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FINE STRUCTURE IN TWO-DIMENSIONAL ELECTRON SCATTERING

Theory is combined with experiment to identify an interference effect in low-energy-electron scattering patterns. The effect involves electron diffraction and the reflection of diffracted electrons from the surface potential barrier of the crystal.

INTRODUCTION

Surface structure and composition play important roles in the interactions of an object with its environment. In many areas of technology, films are added to devices and fabrications to protect them physically, electrically, or chemically and to extend their wear lifetimes. The structure and composition of surfaces determine electrical and magnetic properties in the interfacial region between the solids and the surrounding media. Charged particles of low energy are affected by electrical and magnetic potentials that exist in the vicinity of the surface. Therefore, if one probes a surface with a low-energy beam of electrons, for example, one expects to observe vestiges of surface structures, including the potentials, in the pattern of scattered electrons. In this update of previous results,[1,2] we examine fine structure in electron diffraction patterns caused by electrons scattered from an electrical surface barrier interfering with electrons scattered from the first atomic layer.

EXPERIMENT AND THEORY

The technique known as current image diffraction (CID) was invented at APL in 1982.[3] The experimental configuration has been described in previous articles.[3,4] An electron beam of uniform energy is scanned across a fastidiously prepared surface of a single crystal, and the current absorbed in the crystal is measured as a function of polar and azimuthal angles, θ and ϕ, respectively. The results of the measurement, displayed on a cathode ray tube, reveal diffraction patterns with symmetry that is characteristic of the crystal structure. The interaction of the electron beam with the solid is complex. Fundamentally, some of the current in the beam is absorbed in the crystal, and some is reflected from it. In our experiment, the absorbed current is collected and used to form diffraction images that contain information on the crystal structure and composition.

When the energy of the impinging electrons is less than about 50 eV, the effects of scattering from the surface barrier become more apparent than at higher energies. The barrier is a result of the image charge induced in the metal crystal by the incoming electron. The influence of the surface barrier is relatively strong when the parameters that characterize the electron beam relative to the surface make possible the existence of a new diffracted beam. This situation, referred to as the evanescent condition, is a function of the energy and polar coordinates of the electron beam and the unit cell of the surface. A diffracted electron at near-evanescent conditions has a greater probability of being reflected from both the surface barrier and the atomic layers when the energy of the incident electron beam is less than 50 eV than when it is higher. Thus, as indicated schematically in Figure 1, electrons scattered from the surface barrier interfere with those scattered from the bulk crystal. This situation is manifested by fine structure in the diffraction pattern. Embedded in this pattern is information about the surface barrier that can be extracted by means of dynamical low-energy-electron diffraction calculations that include a surface barrier.

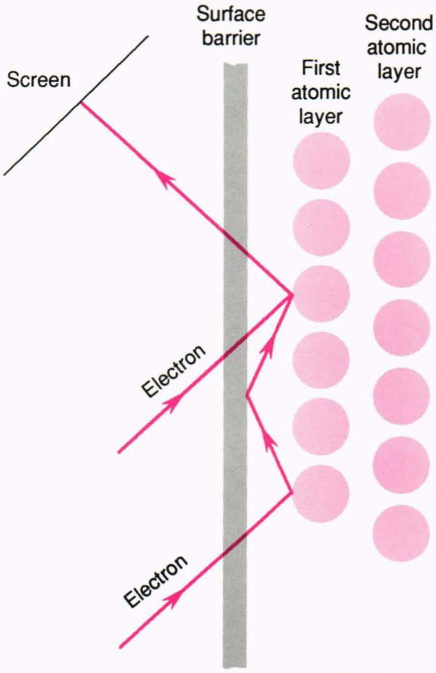

Figure 1. Schematic showing electron interference. Electrons specularly reflected from the first atomic layer interfere with those diffracted into a near-evanescent beam, are reflected from the surface barrier, and are diffracted back into the specular beam.

RESULTS

In a previous article,[2] we presented experimental images of electron interference. Figure 2 reproduces part of one of the figures from that article. The CID pattern obtained at 13.0 eV from the (001) surface of aluminum has the expected fourfold symmetry with the interference patterns of concern observed as two lines, both perpendicular to the {0,1} family of directions, as indicated in the figure. As the energy increases, the interference pattern approaches and crosses the center of the image. Omitting the details of the computations, which may be found elsewhere,[5,6] Figure 3 shows the polar angular dependence of electron reflectivity as given by a dynamical calculation along the [0,1] azimuth for the (001) surface of aluminum for electron energies of 18 and 20 eV. The structure in the curve for 20-eV electrons at about $\theta = 2.45°$ exhibits very sharp peaks, as expected, for the barrier interference effect. That angle is near the evanescence condition of the lowest-order diffraction beams from this surface. Thus, according to the calculations, when a diffracted beam starts to exit the crystal at a near-grazing angle, a portion of the beam is reflected from the surface barrier, is rediffracted from the first atomic layer back into the undiffracted or specular beam, and then exits the crystal. Hence, the calculations corroborate the conclusion that the fine structure observed in CID patterns at low energy is an interference effect.

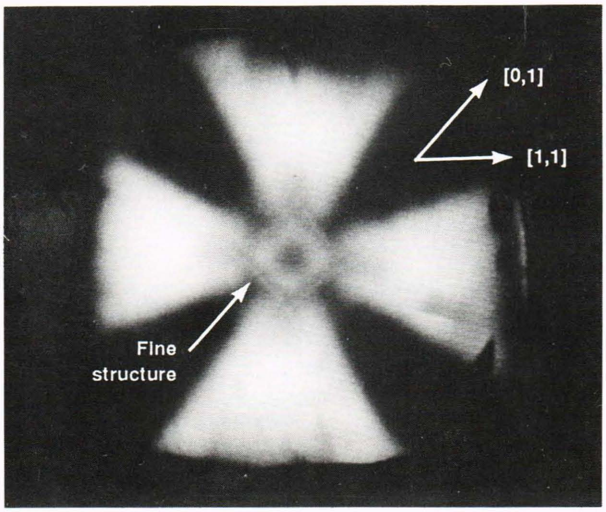

Figure 2. Low-energy diffraction pattern from an aluminum (100) surface showing fine structure in the absorbed current image for a beam energy of 13 eV. The two-dimensional crystal directions are indicated by the arrows.

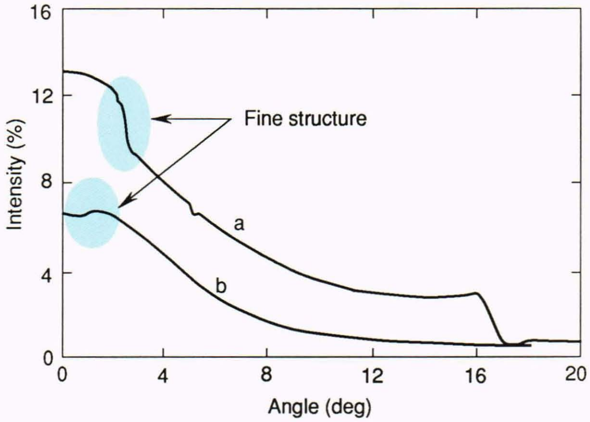

Figure 3. Calculated angular dependence of the electron reflectivity for the modified image potential barrier model. The electron energies are (curve a) 20 eV and (curve b) 18 eV.

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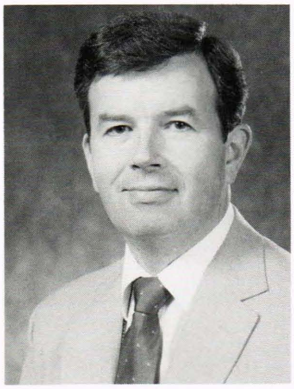
THE AUTHORS



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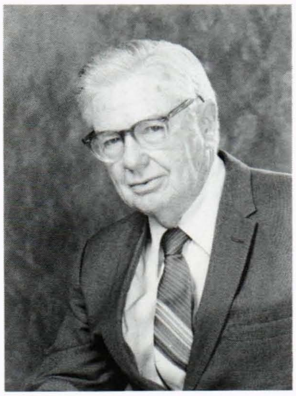

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