Diffraction of conduction electrons by the (110) face of a tungsten single crystal

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It is shown that the interaction of conduction electrons with a metal surface has a diffractive nature. The surface recombination of electrons is investigated.

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According to the ideas developed previously,[1,2] the reflection of conduction electrons, which depends on the state of the metal surface, is determined by diffraction effects in the outer atomic layer of a solid. This allows us to assume that the tangential components of quasimomenta of incident and reflected electrons are related by the vectors of the reciprocal surface lattice of a crystal. For regular surfaces that preserve their natural translational symmetry, this may produce a specular reflection of all the electron groups. The experiments[3–6] confirm this fact.

Just as important are the cases which the metal surface has an ordered impurity film whose symmetry differs from that of the substrate face. This paper is devoted to the investigaiton of the effect of adsorbed, ordered oxygen films on the reflection of electrons by the (110) face of a W single crystal. The data for structural transformations in the adsorbed layer were obtained by using the method of diffraction of slow electrons (DSE). The data for reflection were obtained by the method of static skin effect.[3,7] As is known, the reluctance of the plate in this case depends on the reflection of electrons and orientation of the magnetic field.

The design of the experimental apparatus allowed us to measure pure samples that were stored under high vacuum conditions (6×10^{-10} mm Hg). The apparatus comprised a DSE system, a cooling system for the sample, a temperature monitoring system for the sample, a gaseous oxygen source, a manometer, and a getter pump. The investigated samples were cut of a bar in the shape of $10\times4\times.12$-mm^3 plates, with a ratio $R_{300\ K}/R_{4.2\ K}\sim10^5$. The procedure associated with the surface purification has been described elsewhere.[3] A strong ($\omega_c\tau\gg1$) magnetic field ($H=9.4$ kOe) oriented in the plane of the sample was perpendicular to the electric current passing through the plate ($j\perp H$). The oxygen was sprayed on a purified surface of the crystal cooled to ~5 K.

The corresponding variation of the reluctance $R_{xx}(t)$ is shown in Fig. 1. Annealing the film at ~400 K changed the behavior of the $R_{xx}(t)$ dependence in the region of ordered structures (open circles). The minimum on this curve corresponds to the

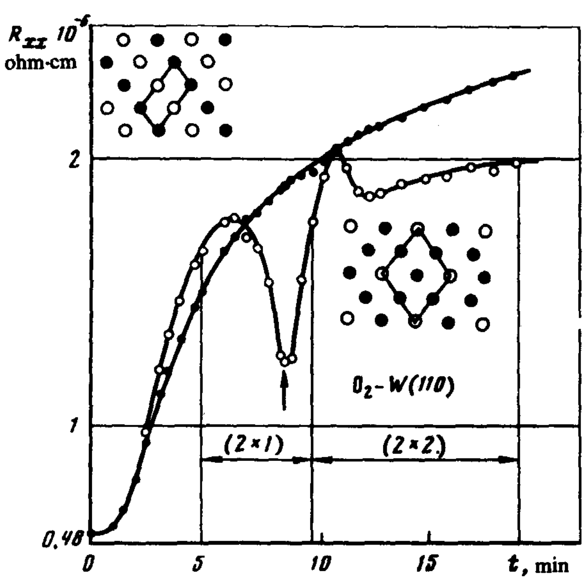

FIG. 1. Dependence on R_{xx} on the spraying time of oxygen: •, the film was not annealed; ∘, after annealing the film.

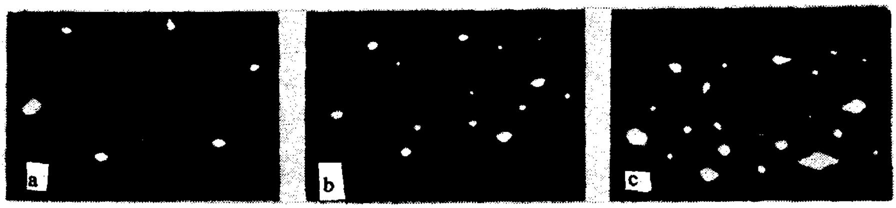

FIG. 2. Sequence of diffraction patterns: a, pure surface; b, (2×1) structure; *c*, (2×2) structure. The screen is inclined at an angle of $\sim 45^\circ$in the field of view of the objective.

largest growth of the (2×1) structure; at the maximum the (2×2) structure reaches the largest growth and then remains almost constant. The sequence of observed DSE patterns is shown in Fig. 2. The first one corresponds to a diffraction pattern for pure tungsten. We note that the O_2-(110) face system of *W* was investigated many times by using the DSE method and our data in this section coincide with the well-known data.[8,10] We also note that, as a result of a sharp decrease of the sticking coefficient of oxygen in the region of film thickness $\theta = 0.8$,[11] the (1×1) structure corresponding to a filled monolayer was not obtained under our conditions.

In evaluating the obtained data we shall assume that the reflected conduction electrons can go over to those states which are governed by the symmetry group corresponding to a two-dimensional surface lattice and by the geometry of the Fermi surface of a metal. The examined geometric situation is illustrated in Fig. 3, which shows the shadow projection of the Fermi surface of tungsten on the (110) plane.[12] We shall investigate the electron reflection assuming that the symmetry was reduced by a factor of 2. According to the established terminology, theis corresponds to a two-dimensional structure (2×2), illustrated in Fig. 2c and in the inset in Fig. 1. Since the vectors of the reciprocal surface lattice are now equal to $\pi\mathbf{b}_{1,2}$ rather than $2\pi\hbar\mathbf{b}_{1,2}$ the reciprocal lattice points corresponding to them can be situated in both the electronic

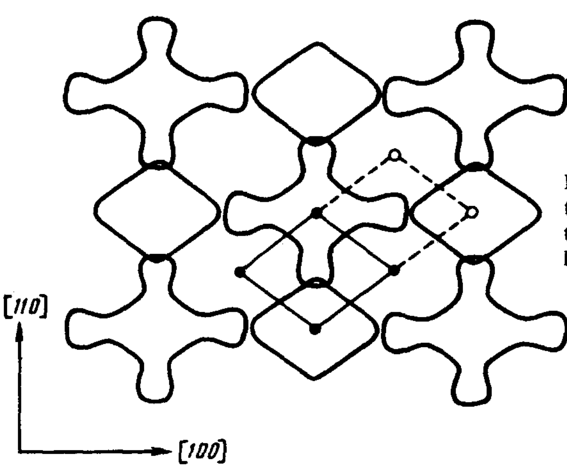

FIG. 3. Projection of the Fermi surface on the (110) plane. The solid lines represent the (2×1) reciprocal lattice and the dashed lines complete the cell to (2×2).

and hole regions of the Fermi surface. In addition, a part of the Bragg scattering is not realized, since some of the lattice points do not coincide with any regions of the Fermi surface. Thus, an indeterminate momentum in the tangential directions may lead to transitions between the electronic jack and the hole "octahedron": the impurity ordered oxygen film in this case includes the surface electron recombination mechanism.

We now examine another situation that arises as a result of formation of the (2×1) structure (Fig. 2b and inset in Fig. 1). For this structure the intermediate momentum in the tangential directions may lead to transfers between physically equivalent points in the phase space. Such structures evidently produce specular reflections. We also not that as a result of "disintegraton" of the film in the limiting case of random distribution of adsorbed particles, the surface scattering, which is apparently isotropic in nature, is accompanied by intraband and interband transitions.

Returning to the experimental data in Fig. 1, we should mention the following fact. The first maximum on the $R_{xx}(t)$ curve corresponds to the region of disordered adsorption film and is apparently isotropic to the electron reflection. The appearance of a (2×1) phase leads to a sharp decrease of the plate's resistance and to an electron reflection close to a specular. A transition of the (2×1) structure again increases the R_{xx} resistance. A recombination of the charge carriers in this case reduces the surface current in the plate, since the drift of the electrons and holes, which form the static spin effect, occurs in different directions; this reduces the quasi-particle mobility at the sample's surface.[13,14]

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