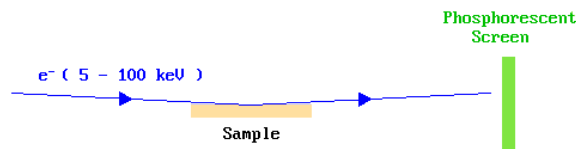


## 6.3: Reflection High Energy Electron Diffraction (RHEED)

Low Energy Electron Diffraction (LEED) utilizes the inherent surface sensitivity associated with low energy electrons in order to sample the surface structure. As the primary electron energy is increased not only does the surface specificity decrease but two other effects are particularly noticeable

1. forward scattering becomes much more important (as opposed to the backward scattering observed in LEED)
2. the scattering angle (measured from the incident beam direction) tends towards 180 degrees for back-scattering and 0 degrees for forward scattering.

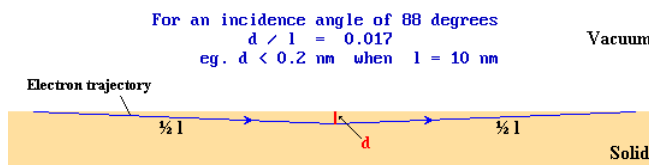
In order to extract surface structural information from the diffraction of high energy electrons, therefore, the technique has to be adapted and the easiest way of doing this is to use a reflection geometry in which the electron beam is incident at a very grazing angle - it is then known as **Reflection High Energy Electron Diffraction (RHEED)**.



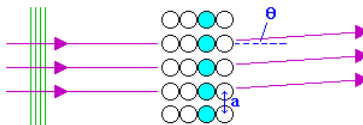
The diagram above shows the basic set-up for a RHEED experiment, with the sample viewed edge-on. In practice the display screen is usually a phosphor coating on the inside of a vacuum window (viewport) and the diffraction pattern can be viewed and recorded from the atmospheric side of the window. The small scattering angles involved are compensated for by using relatively large sample/screen distances.

The sample can be rotated about its normal axis so that the electron beam is incident along specific crystallographic directions on the surface.

In order to understand the diffraction process we need to consider how the electron beam can interact with the regular array of surface atoms in this experimental geometry. It is worth noting, however, that the use of glancing incidence ensures that, despite the high energy of the electrons, the component of the electron momentum perpendicular to the surface is small. Under these conditions an electron may travel a substantial distance through the solid (in accord with the much longer mean free path of such high energy electrons) without penetrating far into the solid. The technique, consequently, remains surface sensitive.



Now consider the **plan view** of a surface illustrated below in which we concentrate attention on just one row of atoms (shown shaded in pale blue) running in a direction perpendicular to the incident electron beam (incident from the left)



In addition to the change in momentum of the electron perpendicular to the surface, which leads to the apparent reflection, the diffraction process may also lead to a change in momentum parallel to the surface, which leads to the deflection by an angle  $\theta$  when looked at in plan view. Constructive interference occurs when the path difference between adjacent scattered "rays" ( $a \sin \theta$ ) is an integral number of wavelengths (i.e. the same basic condition as for LEED). This gives rise to a set of diffracted beams at various angles on either side of the straight through (specularly reflected) beam.

#### What, if any, advantages does RHEED offer over LEED?

In terms of the quality of the diffraction pattern absolutely none ! - moreover, diffraction patterns have to be observed for at least two sample alignments with respect to the incident beam in order to determine the surface unit cell. However, ....

1. The geometry of the experiment allows much better access to the sample during observation of the diffraction pattern. This is particularly important if it is desired to make observations of the surface structure during growth of a surface film by evaporation from sources located normal to the sample surface or simultaneous with other measurements (e.g. AES, XPS).
2. Experiments have shown that it is possible to monitor the atomic layer-by-atomic layer growth of epitaxial films by monitoring oscillations in the intensity of the diffracted beams in the RHEED pattern.

By using RHEED it is therefore possible to measure, and hence also to control, atomic layer growth rates in **Molecular Beam Epitaxy** (MBE) growth of electronic device structures - this is by far and away the most important application of the technique.

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