Large effective mass enhancement of the $InAs_{1-x}N_x$ alloys in the dilute limit probed by Shubnikov-de Haas oscillations

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There are currently considerable interest in III-V alloys containing nitrogen because of their potential application for use in infrared devices and their interesting physical properties. In contrast to conventional alloys in which electronic properties vary smoothly with composition, the incorporation of even a small fraction of nitrogen into the host III-V crystal brings about drastic modifications of the electronic properties of the alloys. The most renowned peculiar behavior is the significant band-gap reduction. This anomaly has motivated many theoretical efforts to understand the observed results. The band anti-crossing model and the impurity band model are most widely discussed in the research communities. Yet the actual underlying mechanism is still being debated and this issue stills needs further theoretical tests and experimental investigations.

For optoelectronic applications in the mid-infrared wavelengths, the InAsN-based heterostructures are very promising. Recently, it has been shown that a better heterointerface and a better carrier confinement can be achieved by replacing InAs with InAsN alloys [1]. Hence the study on InAsN alloys improves optoelectronic device qualities and broadens our knowledge of III-N-V alloys. In this paper, we present our investigation of Shubnikov-de Haas (SdH) oscillations of two-dimensional electron gas formed in composition-dependent InAsN/InGaAs single quantum wells (QW). The samples are grown on InP substrates by gas source molecular beam epitaxy and a radio-frequency plasma nitrogen source. The photoluminescence (PL) peak energy decreases after nitrogen is incorporated. This agrees with the bowing effect due to the incorporation of nitrogen atoms. The nitrogen content can be determined by PL peak positions as well as X-ray diffraction. The largest nitrogen content is estimated to be 0.4 %. The composition-dependent effective mass value is determined from the SdH measurements. For the sample with nitrogen composition 0.4%, a large effective mass of 0.1 m_0 is found. The enhancement of the effective mass is mainly due to the incorporation of nitrogen atoms in the InAs lattice, which is consistent with a recent study on InAsN bulk alloys [2]. The large increase of the effective mass cannot be explained by the simple band anti-crossing model. Our result is useful for reexamining the validity of assumptions in different theoretical approaches and for the optimization of devices based on InAsN/InGaAs QWs.

References:
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[2] W. K. Hung *et al*., Appl. Phys. Lett. **80**, 796 (2002).

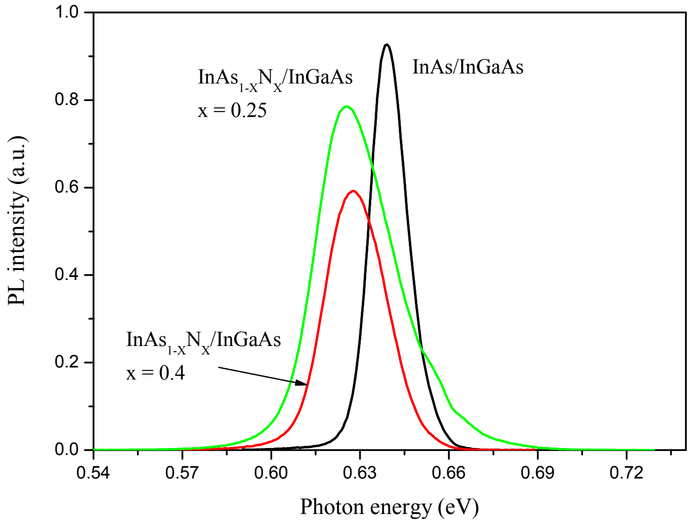
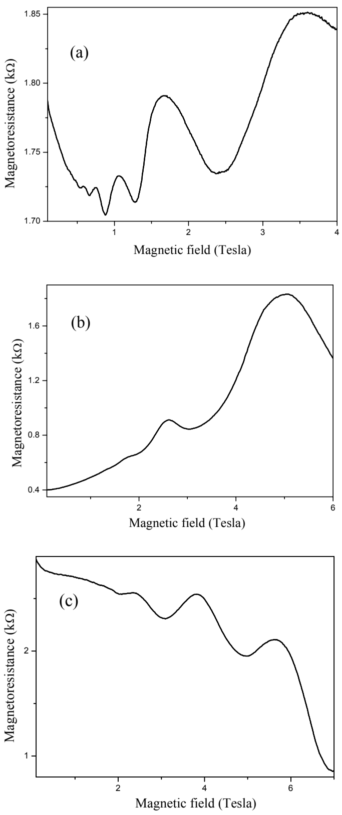


Figure 1. Photoluminescence spectra of $InAs_{1-x}N_x/InGaAs$ QWs taken at temperature 10 K.



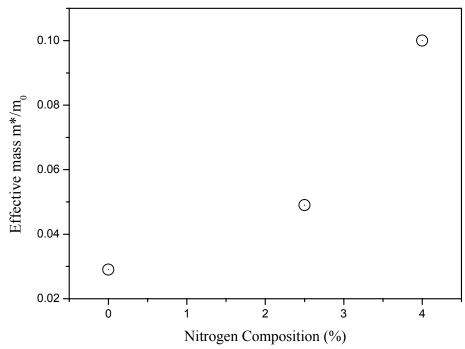


Figure 3. The composition-dependent effective mass.

Figure 2. Typical SdH oscillations at temperature 0.33 K of the $InAs_{1-x}N_x/InGaAs$ QWs samples (a) x = 0 (b) x= 0.25 (c) x = 0.4.