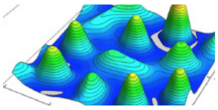

Bare quantum dots boost UV photoluminescence

Nitride-based devices are common in common electronic or opto-electronic devices (white LED, blue laser diodes...). The developpement of new materials based on Alx Ga$_{1-x}$N allow, by varying x, to span a large ultra-violet spectrum that is interesting e.g. for water purification or sanitization. Their epitaxial growth is often characterized by a large density of defects, but the growth of GaN on Alx Ga$_{1-x}$N leads to quantum dots that lessen their impact and enhence UV emission. More surprisingly, researchers in CRHEA showed that after an annealing with evaporation, the wetting layer that spreads in between dots and is traditional in the Stransky-Krastanov mode, disappears and leads to nanostructures with an amplified UV emission. The understanding and control of this evolution requires the description of the out-of-equilibrium dynamics, that has been done in collaboration INSP/InPHY, revealing a new epitaxial growth mode.

We considered the deposition by molecular beam epitaxy of 1-2 nm of GaN on $Al_{0.5}Ga_{0.5}N$. Growth is monitored in situ by electron microscopy and shows the growth of quantum dots and their subsequent partial evaporation under anneling. Their analysis by scanning transmission electron microscopy reveals two lay-outs. Just after growth, the dots are separated by a wetting layer, as described in the Stransky-Krastanov mode. But after annealing, the wetting layer has evaporated preferentially, leading to quantum dots deposited on a bare substrate. Their photoluminescence is amplified by a factor 6 compared to traditional dots.

To modelize this growth, we considered the free-boundary problem associated with the surface dynamics driven by surface diffusion. The growth of quantum dots relaxes the elastic strain between the film and substrate. Accounting for evaporation and the cristalline anisotropy, we solved the non-linear evolution equations based on the elastic Green functions. With conditions that ensure wetting conditions between the film and its substrate, we found three dynamical regimes as a function of the evaporation to diffusion ratio. The experimental parameters are well associated with the growth of quantum dots without their wetting layer, as coarsening leads to a preferential evaporation of the wetting layer.

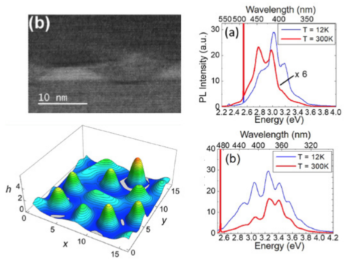

Figure 1
(left) Microscopy image of quantum dots without their wetting layer, and modelization of their growth ; (right) comparison between the luminescence of quantum dots with (top) and without (down) their wetting layer.

This joint theoretical/experimental study allows to rationalize and control the geometry of these epitaxial nanostructures. The new growth mode revealed, "beyond" Stransky-Krastanov, leads to nanostructures that have a photoluminescence power increased, and opens the path to new devices that emit in the deep UV.

Reference

"Wetting-Layer-Free AlGaN Quantum Dots for Ultraviolet Emitters"
G. Schifani, T. Frisch, J. Brault, P. ennéguès, S. Matta, M. Korytov, B. Damilano, J. Massies, J.-N. Aqua
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