A Study on Submonolayer InAs Quantum Well Islands for Upconversion Applications

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Disk-like InAs Quantum well islands (QWIs), grown by Stranski-Krastanov (SK) mode, have been shown to exhibit efficient photon upconversion and is good candidate for intermediate-band solar cell (IBSC) applications.[1-3] However, we have realized that submonolayer (SML) growth of QWIs may lead to several unique advantages compared to SK, including the ability to control the size and shape of SML-QWIs by changing the layer thicknesses of the InAs and GaAs layers as well as the number of stacks.[4] In this report, tunability of the optical properties of various SML-QWI structures is investigated by photoluminescence (PL).

The general sample structure is shown in Fig. 1. The samples were grown on s.i. (001) GaAs substrates by MBE. After oxide desorption at 600°C, a 100-nm GaAs buffer was grown at 590°C. This was followed by the growth at 500°C of a 30-nm GaAs barrier layer, a 6-ML InGaAs quantum well (QW), a 30-nm GaAs barrier layer, an InAs/GaAs SML-QWI layer, and a 50-nm GaAs cap layer. For the SML-QWI layer, the GaAs layer thickness was kept at 2.0 ML for all samples, whereas the InAs layer thickness was varied from 0.4 to 0.8 ML. Furthermore, the number of SML stacks was also varied from 3 to 4. The QW layer is used as the luminescence probe to investigate the potential photon upconversion process in the SML-QWI samples. The PL measurements were carried out at 4K using a He cryostat. A Ti:sapphire laser was used to excite the sample at λ_{ex} = 740 nm.

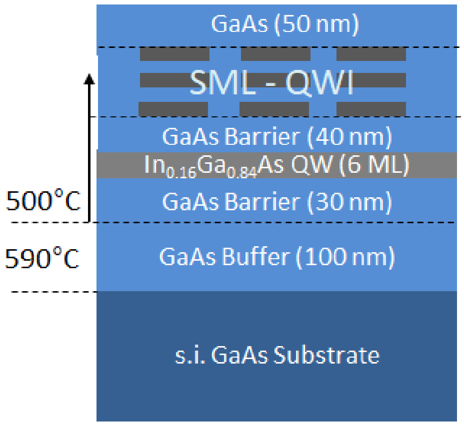

Figure 1. Schematic diagram of sample structures for upconversion with 6 ML (1.7 nm) InGaAs QW and InAs/GaAs SML-QWIs.

Shown in Fig. 2(A) is the PL spectra of 3-stack SML-QWI samples with different InAs thicknesses. As the InAs layer thickness is increased from 0.4 to 0.8 ML the PL peak redshifts from 840 to 947 nm. The redshift is attributed to the larger island size with the thicker InAs layer. This clearly demonstrates the tunability of the optical property of SML-QWIs even for a fixed GaAs thickness and number of SML stacks.

Shown in Fig. 2(B) are the PL spectra of 4-stack SML-QWI samples with different InAs thicknesses. Similar to those in Fig.2(A), the InAs thickness was varied from 0.4 to 0.8 ML. As the InAs thickness increases, the PL peak redshifts from 850 to 1005 nm. As expected, the PL peak for 4-stack SML-QWIs is at longer wavelength than those of the 3-stack. This is attributed to the increase the height of the SML-QWI structures moving from 3 to 4 stacks. This again exhibits the high tunability of SML-QWIs.

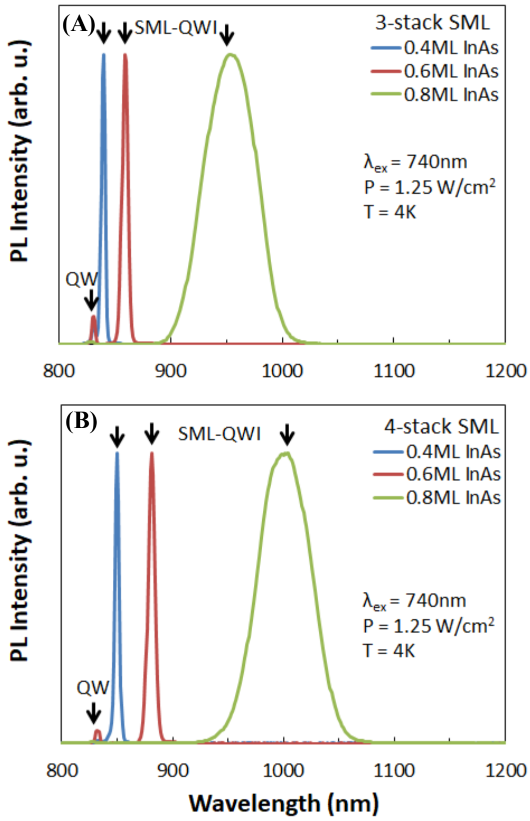

Figure 2. Photoluminescence spectra of sample with varying InAs thickness with (A) 3 stacks and (B) 4 stacks. QW peak center remains at 832 nm regardless of SML-QWI structure.

The high degree of tunability and flexibility of SML-QWIs is highly desirable for photon upconversion and IBSC applications, as combinations of various SML-QWI structures can be utilized to cover the broad IR solar spectrum. For future work, the upconversion properties of the SML-QWIs will be investigate. A comparison of the upconversion properties between SK- and SML-grown QWIs is also of interest.

References: 1.) D. Tex & I. Kamiya, Phys. Rev. B **83**, 081309 (2011). 2.) D. Tex *et al.*, Phys. Rev. B **87**, 245305 (2013). 3.) G. Cassabois *et al.*, J. Appl. Phys. **91**, 5489 (2002). 4.) P. Wang *et al.*, Appl. Phys Lett. **64**, 1526 (1994).