Investigation of MOVPE-InSb Quantum Dots Grown Using TMIn and TDMASb

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Introduction

- High levels of carbon incorporation measured for low-temperature growth using several other Sb precursors can be avoided using TDMASb[1].
- Most reported data on InSb dots in a GaSb matrix [2-6] reveals that the density of InSb/GaSb quantum dots (QDs) obtained are in the $10^9/cm^2$ range with typically large dot lateral size (50-100nm)[2] , except for Shusterman[7] who reported a QD density of $10^8/cm^2$.
- According to Deguffroy[6], all other studies have shown that a low density of large InSb islands are formed irrespective of the growth technique (MBE or MOVPE).

Objectives

- To investigate the size distribution and growth conditions of self-assembled InSb QDs on a GaSb Substrate using different V/III ratios.
- To show that the growth of high density InSb/GaSb QDs using atmospheric pressure MOVPE can be achieved using TDMASb precursor as Sb source.
- To study the effect of growth time and V/III ratio on the topology of InSb/GaSb QDs.

Experimental details

- Atmospheric pressure MOVPE
- Substrate: GaSb 2° off (100)
- Substrates etched with HCl for 5 s
- Substrate annealed at 500°C for 300 s
- 300 nm GaSb buffer layer grown at 500°C
- Typical growth rate ~0.27 nm/s
- QD growth time 5-10 s; Growth temp 425 °C

Parameters varied:

V/III Ratio	TMIn Mole Fraction	TDMASb Mole Fraction
1	$\sim5.75\times10^{-5}$	$\sim5.75\times10^{-5}$
2	$\sim3.0\times10^{-5}$	$\sim6.0\times10^{-5}$
3	$\sim1.93\times10^{-5}$	$\sim5.8\times10^{-5}$

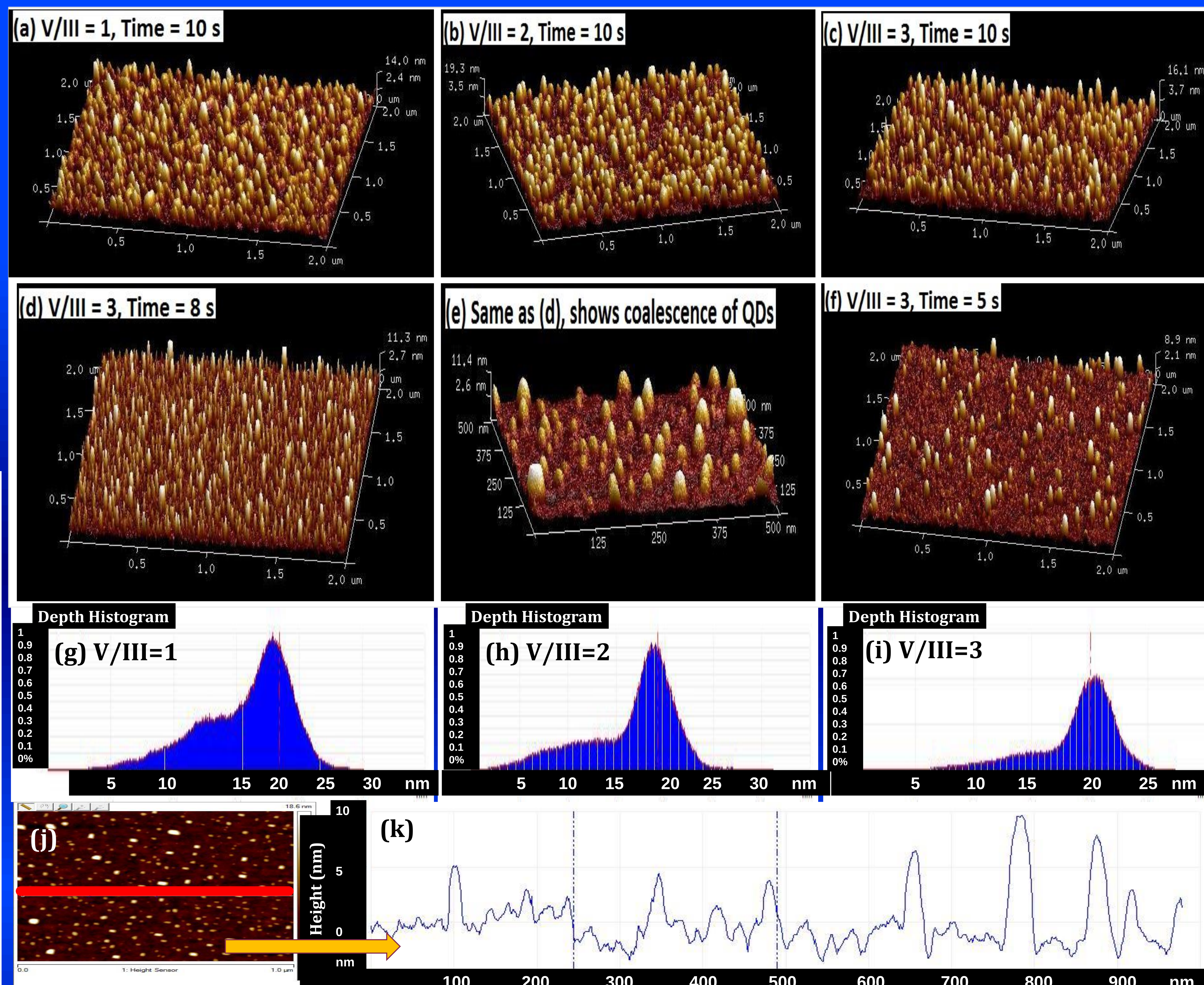

FIG 1. SPM Images, Depth Histograms and Line Scan Analysis of InSb QDs for various V/III ratios and time

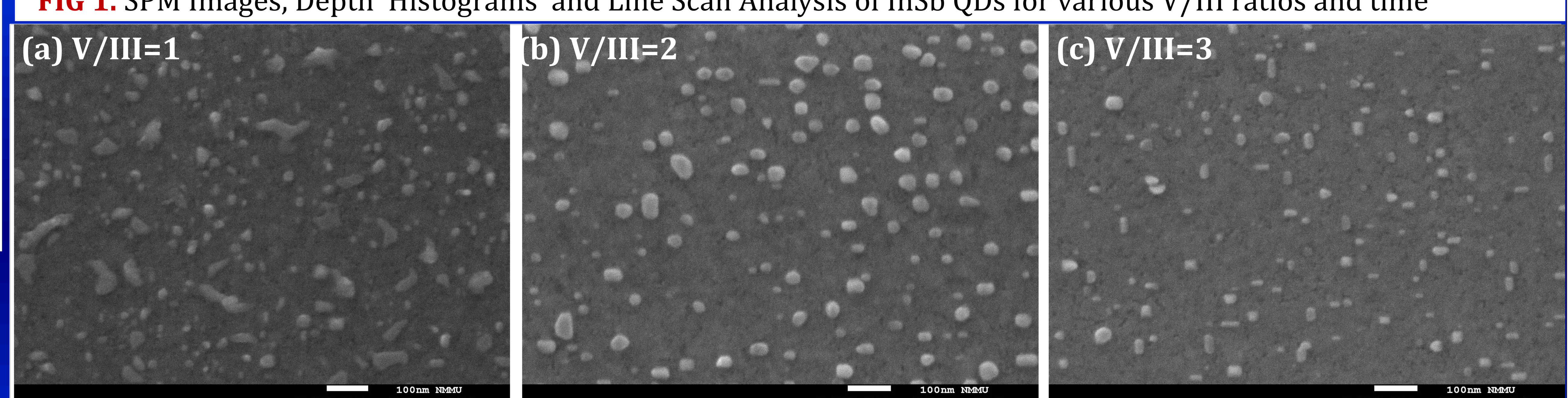

FIG 2. SEM images of InSb QDs for various V/III ratios

Results and discussion

- **FIG 1.** Scanning probe microscopy (SPM) images and depth histograms. Reduction in dot density as V/III ratio increases from 1 to 3. The two peaks in each of the histograms **(g-i)** indicate bimodal size distribution.

FIG 1	Dot Diameter (nm)	Dot Height (nm)	Dot Density (cm^{-2})
a	20-60	5-12	$\sim1.0\times10^{10}$
b	20-40	6-16	$\sim8.0\times10^{9}$
c	10-30	5-13	$\sim7.0\times10^{9}$
d	10-30	5-11	$\sim5.0\times10^{9}$
f	10-22	5-8	$\sim1.0\times10^{9}$

- **FIG 2.** Scanning electron microscopy (SEM) images of the QDs. The topology of the dots reveals a large size distribution. Changes in size and density with V/III ratio are attributed to a change in the surface migration length of the indium species.
- The large variation in size in **FIG 2 (a)**, is most likely due to the coalescence of QDs as a result of their large density and short migration distance of indium species. **FIG 1 (i) and FIG 2(c)** shows a slow transition from bimodal to almost single-modal size distribution.

Conclusions

- The low growth rate associated with TDMASb is beneficial for the growth of a high density of QDs, depending on the V/III ratio used.
- An increase in V/III ratio yields a reduction in QD density and a gradual change from bimodal to single modal size distribution.
- The high dot density (~10^{10} cm^{-2}) for lower V/III ratio is promising for future work.
- The bimodal size distribution on the misoriented surface of the GaSb substrate is ascribed to:
  - Reduced adatom migration due to energy barriers at step or kinks. This can decrease the conversion of tiny QDs into the thermodynamically suitable larger dots.
  - Coalescence of QDs, depending on the surface migration length of the indium species and resultant dot density.

References

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