abstract

An investigation into the information provided by the concurrent use of in situ reflection high energy electron diffraction (RHEED) and reflection electron energy loss spectroscopy (REELS) was performed. These two analytical methods were employed during growth by molecular beam epitaxy (MBE) of metal, semiconductor and superconductor thin films. Surface sensitivity of the REELS spectrometer was found to be less than 1 nm for 20 KeV electrons incident at a 2 degree angle to an atomically flat film surface, agreeing with the standard electron escape depth data when adjusted for the incident angle.

Film surface topography was found to strongly influence the REELS spectra and those findings were correlated with in situ RHEED patterns and ex situ analysis by atomic force microscopy (AFM). It was observed in all the experimental results that from very smooth films the plasmon peak maxima did not fall at the predicted surface plasmon values but at slightly higher energies, even for nearly atomically flat films. These results suggested the REELS plasmon loss spectra are always a combination of surface and bulk plasmon losses. The resulting summation of these two types of losses shifted the peak to below the bulk plasmon value but held its minimum to a higher energy than the pure surface plasmon value.

Observation and interpretation of the diffraction pattern and energy loss spectrum allowed chemical analysis of the material. RHEED and REELS during resonant tunneling device growth allowed for rapid and efficient adjustment of process parameters, enabling production of devices exhibiting negative differential resistance. Plasma cleaning of natively oxidized Nb films, then nitriding the clean surface produced RHEED patterns and REELS spectra that clearly changed from that of native Nb oxide to a metallic Nb surface then to one characteristic of NbN.

One may easily discern from observation and interpretation of the RHEED diffraction image with the REELS spectrum whether a thin film growth process is proceeding as desired. The paired use of these two instruments allow for better interpretation of thin film composition, surface morphology and texture than either of them used alone.