RADIATION SPUTTERING OF A SINGLE CRYSTAL OF GOLD BY FAST NEUTRONS

R. I. Garber, G. P. Dolya, V. M. Kolyada, A. A. Modlin, and A. I. Fedorenko
Physico-technical Institute, Ukrainian Academy of Sciences
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1. High-energy radiation sputtering of gold atoms was observed [1] following bombardment of single-crystal gold foil by a beam of 0.3-MeV protons in vacuum. The picture of the spots of the residue of the sputtered gold atoms, obtained on a collector located behind the bombarded target, revealed a symmetry connected with the structure of the crystal and attributed to transfer of energy and momentum from the bombarding protons predominantly along the close-packed rows of atoms in the single-crystal lattice. The mechanism of this process is called collision focusing [2].

The sputtering of crystals under the influence of fast ions and particularly the accompanying atomic collision focusing have been exhaustively investigated for a long time [3]. However, in spite of the fact that there is no principal difference between the mechanism of sputtering of crystals by accelerated ions and fast neutrons, there is only one investigation devoted to the sputtering of a metal by fast neutrons [4], although indirect information on the transport of atoms of matter over considerable distances by fast-neutron irradiation was obtained long ago [5], and it was even proposed to use the sputtering of atoms by fast neutrons to determine the number of displaced atoms [6].

It was of interest to investigate whether atomic collision focusing causes anisotropy of the sputtering of atoms from a gold crystal bombarded by fast neutrons.

2. The experiment was performed with a 14-MeV neutron beam of 10^8 cm^{-2} sec^{-1} intensity, obtained via the D-T reaction from the neutron generator of the Physico-technical Institute of the Ukrainian Academy of Sciences.

A single-crystal gold target 2500 Å thick with area 1 cm^2 and with crystallographic orientation {100}, obtained by epitaxial growing on a NaCl substrate, was mounted on an electron microscope copper grid inside a glass ampoule (Fig. 1). A glass screen was mounted 2 mm away from the target and served as a collector for the sputtered atoms; the screen had a diameter of 15 mm and was covered on the target side by a layer of aluminum for better adhesion of the sputtered gold atoms. The ampoule was evacuated to 10^{-6} mm Hg and then sealed.

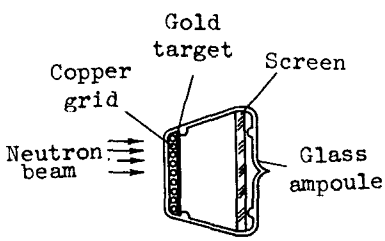

Fig. 1

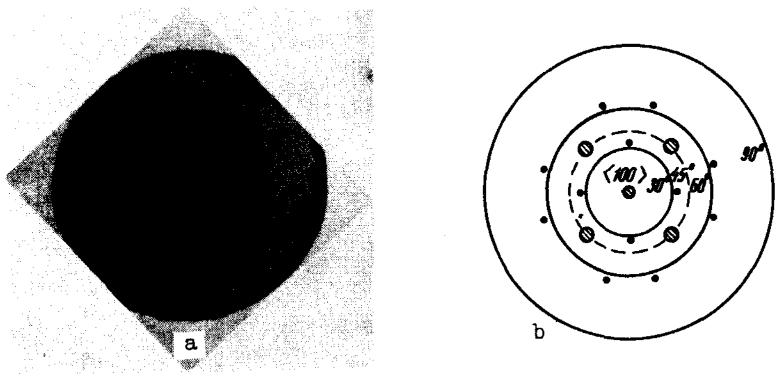

Fig. 2

After irradiation of the target with an integrated fast-neutron flux of 2.32×10^{13} cm^{-2}, the ampoule was opened and the screen collector with the residue of the sputtered atoms was removed. The screen was placed in a special aluminum container which in turn was placed in the VVR-M nuclear reactor of the Physics Institute of the Ukrainian Academy of Sciences, where it was activated with a flux of thermal neutrons of 10^{13} cm^{-2} sec^{-1} for five days. The gold isotope Au^{198} produced thereby had a half-life of 2.7 days. The number of gold atoms on the screen was determined with the aid of a scintillation counter in an AI-100 analyzer by registering the seondary 0.412-MeV γ rays emitted in the decay of Au^{198}.

The angular distribution of the sputtered atoms in the residue of the screen was determined by autoradiography.

3. It was observed that neutron bombardment knocked out 6×10^{10} atoms of gold from the surface of the single-crystal gold target, corresponding to a sputtering coefficient 3×10^{-3} atoms per fast neutron incident on the target.

It follows from neutron scattering theory [7] that 14-MeV neutrons produce in gold primary displaced atoms of average energy 0.12 MeV. If we assume the threshold energy of the displacement of the atom from the lattice site of the gold crystal to be $E_d = 30$ eV, then the average number of displaced gold atoms per energetic primary displaced atom, calculated in accordance with [8], is 2×10^4 toms, and the average number of all the displaced atoms in the volume of the target following irradiation by an integrated fast-neutron flux of 2.72×10^{13} cm^{-2} is 2.28×10^{12}. Thus, 10^{10} out of the 10^{12} atoms displaced in the volume of the target were emitted from its surface.

Figure 2 (a and b) shows an autoradiogram of the residue of the sputtered gold atoms on the screen after bombarding a single-crystal gold target with crystallographic orientation {100}, and the stereographic projection of the fcc lattice on a plane parallel to the (100) face. The picture of the residue consists of four lateral spots and one central spot; the spots are due to the preferred sputtering of the gold atoms in the four ⟨110⟩ directions and one ⟨100⟩, respectively.

The observed preferred emission of the sputtered particles in low-index crystallographic directions confirms the existence of a collision-focusing mechanism in neutron bombardment of crystals.

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