Global COE program "Electronic Devices Innovation"

Global Seminar

Material research based on GaInNAs for the next generation opto-electronic devices

5 March, 2008, 13:30 – 14:30

Room E3-112, Division of Electric, Electronic and Information Engineering,

Graduate School of Engineering, Osaka University, Suita, Osaka, Japan

Speaker

Esperanza Luna

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Esperanza Luna was born in Madrid (Spain) on December 19th,1974. She received the B.E. and M.S. degrees in Physics (Materials Science) from Universidad Complutense de Madrid in 1997. She obtained the PhD degree in 2004 at the High Technical School of Telecommunications Engineering (Universidad Politécnica de Madrid) with a thesis entitled " Photovoltaic double barrier quantum well infrared photodetectors, operating in the 3-5 μm spectral region". She has been involved in Solid State Physics research for the last 10 years, with experience in the growth by molecular-beam epitaxy (MBE) of III-V semiconductors based on GaAs and their optical, electrical and structural characterization. Since October 2004, she works as a postdoctoral researcher at the Paul-Drude-Institute in Berlin on the characterization by transmission electron microscopy (TEM) of III-V semiconductor heterostructures. At present, her main research topics include the study of the interfaces of dilute nitrides (Ga,In)(N,As) heterostructures and the TEM analysis of MBE-grown (Ga,In)(N,As) quantum wells with Sb as a surfactant. Other research topics include the structural characterization of group-III nitrides nanostructures and of InSb-based heterostructures for laser emission in the mid-infrared.

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Abstract

Study by transmission-electron-microscopy of the effect of the growth conditions on the morphology of (Ga,In)(N,As,Sb) quantum wells grown by molecular-beam-epitaxy

Quaternary (Ga,In)(N,As) quantum wells (QWs) on GaAs are materials of interest due to their band gap tunability, which is promising for the realization of 1.3 µm and 1.55µm telecommunication lasers. The incorporation of large amounts of In (> 30%) and N (> 3%) into the QWs is required for the emission above 1.55 µm. This, however, enhances the phase separation tendency related to the inherent large miscibility gap and complicates the growth of high-quality epitaxial layers. The Sb-mediated growth is reported to expand the growth window for layers with high optical quality emitting at 1.55 µm. At the same time, several groups have reported emission beyond 1.5 µm from (Ga,In)(N,As) QWs without Sb, using specific growth conditions characterized by a lower substrate temperature (T_s) and a lower As beam equivalent pressure (BEP), compared to the commonly used T_s of 400-450 °C and V/III BEP ratio (R_{BEP}) of 15-20. Despite the high photoluminescence (PL) reported, the impact of T_s, R_{BEP} and the supply of Sb on the morphological, structural and composition properties is still unclear.

In this work, $In_{0.36}Ga_{0.64}N_{0.04}As_{0.96}$/GaAs multiple QWs on GaAs(001) are grown by plasma-assisted molecular beam epitaxy (MBE) and analyzed using transmission electron microscopy (TEM) techniques. One set of samples is grown using the *low T_s-low As* growth concept. The samples with (Ga,In)(N,As,Sb) QWs are grown at the conventional *high T_s (420°C) - high R_{BEP}* conditions under different Sb fluxes.

In the samples grown at *low T_s - low As*, we investigate the impact of T_s and R_{BEP} on the layers morphology and surface roughening. In addition, we determine the local In and N concentration profiles along the growth direction. We are able to directly detect the existence of In segregation and its dependence with the growth conditions. In this case, the In distribution *inside the QW* is described by Muraki´s segregation model, but segregation models fail in reflecting the concentration profile *at the interfaces*. In order to characterize the interface-related part of the profile, we introduce a model that is based on sigmoidal functions. The model includes the interface thickness as the main fitting parameter, thus allowing a quantitatively characterization of the interfaces. The thermal stability of the (Ga,In)(N,As)/GaAs interfaces and their interplay with segregation effects are discussed.

Concerning the Sb-containing QWs, our work is mainly focused in understanding the role of Sb with respect to the layer morphology. We find that (Ga,In)(N,As) QWs with and without Sb grown under the same conditions exhibit a similar morphology, with smooth and abrupt interfaces in both cases. No direct perceptible improvements in the structural quality arise from the introduction of Sb. Moreover, contrast variations and surface roughening at the upper interface are observed in the TEM micrographs from QWs grown under high Sb fluxes ($2.4x10^{-8}$ torr). These features can be explained by inhomogeneously incorporated Sb. The fact that the Sb containing QWs show a less perfect morphology, but an improved PL efficiency compared to the Sb-free material, suggests that Sb modifies the growth kinetics and thus reduces the introduction of non-radiative point defects. We propose that for low Sb-fluxes Sb mainly behaves like a surfactant, while for high Sb-fluxes, Sb mainly behaves like a regular group V-element that is incorporated into the lattice.