Physics of Nanotechnology

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Surface/Structural Analysis

- Electron techniques
  - Reflection high energy electron diffraction
  - Low energy electron diffraction
  - Auger electron spectroscopy
- X-ray techniques
  - X-ray diffraction,
  - X-ray reflectivity,
  - X-ray photoelectron spectroscopy

Reflection high-energy electron diffraction

Reflection high-energy electron diffraction (RHEED) is a technique used to characterize the surface of crystalline materials. RHEED systems gather information only from the surface layer of the sample, which distinguishes RHEED from other materials characterization methods that also rely on diffraction of high-energy electrons. Transmission electron microscopy, another common electron diffraction method samples the bulk of the sample due to the geometry of the system. Low-energy electron diffraction (LEED) is also surface sensitive, but LEED achieves surface sensitivity through the use of low energy electrons.

Introduction

A RHEED system requires an electron source (gun), photoluminescent detector screen and a sample with a clean surface, although modern RHEED systems have additional parts to optimize the technique. The electron gun generates a beam of electrons which strike the sample at a very small angle relative to the sample surface. Incident electrons diffract from atoms at the surface of the sample, and a small fraction of the diffracted electrons interfere constructively at specific angles and form regular patterns on the detector. The electrons interfere according to the position of atoms on the sample surface, so the diffraction pattern at the detector is a function of the sample surface. Figure 1 shows the most basic setup of a RHEED system.

Surface diffraction

- In the RHEED setup, only atoms at the sample surface contribute to the RHEED pattern. The glancing angle of incident electrons allows them to escape the bulk of the sample and to reach the detector. Atoms at the sample surface diffract (scatter) the incident electrons due to the wavelike properties of electrons.
- The diffracted electrons interfere constructively at specific angles according to the crystal structure and spacing of the atoms at the sample surface and the wavelength of the incident electrons. Some of the electron waves created by constructive interference collide with the detector, creating specific diffraction patterns according to the surface features of the sample. Users characterize the crystallography of the sample surface through analysis of the diffraction patterns. Figure 2 shows a RHEED pattern.

- Two types of diffraction contribute to RHEED patterns. Some incident electrons undergo a single, elastic scattering event at the crystal surface, a process termed kinematic scattering. Dynamic scattering occurs when electrons undergo multiple diffraction events in the crystal and lose some of their energy due to interactions with the sample. Users extract non-qualitative data from the kinematically diffracted electrons. These electrons account for the high intensity spots or rings common to RHEED patterns. RHEED users also analyze dynamically scattered electrons with complex techniques and models to gather quantitative information from RHEED patterns.

Figure 1. Systematic setup of the electron gun, sample and detector /CCD components of a RHEED system. Electrons follow the path indicated by the arrow and approach the sample at angle θ. The sample surface diffracts electrons, and some of these diffracted electrons reach the detector and form the RHEED pattern. The reflected (specular) beam follows the path from the sample to the detector

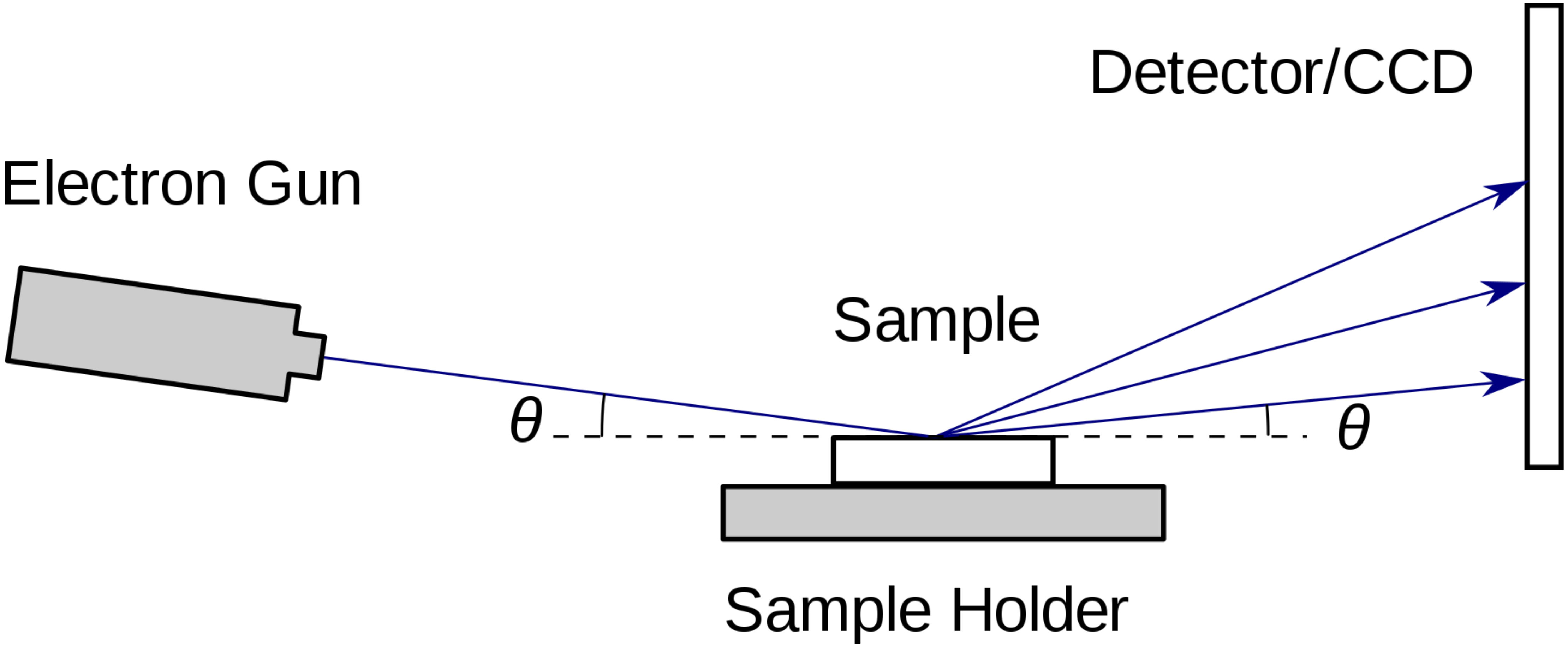

Figure.2 The incident electron beam is incident on an identical surface structure at a different azimuth angles in a) and b). The sample is viewed from the top in the figure, and the points correspond to the reciprocal lattice rods, which extend out of the screen. The RHEED pattern would be different for each azimuth angle