Height control of self-assembled quantum dots

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The capping of epitaxially grown Quantum Dots (QD) is a key process in the fabrication of devices based on these nanostructures because capping can significantly affect the QDs morphology [3]. We have studied the QD morphology after capping in order to better understand the role of the capping process. We have grown real structures and compared the QD morphology obtained by cross-sectional Scanning Tunneling Microscopy (X-STM) with the morphology of QDs that were virtually grown in simulations based on a Kinetic Monte Carlo model (KMC) [1].
Molecular Beam Epitaxy (MBE) was used to grow Stranski-Krastanov QDs of InAs on a GaAs substrate. These dots were capped with a thin layer of $In_xGa_{1-x}As$ having different Indium concentrations, ranging from 0% to 20%. These samples were cleaved in vacuum and the cleavage facet was imaged by STM in order reveal the QD morphology [2].

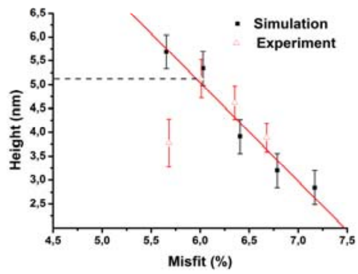

Fig.1 Plot of the height of capped QDs as function of the lattice mismatch between the capping layer and the QD. The dashed line corresponds to the height of uncapped QD. For high In concentration inhomogeneity in the capping layer are observed experimentally, which originate the point off the line.

These experimental results were compared with those obtained with simulations of the QD formation and the capping process. The KMC model that we used allows simulating a finite 3D system with realistic time and length scale. This model was successfully used to reproduce and predict features in the growth of III/V nanostructures [1].
Both in the experiment and in the simulations we observe a clear correlation between the QD height and the lattice mismatch between the QDs and the capping material, see Figure 1. Our results suggest that this is directly related to the total elastic energy present in the dot after capping. Other self-assembled and droplet dots that we studied in different material systems support this observation.
Our results thus show that the elastic energy introduced by the capping is a key parameter for the dot preservation after capping and that the lattice mismatch between the QD material and the capping layer can be used effectively to control the height of QDs.

References

[1] Baskaran, A. and Smereka, P. 2012 *J. Appl. Phys*, *111*, 0044321.

[2] Keizer, J., Koenraad, P., Smereka, P., Ulloa, J., Guzman, A. and Hierro, A. 2012 *Phys. Rev. B*, *85*(15), 155326.

[3] Offermans, P., Koenraad, P. M., Wolter, J. H., Granados, D., & Garcı, J. M. , 2006 Phys. E, *32*, 41–45.