of dislocations. The slip traces are also seen on (111) surface as in Figure 5.

Figure 6. Blister formation on (111) surface by irradiation.

Some bubbles or dome like structure were observed on the etched surfaces (111) and (100) after irradiation as seen in Figures 6 and 7. Such structures could be formed as a result of the migration of vacancies and dislocations. Several slips have taken place along crystallographic directions as shown in Figure 7.

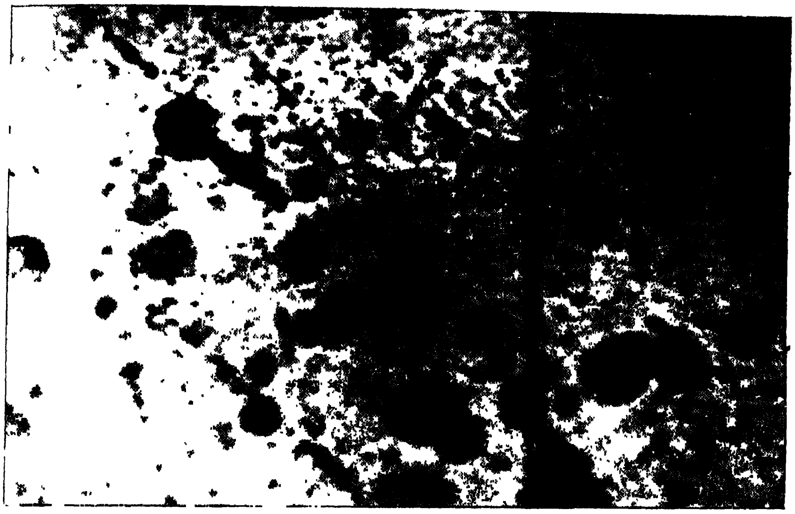

Figure 7. Blister and Dome-like structure on (100) surface after irradiation.

Such structure of bubbles formation was earlier observed on gold samples, after bombardment with 3.52 MeV $^4He^+$ particles (Paszti *et al* 1981).

They attributed this structure to the implantation of He^+ ions with high doses. Some of the formed bubbles or blister structure on (621) surface were opened chemically as a result of several re-polishing and re-etching of the sample surfaces (see Figure 8).

Figure 8. Open-Blisters on the surface (621) by re-polishing and re-etching.

The bubbles or blisters can not be represented as etch pits which correspond to dislocation lines. This is clear after comparing these few bubbles with etch pits which covered all surfaces of the samples as shown in Figure 8. As a results of exposing Cu-single crystals to low energy of γ-rays it can be concluded that :

i) The dislocation density is increased,

ii) Formation of glid bands and polygon walls takes place,

iii) Formation of clusters as a result of the movement of vacancies and dislocations occurs,

iv) Bubbles or blisters are formed as agglomeration of vacancies.

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