Quantum dot formation induced by surface energy change of a 2D strained layer: the case of II-VI and nitrides nanostructures

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The formation of quantum dots (QDs) above a critical film thickness is well established for III-V lattice-mismatched semiconductors such as InAs/GaAs. The large lattice mismatch ($\Delta a/a$ = 6.7%) between these two semiconductors is seen as the driving force which induces the 2D-3D change of the surface morphology with the formation of coherent Stranski-Krastanow (SK) islands. However, in the case of II-VI systems, which have mismatch as large as 6% for CdTe/ZnTe or CdSe/ZnSe, the 2D-3D transition is more difficult to obtain. Indeed, in II-VIs, above a critical thickness h_c, a plastic relaxation occurs by generating misfit dislocations (MD). On the other hand, there are systems such as GaN/AlN, with lower misfit (2.4%), which exhibit a clear SK transition with the formation of coherent islands.

Thus, there are key parameters other than the lattice mismatch that determine the occurrence (or not) of the 2D-3D transition. For this purpose, we have developed a simple equilibrium model [1] taking into account not only the lattice mismatch but also the dislocation formation energy E_{MD} and the cost in surface energy $\Delta\gamma$ associated with the creation of facets when forming the islands. This approach demonstrates the crucial importance of these parameters especially for II-VI systems such as CdTe/ZnTe and CdSe/ZnSe: indeed in II-VIs, E_{MD} is smaller than in III-Vs, so that misfit dislocations are easier to form and the 3D elastic relaxation is short circuited by the plastic one.

However, by lowering the surface energy cost $\Delta\gamma$, telluride and selenide quantum dots can also be grown, as predicted by this model. We will describe the various procedures which have been used experimentally for both CdTe/ZnTe [2] and CdSe/ZnSe [3] in order to decrease this surface energy cost. They rely on a surface rearrangement *after the growth* when the II-VI layer is exposed to its group-VI element in appropriated conditions.

This model can account also for the results obtained with GaN/AlN. In this case *ab initio* calculations of the surface energies in the presence (or not) of a Ga-bilayer on the growth front has been calculated [4]. As observed experimentally [5], with an excess of Ga, the GaN layer stays 2D, whereas, by stopping the growth and by evaporating this Ga excess, a clear SK transition occurs. This corresponds to a decrease of the surface energy cost $\Delta\gamma^N$ as calculated by J. Neugebauer *et al*. [4].

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