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Electron Microscopy Imaging and "3D" Reconstruction of Crystal Surfaces [1]

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While normally operated in transmission mode, the transmission electron microscope (TEM) can be operated to collect the electrons reflected off the crystal surfaces for forming the real space images of these surfaces. This technique, called reflection electron microscopy (REM) [2, 3, 4] is an extension of a more familiar technique, reflection high energy electron diffraction (RHEED). In REM, high energy electrons are reflected off the surface of the specimen to form the RHEED pattern. A high intensity spot in the RHEED pattern is then selected with the objective aperture. Electrons passing the aperture go through the lens system and form an image on the view screen of the electron microscope.

The REM image of the surface is a foreshortened picture equivalent to viewing the surface at a glancing angle of no more than 5°. The power of REM lies in its capability of detecting single defect, such as dislocation, stacking fault, atomic step, etc., on the crystal surface. It is also useful in imaging the non-uniform distributions of these defects, domains of reconstructions, and the periodic structure of surperlattices.

All images are two dimensional. REM images are no exceptions, but when the surface fluctuation is more than a few atomic layers, the reflected electron intensity may be affected by mor-phology. Consequently, the REM image may appear to be 3D although it is actually still a density distribution in the plane of the picture. Then the 3D model of the surface can be reconstructed from one or more REM images, based on information on the crystalline structure of the surface extracted from the sim-ultaneous RHEED data. This process usually requires modeling on a computer and may require more than one REM image of the same surface area.

Fig. 1. This REM image of a polished α-Al_2O_3(1100) surface appears 3D and is actually constructed with two types of facets unparallel to each other.

Spatial resolution of REM is about 1 to 2 nm, which lies between that of STM and SEM. In the surface normal direction, REM is capable of detecting one atom high steps. Since contrast of REM comes from diffraction, the technique is very sensitive to crystalline structure of the surfaces. Geometry of the surface can be precisely measured from REM and RHEED.

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