Novel InAs SK/SML/SK quantum dot structure and steps toward new broadband IR detectors

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Infrared (IR) detectors have played a huge role in pushing the boundaries of science in various fields through applications such as night-vision, free-space communication, thermography, remote sensing, etc.[1,2] Quantum dots (QDs) have attracted significant attention as the building block of these devices, i.e. IR detectors. Attempts have been made to couple InAs Stranski-Krastanov (SK) and submonolayer (SML) grown structures for solar cell applications.[3,4] Proposed advantages of coupled SK-SML QDs include better IR efficiency due to reduced strain between the SK and SML QDs. In this study, we aim to investigate the effect of strain interaction between SK and SML QDs to their optical properties. Furthermore, we also prepared structures for broadband IR detection using a triple-layer SK/SML/SK QDs.

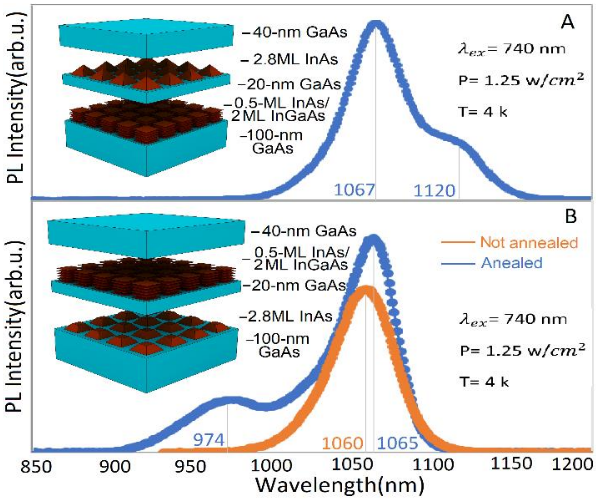

Figure 1. PL spectra of (A) SK/SML and (B) SML/SK samples (with and without annealing). Insets: structure of (A) SK/SML and (B) SML/SK samples.

All samples were grown by MBE on semi-insulating (s.i.) GaAs (001) substrates sharing the same 100-nm GaAs buffer grown at 580°C and 40-nm GaAs cap, stacked layers of InAs QDs grown either by SK or SML. Layers after the buffer were grown at 500°C. For all samples the SML QD layer consists of 0.5 ML InAs/2 ML InGaAs multilayers with 6 stacks. First, in order to investigate the strain interaction between SK and SML QD layers, two different samples were prepared [Fig. 1, inset]: a sample with SK QDs on SML QDs (SK/SML), and samples with SML QDs on SK QDs (SML/SK). The effect of annealing on the SK QDs was also investigated for the SML/SK. Secondly, in order to realize broadband IR detection, structures with SK/SML/SK triple QD layers were also prepared. To allow the most desirable results in the IR region, the SK QD size and the barrier thickness between the QD layers were varied.

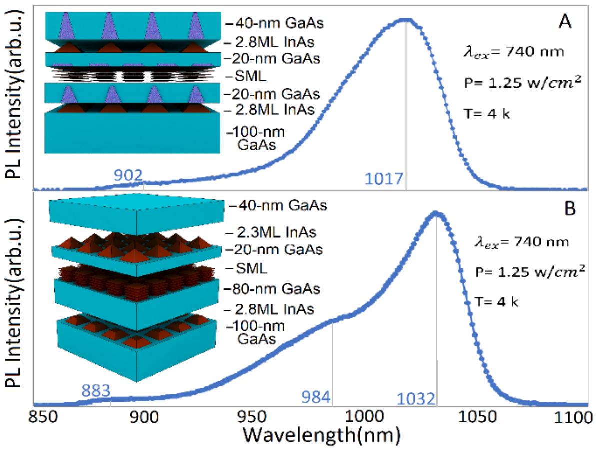

Figure 2. PL spectra of SK/SML/SK samples. The growth orders are: (A) 2.8 ML InAs SK QD/20nm GaAs/SML QD/20nm GaAs/ 2.8ML InAs SK QD and (B) 2.8 ML InAs SK QD/80nm GaAs/ SML QD/20nm GaAs/2.3ML InAs SK QD. Insets: corresponding structures for (A) and (B).

Figure 1(A) shows the photoluminescence (PL) spectrum of the SK/SML sample. The SML peak can be observed at 1067 nm, whereas the SK peak at 1120 nm. Figure 1(B) shows PL spectra of the SML/SK samples (non-annealed and annealed). For the non-annealed sample, only a single peak at 1060 nm was observed, which is attributed to the tunneling of carriers from the SK to the SML QDs. By annealing at 600°C, the spectrum changes to two peaks at 974 and 1065 nm, which is attributed to the SK and SML QDs, respectively. Here, the *in situ* annealing is presumed to have changed the size of the SK QD and hence the energy alignment between the SK and SML QDs, effectively stopping carriers from tunneling. Note that annealing was only performed in the bottom SK QD layer, and the SML QD layer was grown after the annealing. The significant difference in the SK/SML [Fig. 1(A)] and SML/SK [Fig. 1(B) non-annealed] spectra suggest different strain interaction for the two, where the SML/SK is assumed to have greater initial strain because the SK layer is at the bottom.

Figure 2 shows the PL spectra for two SK/SML/SK samples for broadband IR detection: the first sample [Fig. 2(A)] consists of a thin 20-nm GaAs layer between the bottom SK and the SML layer, whereas the second sample [Fig. 2(B)] of a thick 80-nm GaAs layer between the bottom SK and the SML layer as well as a 2.3-ML SK top QD layer. For the first sample, two peaks at 902 and 1017 nm are related to bottom SK and SML, while the top SK peak is presumed to overlap with the SML. To achieve better broadband IR coverage for the second sample, the top SK QD size reduced to 2.3ML and barrier between bottom SK and SML changed from 20 to 80 nm. Separate peaks at 883, 984 and 1032 nm are observed [Fig. 2(B)], and are attributed to the bottom SK, top SK and middle SML QDs, respectively. This demonstrates the improvement in broadband coverage of the SK/SML/SK structure. In conclusion, the strain interaction between the SK and SML QD layers were investigated. An attempt and improvement of broadband IR detection based on the SK/SML/SK QDs will also be shown.

References:

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