MOPM
MEXICAN OPTICS AND PHOTONICS MEETING
September 9 -11, 2015
Leon, Guanajuato Mexico

Semiconductor crystal growth: Real-time optical monitoring

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ABSTRACT

The fabrication of atomic-sharp interfaces in modern electronic devices based on zincblende semiconductors demands of real-time control of the epitaxial growth process. Light probes, being non-invasive, result very convenient tools to monitor such process in a closed-loop control system. For this purpose, light is introduced into the growth chamber and, upon reflection on the growing surface, exits the chamber for analysis. Depending on photon energy, nevertheless, light impinging on the substrate penetrates to a depth somewhere in the range from 50-500 monolayers, thus limiting the surface sensitivity of the probe. D.E. Aspnes demonstrated more than two decades ago that this limitation could be overcome by employing a reflectance anisotropy technique that measures the difference in reflectance for two orthogonal crystal directions. This technique takes advantage of the fact that while zincblende crystals are nominally isotropic, the reconstruction of the surface during epitaxial growth renders the reflectivity anisotropic.

Despite the demonstrated surface sensitivity of the reflectance anisotropy technique, its use as a probe for epitaxial growth monitoring has been hindered for the lack of reflectance anisotropy spectrometers fast enough to follow atomic processes during growth. In this regards, most of the results reported to date were obtained at a single wavelength. In this talk, Reflectance Anisotropy Spectroscopy (RAS) will be first introduced and some examples of application of this technique will be discussed. Further, some recent results on real-time monitoring of III-V semiconductor homoepitaxial and heteroepitaxial growth will be presented. Such results were obtained by employing a recently developed rapid RAS spectrometer with time-resolution down to 100 ms per spectrum. The sensitivity of such spectrometer to investigate surface processes such as adatom diffusion and incorporation, and surface coverage quantification, will be discussed.