Structural and optical properties of GaAs(111)A tensile-strained quantum dots using As_2 and As_4

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GaAs(111)A tensile-strained quantum dots (TSQDs) are the first optically active materials system to combine the benefit of epitaxial self-assembly, (111)-orientation, and tensile strain[1]. They are structurally and optically tunable, dislocation-free, exhibit low fine structure splitting (FSS), and have a tunably reducible bandgap[2,3]. To outline the full capabilities of this promising new material system, we recently presented a comprehensive study on the customization and optimization of GaAs(111)A TSQD properties[2]. However, all (111) TSQDs were grown using tetrameric arsenic (As_4) for consistency with previous (111) growths[1–4], since much of the original growth optimization on (111) surfaces was done before the advent of valved crackers. However, research shows that dimeric arsenic (As_2) often provides better material properties. Here we present the impact of arsenic species choice on the growth and properties of GaAs/InAlAs(111)A TSQDs.

Using As_2 or As_4 in the growth of GaAs(111)A TSQDs results in different TSQD structure and photon emission behavior. Structural differences with different arsenic species provide a greater ability to tailor TSQDs and reveal different nucleation and growth kinetics. Depending on the substrate temperature and arsenic species, GaAs(111)A TSQDs have a triangular base, with two possible crystallographic orientations, or a hexagonal base (Fig. 1 (a,b)). We attribute these different morphologies to differences in step edge growth rates. For all morphologies, As_2-grown TSQDs exhibits improved photoluminescence (Fig. 1 (c)). Additionally, the higher symmetry of the hexagonal TSQDs may result in lower FSS, which may further improve entangled photon emission.

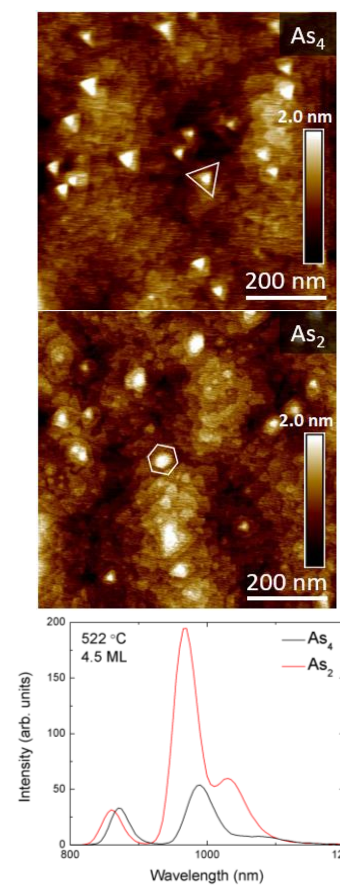

Fig. 1. AFM of triangular (a) and hexagonal (b) TSQDs. Brighter TSQD PL with As_2 (c).

1. Yerino, C. D. *et al.* Appl. Phys. Lett. **105,** 251901 (2014).
2. Schuck, C. F. *et al.* J. Vac. Sci. Technol. B **36,** 031803 (2018).
3. Simmonds, P. J. & Lee, M. L. J. Appl. Phys. **112,** 054313 (2012).
4. Cho, A. Y. Thin Solid Films **100,** 291–317 (1983).

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Supplementary information:

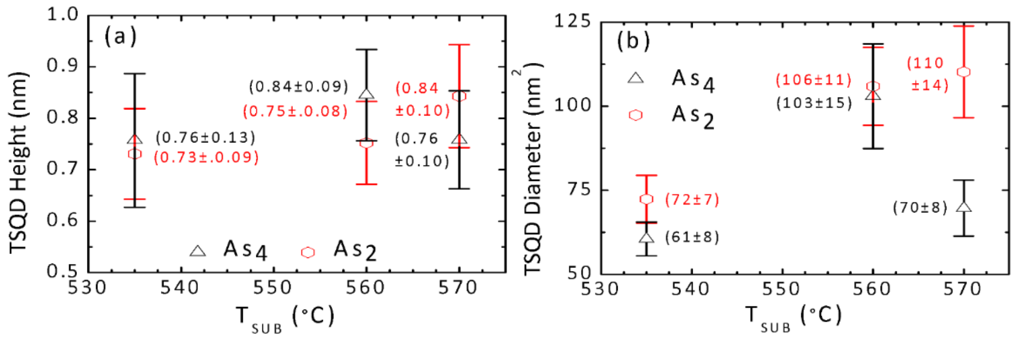

Fig. 2. Scatter plots of the average (a) height and (b) diameter of TSQDs grown with As_4 (black) and As_2 (red), as a function of substrate temperature (error bars represent one standard deviations).

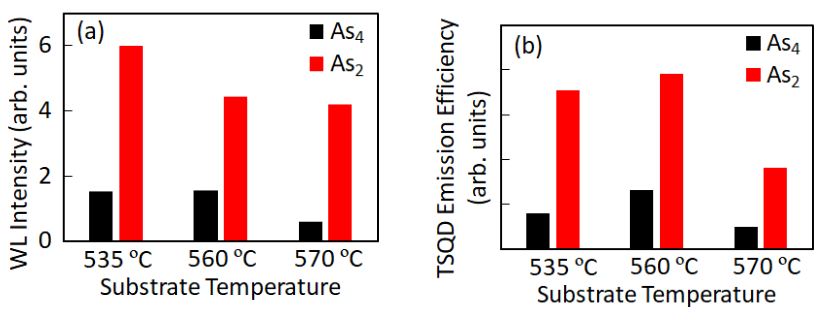

Fig. 3. Plots of GaAs(111)A WL emission intensity (a) and TSQDs emission efficiency (b) with increasing substrate temperature. WL intensity and TSQD emission efficiency are higher consistently higher with As_2 than As_4.

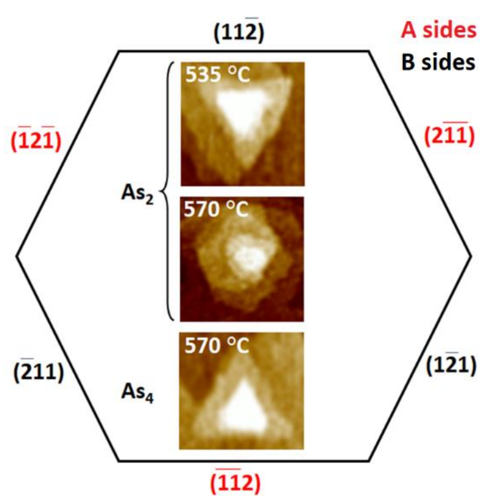

Fig. 4. AFM images of the various GaAs(111)A TSQD morphologies with different substrate temperature and arsenic species combinations. Overlaid is a schematic of the $\{2\bar{1}\bar{1}\}$ planes relative to the possible TSQD step edge orientations.