Improving PL properties of self-assembled InAs SQDs by incorporation of Sb

Literature Review

Motivation

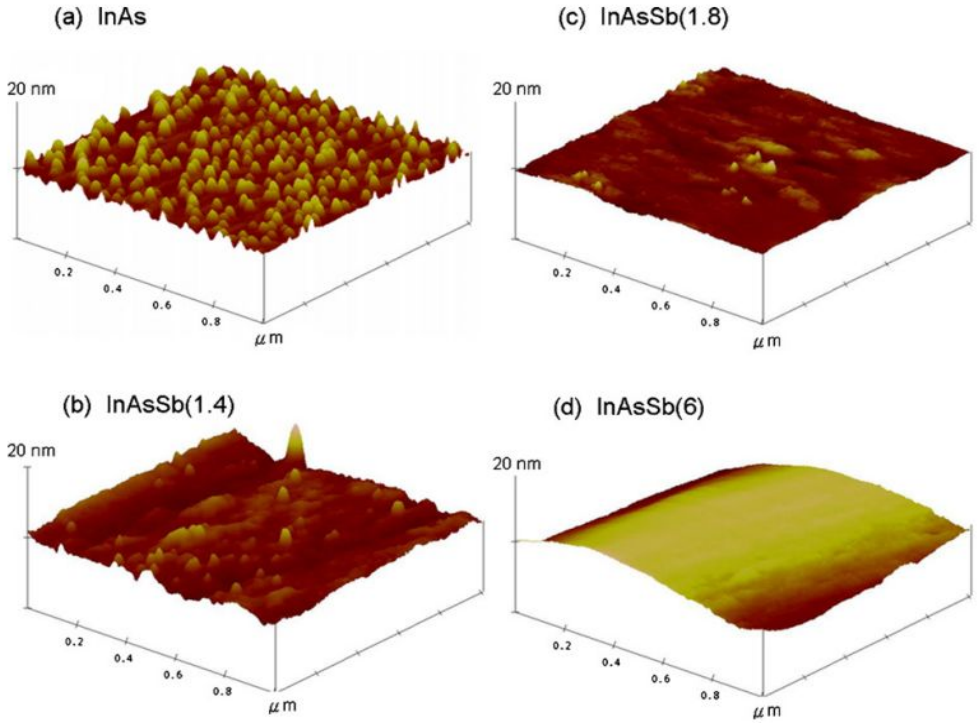
The advantages of incorporating antimony (Sb) as a surfactant into a strained InGaAs quantum well (QW) to delay three-dimensional (3D) growth.

Thus extending the emission wavelength by reducing the surface faceting and delaying the formation of dislocations, several studies have investigated the incorporation of Sb [6–9] or bismuth [10] in InAs or InGaAs QDs.

The range of applications of SQDs is limited by the fact that their PL performance is worse than that of BQDs.

(Surfactant species segregate to the growth front and decrease surface energy and surface diffusion, offering another means of controlling the growth of QDs)

Experiment


(a) InAs
20 nm
0.2
0.4
0.6
0.8
μm
(c) InAsSb(1.8)
20 nm
0.2
0.4
0.6
0.8
μm
(b) InAsSb(1.4)
20 nm
0.2
0.4
0.6
0.8
μm
(d) InAsSb(6)
20 nm
0.2
0.4
0.6
0.8
μm

Results and Discussion

1. Without Sb, the QD density was approximately 3 × 1010 cm−2. Sample InAsSb(1.4) had a lower QD density of 3.5 × 109 cm−2, and sample InAsSb(1.8) had an even lower QD density of 6 × 108 cm−2. Incorporating Sb reduced the density of the SQDs by more than two orders of magnitude.
2. A large Sb BEP worsens the surface morphology as a significant amount of the deposited material tends to form these thick terraces, rather than a thin wetting layer.
3. The AFM results indicate that the Sb-free SQDs have an average lateral diameter of 50 nm and a height of 10 nm.
4. When the QDs are covered by a 0.3 m-thick GaAs cap layer, the emission from the BQDs is blue-shifted by about 171 meV; this shift is expected because of the change in strain as the band gap is increased with the growth of the GaAs capping layer

5. Capping the QD with an InGaAs layer has been shown to reduce the strain and extend the range of emission wavelengths . This strain-reducing InGaAs layer is expected to influence the change in the energy gap that is caused by the growth of the GaAs capping layer.

6. The PL intensity increases as the Sb BEP is increased further.

7. The transfer of carriers from the BQDs to the SQDs may not be responsible for the improvement, because a 0.3 m-thick GaAs blocking layer separates the BQDs from the SQDs. Rather, the enhancement is believed to be strongly related to the incorporation of Sb into the QD layers.

8. The AFM measurements reveal that the incorporation of Sb effectively reduces the density of the SQDs by an Sb surfactant effect, which enhances layer-by-layer growth and suppresses dot formation.

Conclusion

In conclusion, surfactant and segregation effects of Sb in InAs(Sb) SQDs were investigated.

The Sb surfactant effect can extend planar growth and suppress dot formation. The findings in this study suggest that the PL of InAsSb SQDs is strengthened by increasing Sb BEP.

The enhancement of the integrated intensity of PL is attributable to Sb segregation close to the surface of SQDs, and reduces non-radiative recombination.