

Surface energy: a key parameter for epitaxial films growth and plasma atomic layer etching

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When growing epitaxial layers of various lattice-mismatched semiconductor systems, an abrupt change from a layer-by-layer 2D growth to the formation of 3D islands can eventually occur (or not). These islands are expected to be dislocation-free and are thus of high structural quality. Usually their typical sizes are on the scale of a few nanometers, so that these self-assembled quantum dots (QDs) are attractive nanostructures for the study of zero dimensional effects. In particular the growth of these QDs, including the ability to tune their dimensions, their surface density and their positions, has been a topic of intense research effort in the last decades, in order to control their optical properties for optoelectronic applications.

This elastic relaxation known as the Stranski-Krastanow (SK) transition is accounted here by a simple energetic equilibrium model taking into account not only the lattice mismatch, but also the dislocation formation energy and the cost in surface energy $\Delta\gamma$ associated with the creation of facets when forming these islands [1]. This approach demonstrates the crucial importance of these parameters especially for II-VI semiconductor systems: indeed, as misfit dislocations are easier to form in II-VI materials than in III-Vs (such as InAs/GaAs and GaN/AlN) or IV systems (Ge/Si), the 3D elastic transition is short-circuited by the plastic one that induces an array of dislocations. Nevertheless, by lowering the surface energy cost $\Delta\gamma$, II-VI semiconductor quantum dots can also be grown as predicted by our model and as evidenced experimentally by reflection high-energy electron diffraction (RHEED), atomic force microscopy and optical measurements [1]. As far as the III-V QDs are concerned, tuning the surface energy by changing the excess of cations (In or Ga) on the growth front, induces a significant variation of the critical 2D thickness before the appearance of this 3D transition [2,3].

The limits of this approach will be also discussed showing on one hand some experimental data validating this thermodynamic model [4], and on the other one, the changes due to the contribution of kinetics effects.

REFERENCES:

- [1] F. Tinjod, I.-C. Robin, R. André, K. Kheng, H. Mariette. *J. Alloys and Compounds*, 145 (2003); F. Tinjod *et al.* *Appl. Phys. Lett.* **82**, 4340 (2003).
- [2] B. Damilano, N. Grandjean, F. Semond, J. Massies, M. Leroux, *Appl. Phys. Lett.* **75**, 962 (1999); E. Martinez-Guerrero, F. Chabuel, B. Daudin, J.L. Rouvière, H. Mariette, *Appl. Phys. Lett.* 81, 5117 (2002); N. Gogneau, D. Jalabert, E. Monroy, T. Shibata, B. Daudin, *J. Appl. Phys.* 94, 2254 (2003).
- [3] C. Kendrick, A. Kahn, G. Le lay, *Surface Review and Letters*, 5, 229 (1998)
- [4] J.M. Gérard, J.B. Génin, J. Lefebvre, J.M. Moison, N. Lebouché, F. Barthe *J. Cryst. Growth* **150** 351 (1995).