Instrument Presentation

Reflection high-energy electron diffraction (RHEED)

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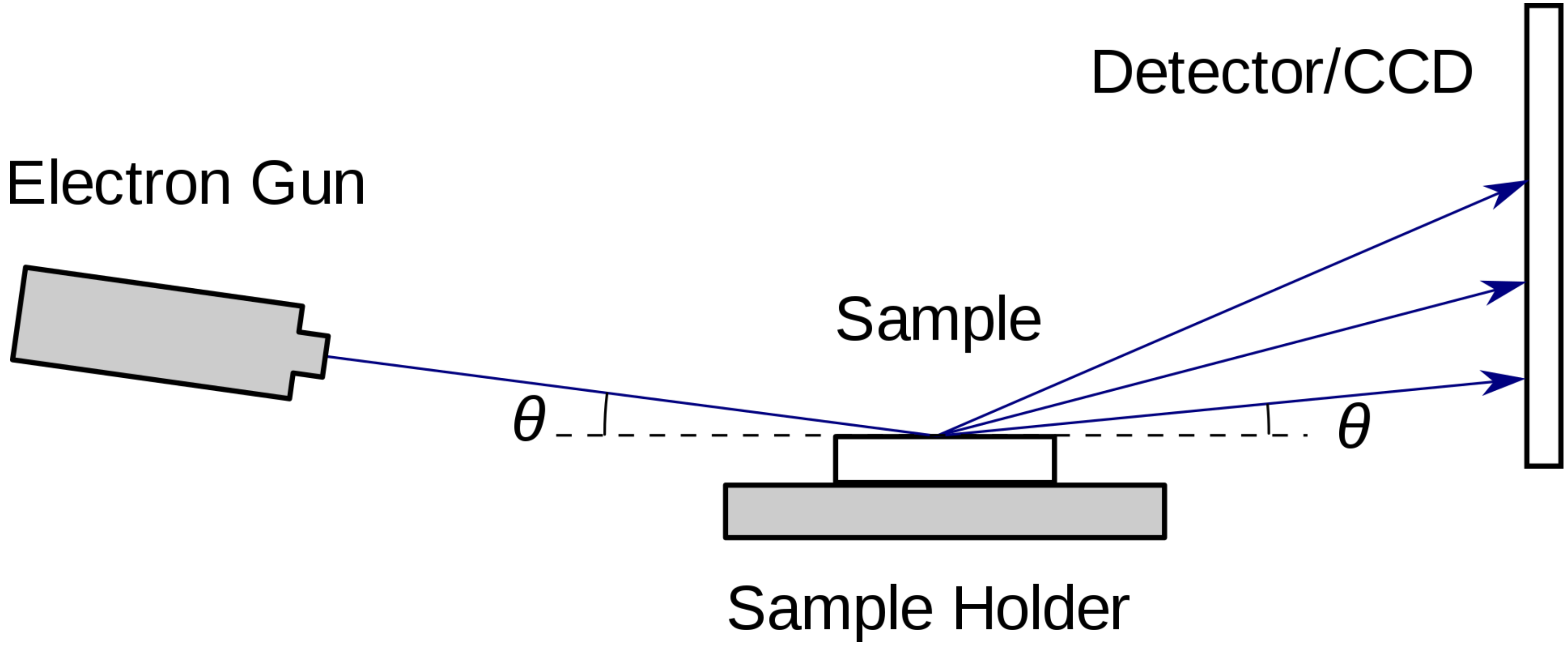
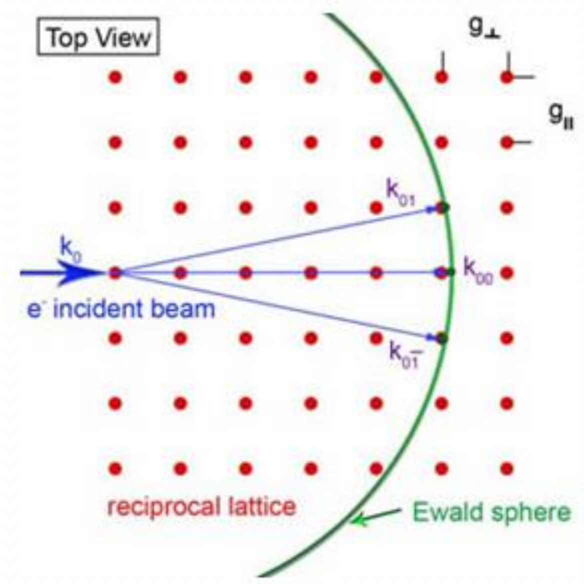
What is RHEED?

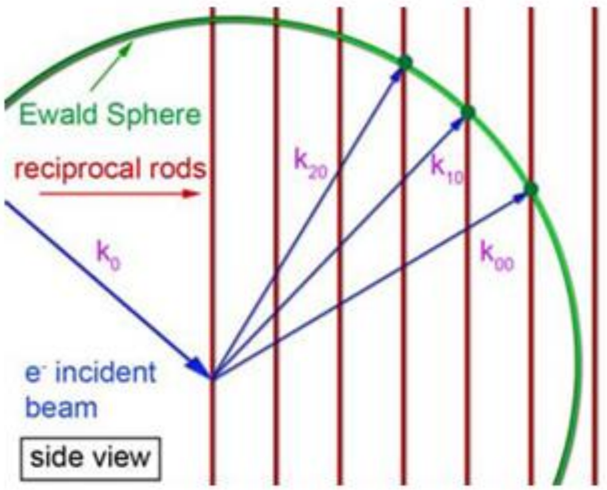
Reflection high-energy electron diffraction (RHEED) is a diffraction technique used to characterize the surface of crystalline materials by a collimated beam of high energy electrons (5-100 keV) and observation of diffracted electrons on a phosphor screen.

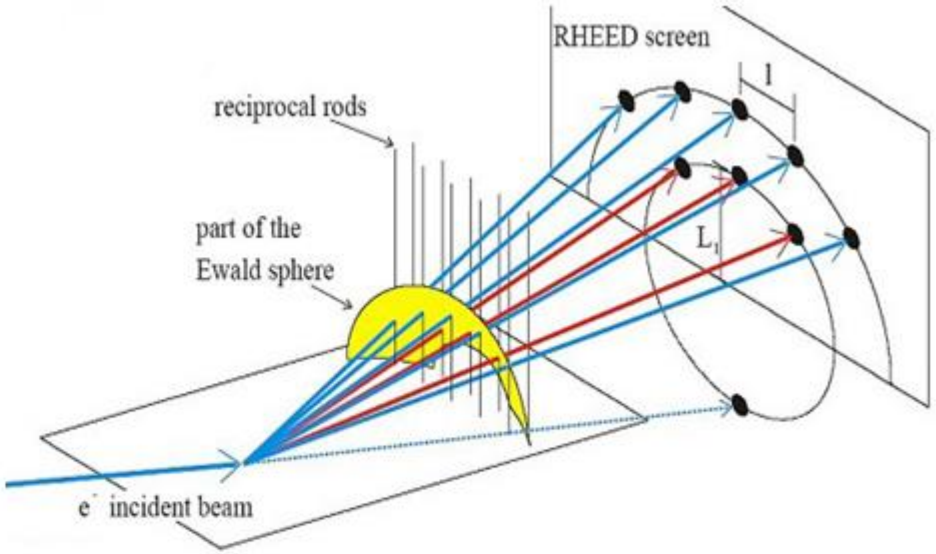


Components: Electron source (gun), photoluminescent detector screen and a sample with a clean surface

Operating principle

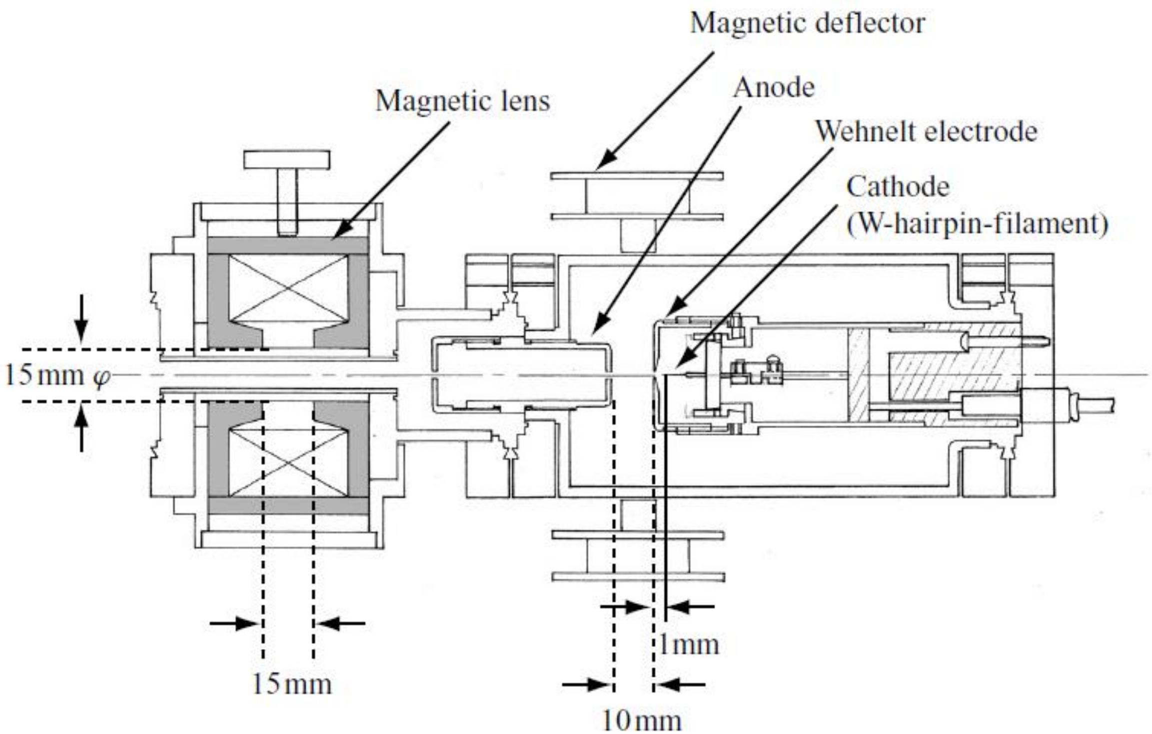






Electron gun

- Tungsten filaments are the primary electron source for the electron gun due to the low work function. The tungsten filament is the cathode and a positively biased anode draws electrons from the tip of the tungsten filament.
- The magnitude of the anode bias determines the energy of the incident electrons. The optimal anode bias is dependent upon the type of information desired. At large incident angles, electrons with high energy can penetrate the surface of the sample and degrade the surface sensitivity of the instrument.

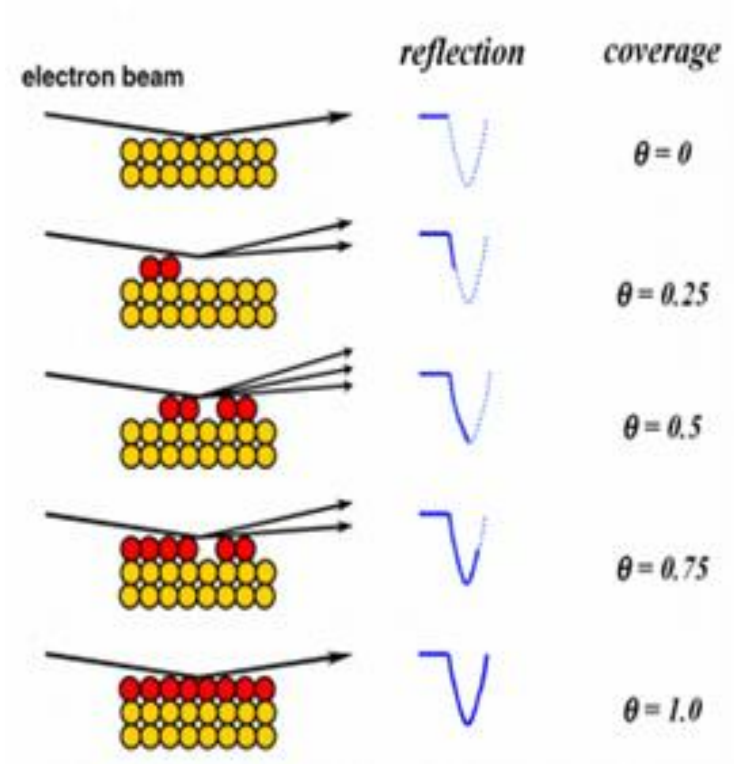


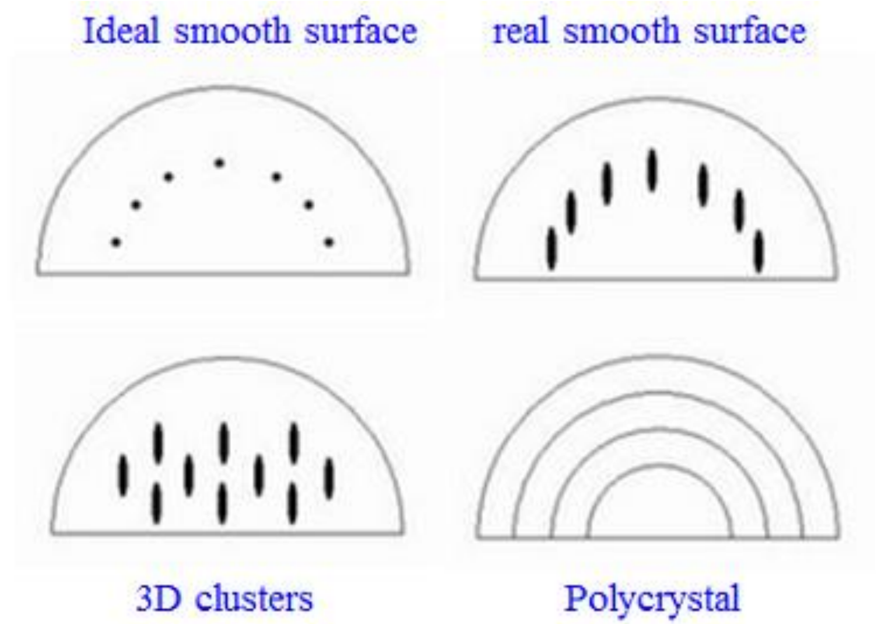
Schematic illustration of an electron gun

- One magnetic and one electric field focus the incident beam of electrons. An adjustable magnetic lens focuses the electrons onto the sample surface after they pass through the anode. A typical RHEED source has a focal length around 50 cm.

Sample surface

The sample surface must be extremely clean for effective RHEED experiments. Contaminants on the sample surface interfere with the electron beam and degrade the quality of the RHEED pattern. RHEED users clean sample surface by cleaving them in vacuum chamber prior to RHEED analysis. Large samples, or those that are not able to be cleaved can be coated with a passive oxide layer prior to analysis. Subsequent heat treatment under the vacuum removes the oxide layer and exposes the clean sample surface.





Growth monitoring by RHEED

Vacuum requirements

- It is known that gas molecules diffract electrons and affect the quality of the electron gun, RHEED experiments are performed under vacuum. The RHEED system must operate at a pressure low enough to prevent significant scattering of the electron beams by gas molecules in the chamber.

- At electron energies of 10 keV, a chamber pressure of 10^{-5} mbar or lower is necessary to prevent significant scattering of electrons by the background gas.

- In practice, RHEED systems are operated under ultra-high vacuum (UHV). The chamber pressure is minimized as much as possible in order to optimize the process.

- The vacuum conditions limit the types of materials and processes that can be monitored in situ with RHEED.

RHEED vs LEED

RHEED

- In RHEED, high energy electrons provide large elastic scattering cross-section for forward-scattered electrons with a grazing incidence to keep short penetration depth
- Theory is not well developed as compared to LEED
- Provides information related to the surface
- Diffraction pattern: streaks; sensitive to roughness

LEED

- In LEED, low energy electrons provide large elastic scattering cross-section for back-scattered electrons with short penetration depth
- A well developed theory exists and hence quantitative analysis is possible
- Provides information not only in-plane but also out-of-plane
- Diffraction pattern: spots. Disadvantage is the normal incidence to the sample surface

Thank you