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Appendix

Further Works: Modified Template for Quantum Dot Molecules

In additional appendix, we illustrated that QDM with low dot number can be grown at specific growth condition. The conventional QDM with 4-5 dots was obtained when the GaAs capping thickness and InAs regrowth thickness was 25 and 1.5 ML, respectively. However, there is different size between center dot and satellite dot, due to the strain resulting from nanohole template, which hinders the QD functionality for such applications as a qubit. In this chapter, a modified technique for growing preferred QDM is conducted. However, this is only a beginning step, therefore, there are several experiment needed to be performed in the near future.

Increasing temperature gradually during regrowth process

It is our objective to create an optimum shape of nanoholes upon which subsequent QDs, both center and satellite dots, can be grown to the same size with good uniformity which is the ideal case for practical QDMs. Therefore, after conventional QDM grown by deposited 25 ML GaAs capping thickness and 1.2 ML InAs regrowth thickness was formed, the regrowth process is continued by ramping up the temperature to 500 °C with 30 °C/min. This process occurs while the In shutter is opened. The 0.3x0.3 μm^2 and 1x1 μm^2 AFM images of both conventional QDM and modified QDM and the height distributions of these two cases are illustrated in Figure 1.

We modified the strain by increasing regrowth temperature while the shutter of In adatom was being opened. As shown in Figure 1, it is obviously seen that the different height between center dot and satellite dot in case of Figure 1 (a) was less than that of Figure 1 (b), while the height of center dot of modified QDM slightly larger than that of conventional QDM. Furthermore, the histograms of dot number per molecule of both conventional QDM and modified QDM are illustrated in Figure 2.

We proposed that increasing temperature during regrowth results in increasing in In-Ga intermixing across the interface of the QDs. Moreover, increasing temperature also increase the thermal dessorption rate, therefore, the amount of In adatoms used to make the island saturated is increase. Thus, we propose to study the shape of modified QDM at more InAs regrowth thickness in further work. In addition, the regrowth interruption and ramping rate will be investigated, in order to fabricate a well-defined QDM in accordance with QCA approach.

Finally, in order to investigate the optical properties, the study of PL coupling, including macro-PL and micro-PL measurements, in all case of QDMs should to be conducted.

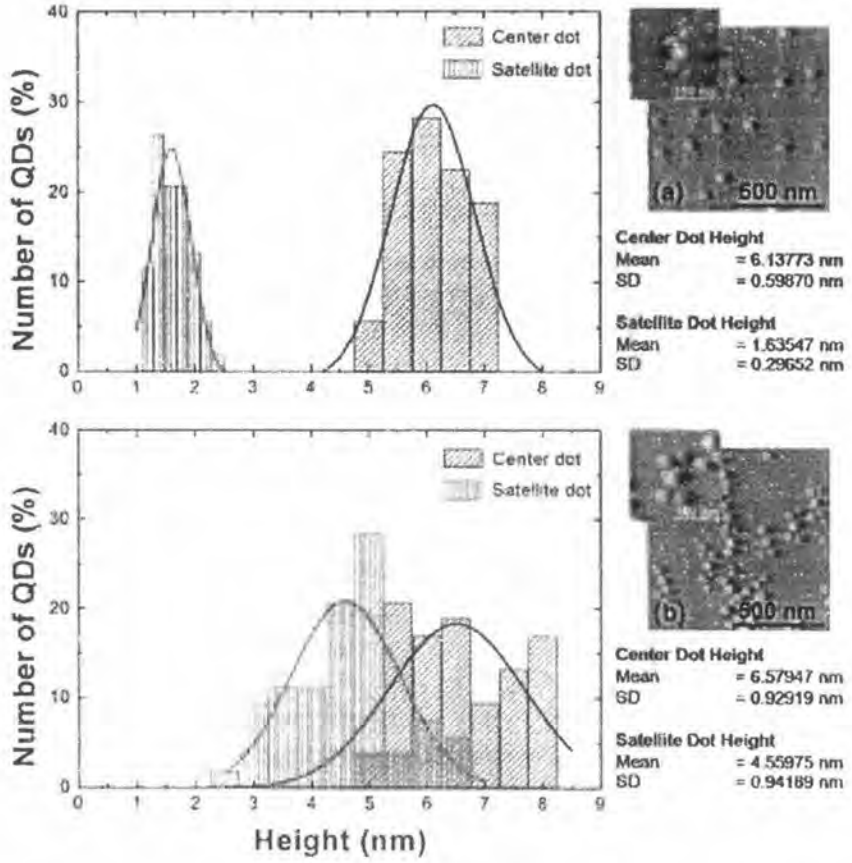


Figure 1 : The 0.3x0.3 μm² and 1x1 μm² AFM images, and histograms of height distribution of center dots and satellite dots in case of (a) conventional QDM comparing to (b) modified QDM.

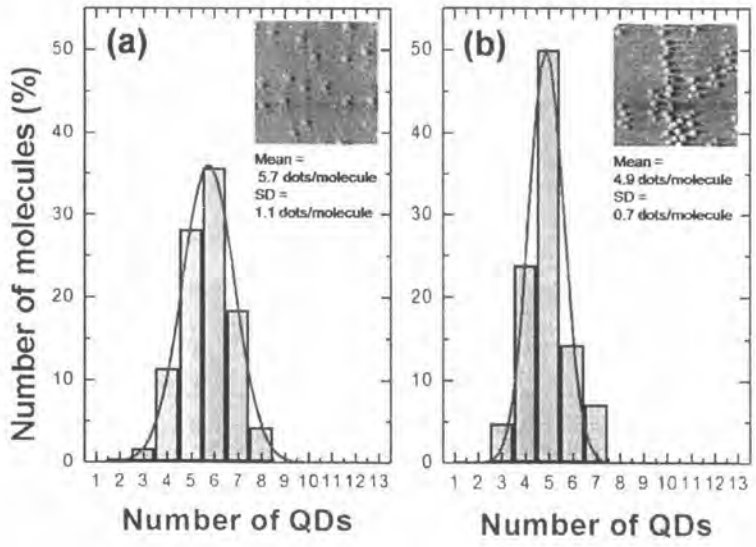
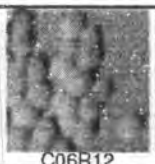
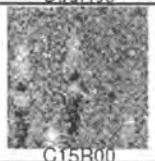
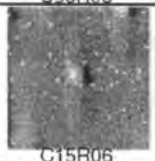
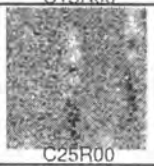
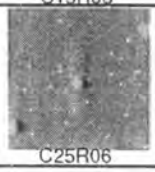


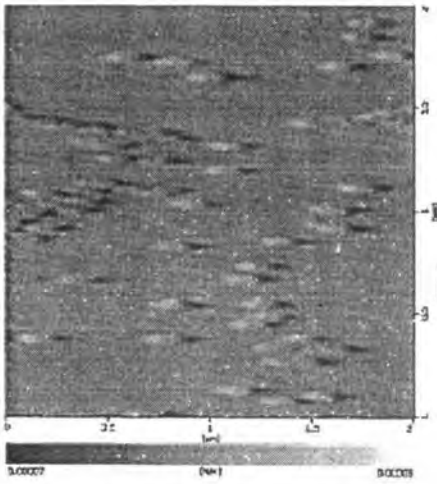
Figure 2 : The statistical results of dot number per molecules in case of (a) conventional QDM comparing to (b) modified QDM.

Sample profiles

300x300 nm² AFM images

GaAs Capping thickness \ InAs Regrowth thickness	0 ML	0.3 ML	0.6 ML	1.2 ML	1.5 ML
6 ML	 C06R00	 C06R03	 C06R06	 C06R12	 C06R15
15 ML	 C15R00		 C15R06	 C15R12	 C15R15
25 ML	 C25R00		 C25R06	 C25R12	 C25R15

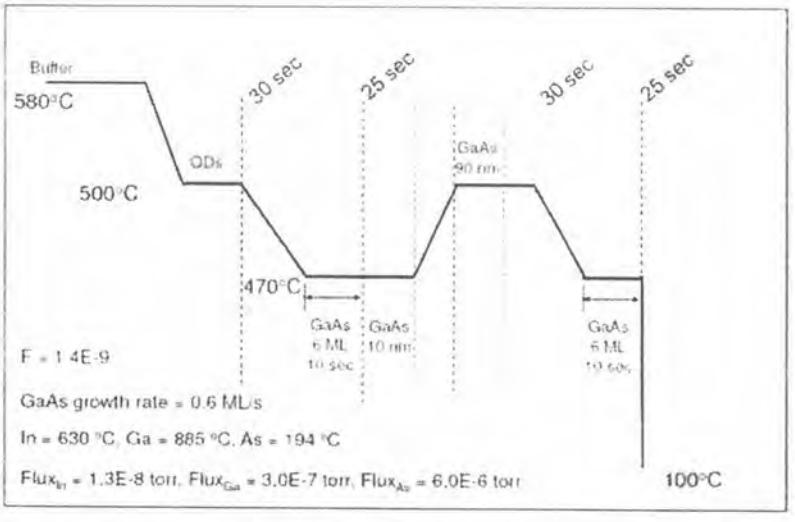
C06R00



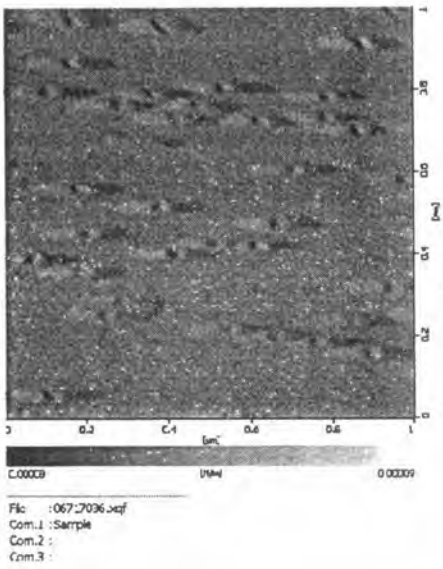
Block 4. T_{desox} = 580 °C, $T_{transition}$ = 517 °C.

- GaAs bulfer was grown at 580 °C
- QDs was grown at 500 °C
  - 1.7 ML = 2:25 min/2:23min
  - 1.8 ML = 2:36 min/2:33min
- Capping with 6 ML GaAs at 470 °C

C06R00



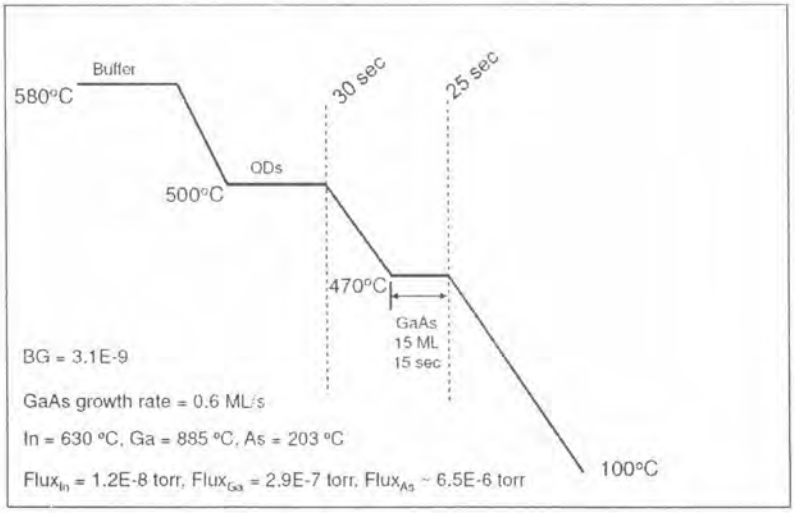
C15R00



Block 7, T_{deox} = 595 °C, $T_{transition}$ = 536 °C,

- GaAs buffer was grown at 580°C
- QDs was grown at 500°C
  - 1.7 ML = 2:40 min
  - 1.8 ML = 2:56 min
- Capping with 15 ML GaAs at 470°C

C15R00



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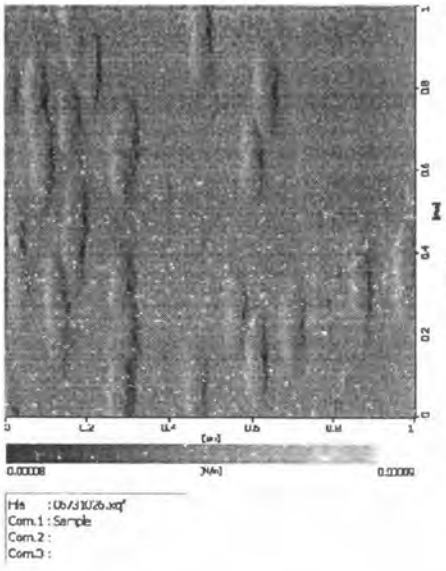
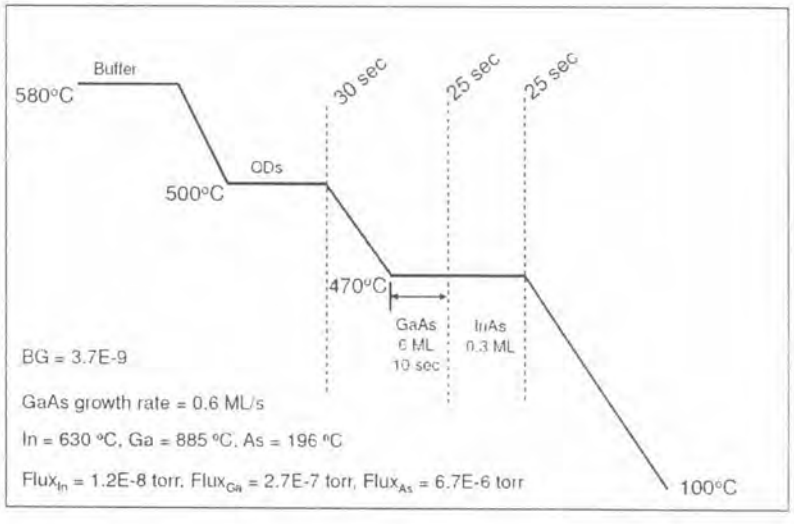


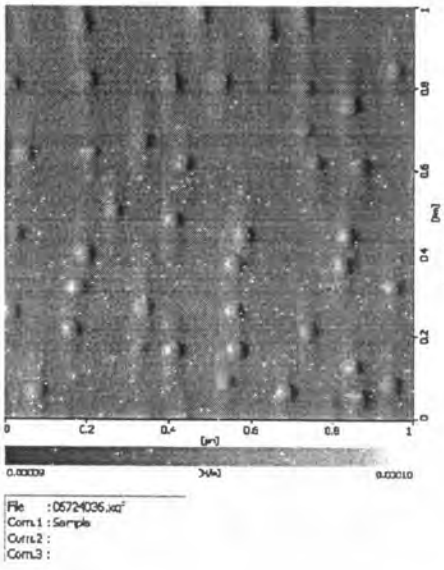
Block A. T_{deox} = 603°C, $T_{transition}$ = 517 °C,

- GaAs buffer was grown at 580 °C
- QDs was grown at 500 °C
  - 1.7 ML = 2:50 min
  - 1.8 ML = 3:00 min
- Capping with 6 ML GaAs at 470 °C
- Regrowth 0.3 ML InAs at 470 °C
  - 0.3 ML = 0:30 min

C06R03



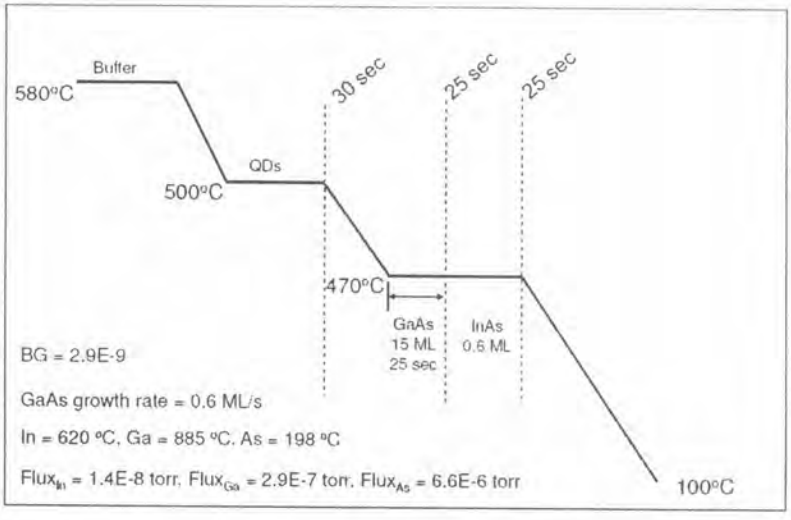
C15R06



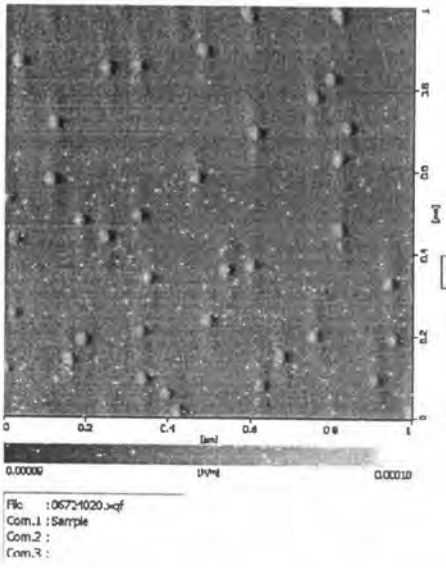
Block 4, T_{deox} = 590 °C, $T_{transition}$ = 505 °C,

- GaAs buffer was grown at 580 °C
- QDs was grown at 500 °C
  - 1.7 ML = 4:10 min
  - 1.8 ML = 5:10 min
- Capping with 15 ML GaAs at 470 °C
- Regrowth 0.6 ML InAs at 470 °C
  - 0.6 ML = 1:30 min

C15R06



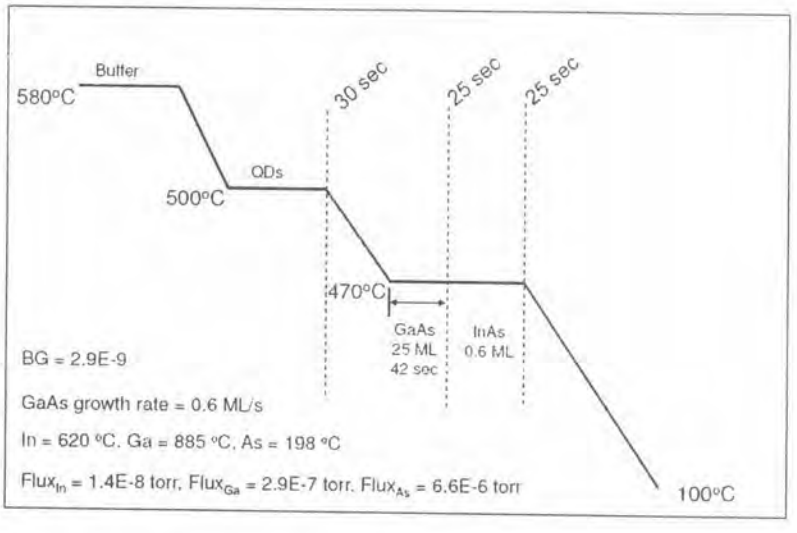
C25R06



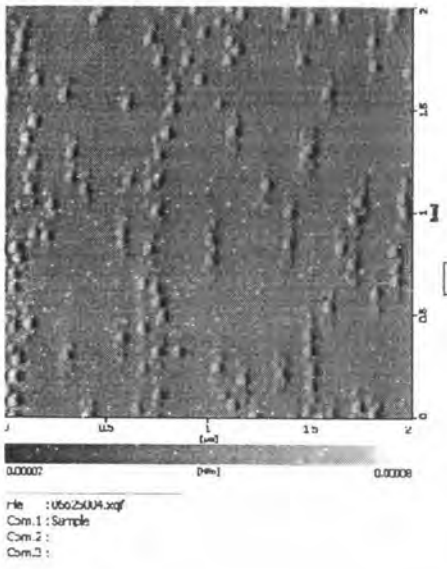
Block 7, T_{deox} = 590 °C, $T_{transition}$ = 532 °C,

- GaAs buffer was grown at 580°C
- QDs was grown at 500°C
  - 1.7 ML = 3:25 min/1:46min
  - 1.8 ML = 3:42 min/2:00min
- Capping with 25 ML GaAs at 470°C
- Regrowth 0.6ML InAs at 470 °C
  - 0.6 ML = 1:30 min

C25R06



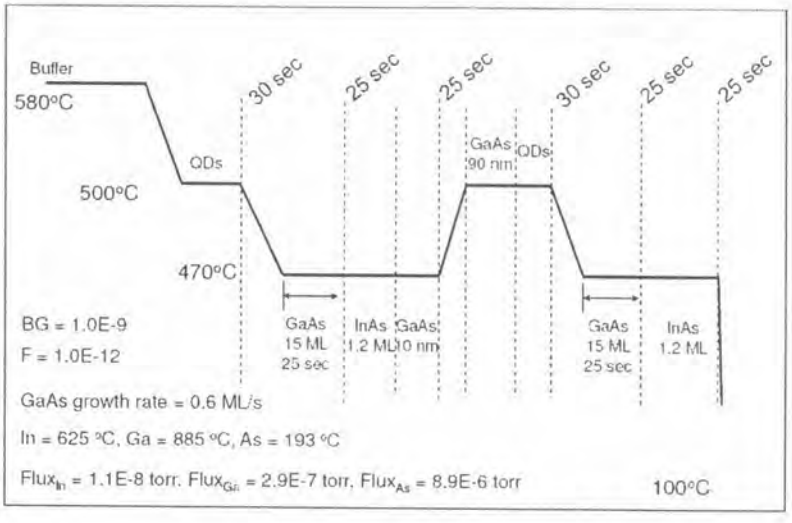
C15R12



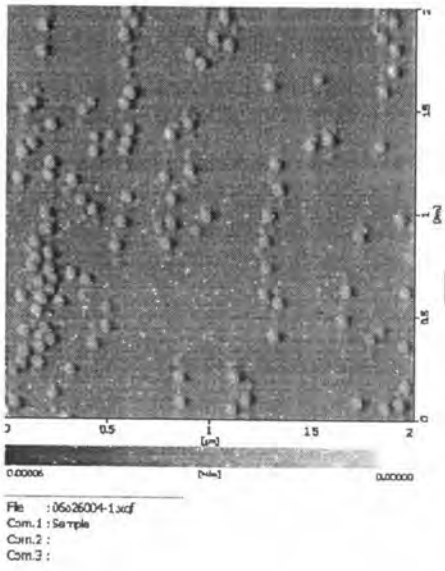
Block 4, T_{deox} = 570 °C, $T_{transition}$ = 509 °C,

- GaAs buffer was grown at 580 °C
- QDs was grown at 500 °C
  - 1.7 ML = 2:52 min/2:50min
  - 1.8 ML = 3:02 min/3:02min
- Capping with 15 ML GaAs at 470 °C
- Regrowth 1.2 ML InAs at 470 °C
  - 0.6 ML = 1:05 min/ 1:05 min
  - 1.2 ML = 2:10 min/ 2:10 min

C15R12



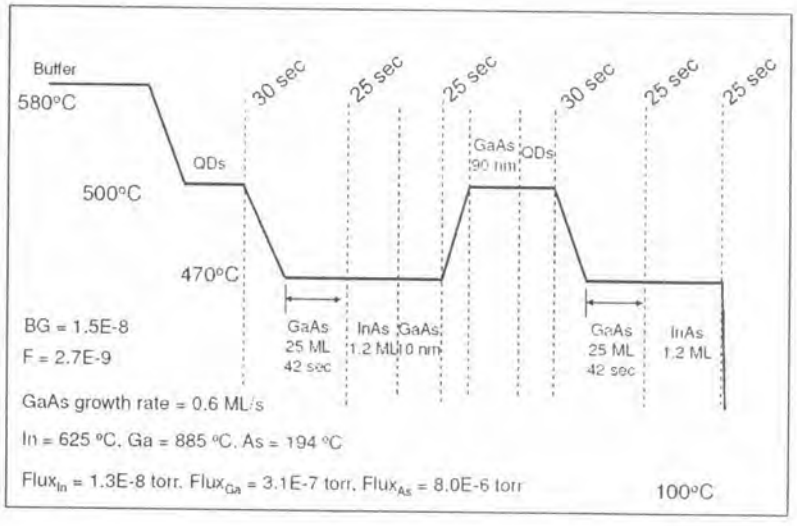
C25R12



Block 4, T_{deox} = 560 °C, $T_{transition}$ = 512 °C.

- GaAs buffer was grown at 580 °C
- QDs was grown at 500 °C
  - 1.7 ML = 2:40 min/2:42min
  - 1.8 ML = 2:50 min/2:50min
- Capping with 25 ML GaAs at 470 °C
- Regrowth 1.2 ML InAs at 470 °C
  - 0.6 ML = 1:10 min/ 1:10 min
  - 1.2 ML = 2:20 min/ 2:15 min

C25R12



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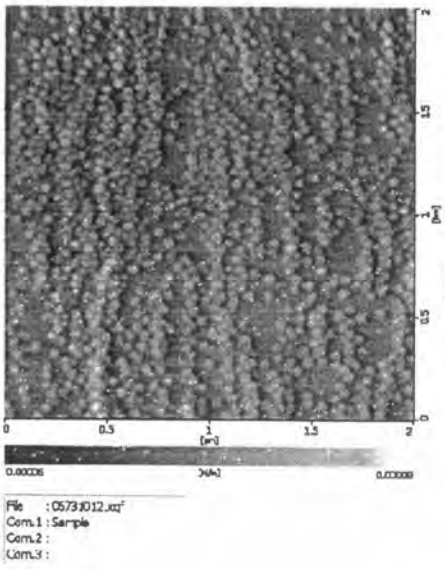
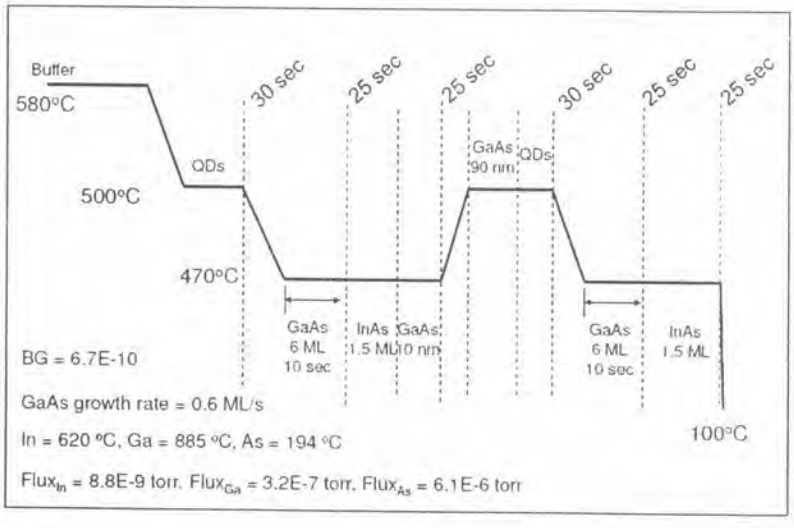


Block 7, T_{dep} = 590 °C, $T_{transition}$ = 531 °C.

- GaAs buffer was grown at 580 °C
- QDs was grown at 500 °C
  - 1.7 ML = 2:50 min/3:15min
  - 1.8 ML = 3:00 min/3:28min
- Capping with 6 ML GaAs at 470 °C
- Regrowth 1.5 ML InAs at 470 °C
  - 0.6 ML = 1:06 min/ 1:09 min
  - 1.5 ML = 2:36 min/ 2:48 min

C06R15



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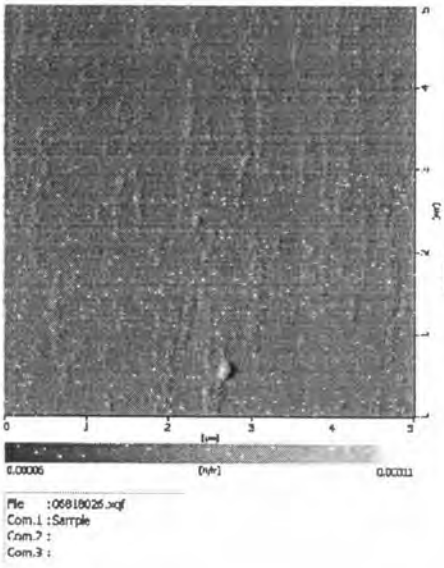
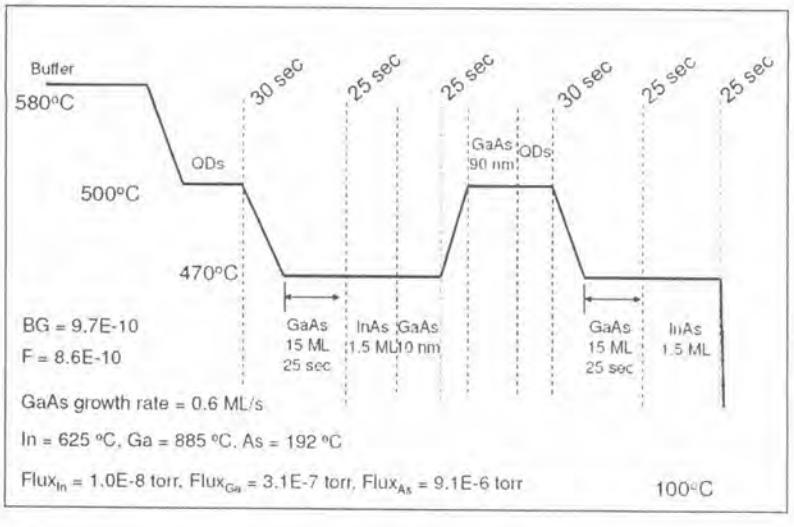


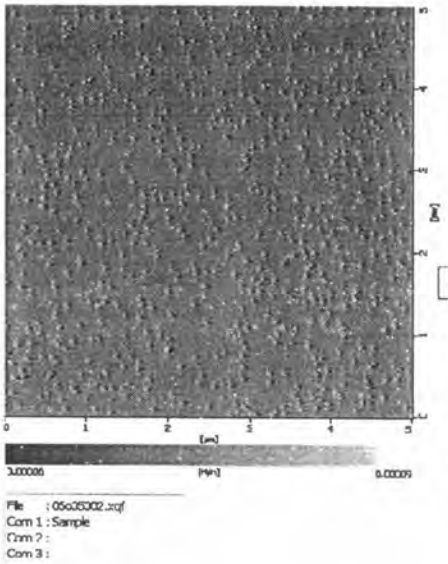
Block 7, T_{deox} = 572 °C, $T_{transition}$ = 539 °C.

- GaAs buffer was grown at 580 °C
- QDs was grown at 500 °C
  - 1.7 ML = 2:50 min/2:50min
  - 1.8 ML = 3:00 min/3:00min
- Capping with 15 ML GaAs at 470 °C
- Regrowth 1.5 ML InAs at 470 °C
  - 0.6 ML = 1:01 min/ 1:00 min
  - 1.5 ML = 2:30 min/ 2:30 min

C15R15



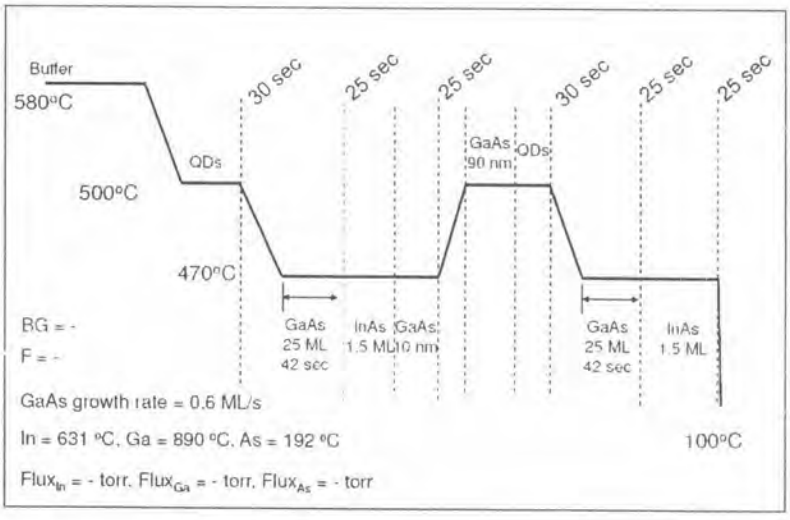
C25R15



Block Aj. T_{deox} = 585 °C, $T_{transition}$ = 550 °C,

- GaAs buffer was grown at 580 °C
- QDs was grown at 500 °C
  - 1.7 ML = 3:27 min
  - 1.8 ML = 3:36 min
- Capping with 25 ML GaAs at 470 °C
- Regrowth 1.5 ML InAs at 470 °C
  - 1.5 ML = 3:00 min

C25R15



List of publications

1. "Quantum Dot Molecules for Quantum Cellular Automata : Future Quantum Computer", Naparat Siripitakchai, Suwaree Suraprapapich, Supachok Thainoi, Songphol Kanjanachuchai and Somsak Panyakeow, ECTI, Transitions on Electrical Eng., Electronics, and Communications, Vol. 3, No. 1 (2005).

2. "Study on Polarized Photoluminescence of Multi-stacked Lateral Quantum Dot Molecules Fabricated by Multi - Cycles of Thin - Capping - and - Regrowth MBE Technique", Naparat Siripitakchai, Suwaree Suraprapapich, Supachok Thainoi, Songphol Kanjanachuchai and Somsak Panyakeow, Proceeding of EECON-28 (2005).

3. "Evolution of Self-Assembled Lateral Quantum Dot Molecules", Naparat Siripitakchai,Suwaree Suraprapapich, Supachok Thainoi, Songphol Kanjanachuchai and Somsak Panyakeow, J. Crystal Growth, Article in press (2007).

List of presentations

Oral presentations

1. "Application of Quantum Computing", Naparat Siripitakchai, Suwaree Suraprapapich and Somsak Panyakeow, National University of Singapore, Singapore, July, 2005.

2. "Study on Polarized Photoluminescence of Multi-stacked Lateral Quantum Dot Molecules Fabricated by Multi - Cycles of Thin - Capping - and - Regrowth MBE Technique", Naparat Siripitakchai, Suwaree Suraprapapich, Supachok Thainoi, Songphol Kanjanachuchai and Somsak Panyakeow, 28th Electrical Engineering Conf. (EECON-28), The Pearl Village Hotel, Phuket, Thailand, 20-21 October, 2005.

3. "Quantum dots for Quantum Computing", Naparat Siripitakchai, Suwaree Suraprapapich, Somsak Panyakeow, Field-Wise Seminar on "Nanoelectronics and Photonics" at Hanoi University of Technology, Vietnam, November, 2005.

Poster presentations

1. "Evolution of Self-Assembled Lateral Quantum Dot Molecules", Naparat Siripitakchai,Suwaree Suraprapapich, Supachok Thainoi, Songphol Kanjanachuchai and Somsak Panyakeow, 14th MBE Conf., Wasada University, Tokyo, Japan, 3-8 September, 2006.

Vitae

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