X-STM study of Interlayer Effects on InAs Quantum Dots in InP

E.G.Banfi[1+], E.M. Sala[2], R.S.R. Gajjela[1], J. Heffernan[2], P.M. Koenraad[1]

[1] Department of Applied Physics, Eindhoven University of Technology , The Netherlands

[2] EPSRC National Epitaxy Facility and Department of Electronic and Electrical Engineering, The University of Sheffield, United Kingdom

Quantum dots (QDs) have been studied in the past two decades in order to optimize their performances in a wide range of applications, from QD lasers, photovoltaics, single photon emitter, memories, and last but not least, quantum communication and information technologies [1-6]. In order to further follow this line of optimization it is relevant to achieve more size and shape uniform QDs. This work targets the optimization process of droplet epitaxy (DE) InAs QDs in InP by the use of interlayers.

In this work we performed, with atomic scale resolution, cross-sectional scanning tunneling microscopy (X-STM) on InAs DE QDs in InP, we also characterized the QDs with atomic force microscopy (AFM) and performed finite element simulations (FES). We measured two samples with different compositions in the interlayer (IL), the region below the QDs. The first sample has an $In_{0.53}Ga_{0.47}As$ IL and consists of two separate QDs layer with different amount of In (referred to as QDL1 and QDL2). The two regions are separated by 100nm of InP in order to reduce the chances of seeding of the QDs formation. The second sample has an IL composed by $In_{0.719}$ $Ga_{0.281}$ $As_{0.608}$ $P_{0.392}$ (Fig. 1) lattice matched to the InP of the host. Our study performed on these samples, highlighted how some previously identified effects (trenches and etch-pit formation [7]) were successfully avoided in these samples. We studied size, shape and composition of all the QDs measured. AFM and X-STM proved that these dots have a rhombic base elongated preferentially along the {110}. We performed FES and we can conclude that in the second sample the QDs purity is 95±5% InAs, while in the other sample the purity is around 90±5%. Results confirmed are not only by the relaxation and lattice constant but also from our X-STM measurements. These results prove that introducing P in the IL region can enhance the purity of the QDs and allow for a stress-free structure.

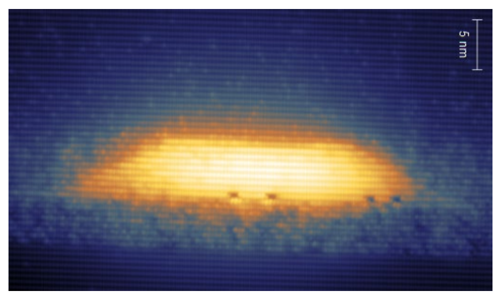

Figure 2 Filled state X-STM image of a QD on the InGaAsP IL sample.

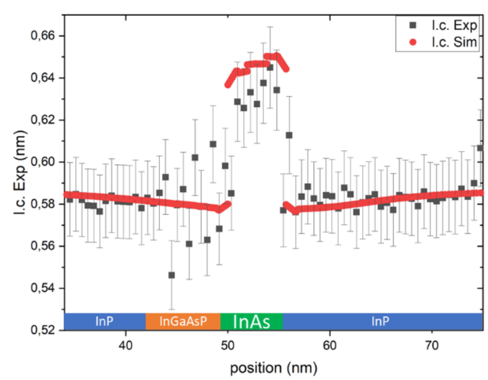

Figure 1 Lattice constant (l.c.) of QD in Fig. 1 both from experiment and from FES. In the InAs region there are three different P concentration, from left to right 10%, 5% and 0% P.

+ Author for correspondence: e.g.banfi@tue.nl

[1] D. Bimberg *et al,* doi: 10.1109/2944.605656
[2] Phu Lam *et al,* doi: 10.1016/j.solmat.2014.03.046
[3] J. Martín-Sánchez *et al*, doi: 10.1021/nn9001566
[4] E.M. Sala *et al*, doi: 10.1002/pssb.201800182
[5] R.H. Hadfield, doi: 10.1038/nphoton.2009.230
[6] R.M. Stevenson *et al*, doi: 10.1038/nature04446
[7] R.S.R Gajjela *et al,* doi: 10.1021/acsanm.2c01197