

Combining *in-situ* measurements in molecular beam epitaxy : Study of $Al_xGa_{1-x}As$ properties at growth temperature

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In-situ measurement is a key feature to better understand and precisely control the growth by molecular beam epitaxy (MBE) of VCSEL structures. However, no universal tool has been developed today to control heterostructure growths in real time [1–3].

In this work, we are developing a methodology to deduce the growth rate and the optical constants at growth temperature (500-600°C) of thin film grown by MBE from *in-situ* measurement of spectral reflectance. The reflectance is measured over a wide spectral range (390 – 1700 nm), allowing the study of epitaxial alloys nearly lattice-matched on GaAs such as $AlGaAs$ or $InGaAs$. Moreover, the knowledge of the optical constants of these alloys at the growth temperature is a key milestone in order to monitor and control the MBE growth of VCSEL in the near infrared range (850-940nm).

By combining the *in-situ* spectral reflectance, and the accurate optical constants database, it is possible to directly deduce the growth rate. In order to ensure precise and reproducible estimation, we have to measure independently the temperature and the alloy composition of the growing film, respectively by optical absorption edge and [4] and wafer curvature measurements [5].

Our methodology to retrieve the complex refractive indices of $Al_xGa_{1-x}As$ at growth temperature relies on *in-situ* reflectance measurement, as illustrated in figure 1a, in combination with *ex-situ* X-ray diffraction measurements (HRXRD). The thicknesses of the sample will be confirmed through FTIR measurement. The accuracy of the thickness measurement by HRXRD is analyzed as well as its impact on the deduced optical indices. As a result the wavelength dispersion of the refractive indices can be obtained as shown on figure 1b.

In the future work, based on this optical constant database of $Al_xGa_{1-x}As$ materials, our goal is to control the growth rate of complex VCSEL heterostructure from real time reflectance and wafer curvature measurements.

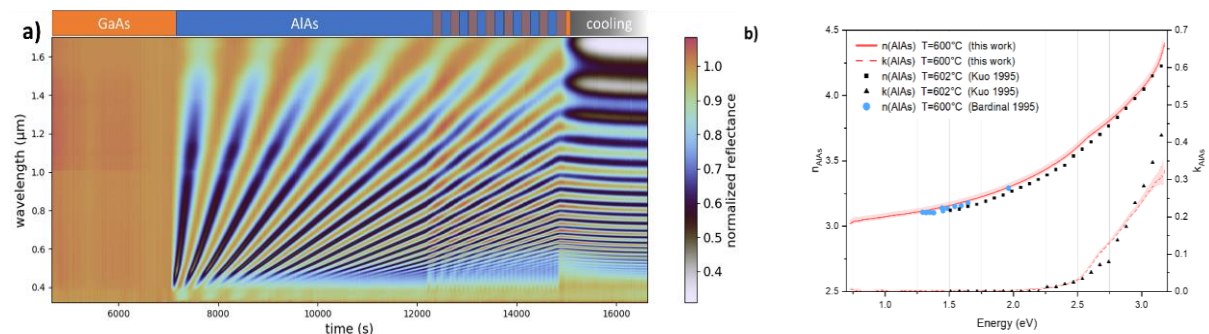


Fig. 1 a) *In-situ* spectral reflectance measurement during the growth, **b)** Deduced refractive indices n and k of AlAs at 600°C and comparison to literature.

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