Strain relaxation in submonolayer InAs/GaAs quantum structures

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Up-converted photoluminescence (UPL) in semiconductor quantum dots (QDs) and quantum wells (QWs) has attracted much attention in recent years for applications such as intermediate band solar cells [1]. Recently, we reported the importance of confined states for improving the efficiency which can be formed by monolayer thick InAs QWs [2]. However, the lattice mismatch between InAs and GaAs limits the stacking numbers of QDs and QWs, and further the UPL efficiency. In this paper, we study the effect of strain relaxation on the optical properties of InAs/GaAs MQW structures submonolayer (SML) InAs layers.

Four samples were grown on s.i. GaAs(001) substrates by MBE. The structures consist of a 200nm GaAs buffer layer, InAs/GaAs MQWs with identical thickness and equivalent average In composition of 20% and a 5nm GaAs cap layer, as shown in Table 1. PL measurements were carried out using a Ti:sapphire laser for excitation at λ_{ex}=780nm at 4K and a liq. N_2 cooled InGaAs diode array detector.

The PL spectra of the samples are compared in Fig. 1. Both samples A and B show single emission peak around 1100nm. In contrast, sample C exhibits an additional emission at 990nm, which coincides with sample D. The evolution of the peak with increased SML InAs represents the strain relaxation during stacking of SML InAs/GaAs QWs. At higher InAs deposition, the lattice mismatch between InAs and GaAs leads to formation of islands which act as nucleating center for QDs. During SML InAs deposition, InAs forms small clusters scattered in the GaAs matrix. With stacking, the strain is accumulated more rapidly in sample A, resulting in QD formation at fewer periods. In sample C, strain field is distributed around scattered clusters, enabling deposition of more InAs layers before QD formation. Hence, emission over 1000nm in sample A, B and C is attributed to QDs while emission at 990nm in sample C is associated with QWs. With decreased InAs deposition in each period, more Ga is incorporated to contribute to the formation of InGaAs QDs, suggesting a promising way for stacking QDs with decreased lattice mismatch.

[1] D. M. Tex and I. Kamiya, Phys. Rev. B **83**, 081309(R) (2011).

[2] Y. Zhang and I. Kamiya, JSAP Spring Meeting (2016).

Table 1. Structure of SML InAs/GaAs

Sample A		Sample B		Sample C		Sample D
5nm GaAs cap		5nm GaAs cap		5nm GaAs cap		5nm GaAs cap
1nm GaAs	x10	0.75nm GaAs	x13	0.5nm GaAs	x20	13nm $In_{0.2}Ga_{0.8}As$
1ML InAs		0.75ML InAs		0.5ML InAs		
200nm GaAs buffer		200nm GaAs buffer		200nm GaAs buffer		200nm GaAs buffer
S.I GaAs substrate		S.I GaAs substrate		S.I GaAs substrate		S.I GaAs substrate

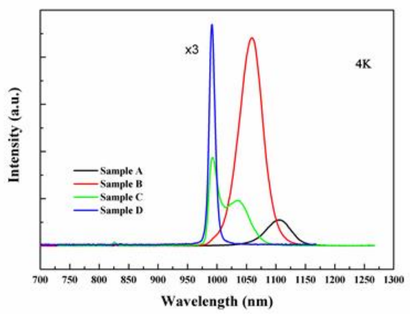

Fig. 1 PL spectra of samples A, B, C and D at 4K with λex = 780nm.