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Droplet Etching during Semiconductor Epitaxy for Single and Coupled Quantum Structures

Dr. Christian Heyn
Department of Physics
University of Hamburg, Germany

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For more information contact:
Michael Scheibner
mscheibner@ucmerced.edu

ABSTRACT

Self-assembly schemes during molecular beam epitaxy (MBE) allow the generation of large ensembles of semiconductor nanostructures without the need of any lithographic steps. Here, we functionalize nanodroplets to drill spatially well separated shape- and size-tunable nanoholes into semiconductor surfaces. This technique is called local droplet etching (LDE) and the mechanisms behind droplet etching are studied experimentally and theoretically. In detail, the influence of substrate and droplet materials as well as the control of the nanohole structural properties by the process parameters are discussed. For functionalization, the LDE nanoholes are filled with a material different from the substrate. This allows the creation of various types of nanostructures like ultra-short nanopillars, strain-free GaAs quantum dots (QD) in AlGaAs matrix, and self-aligned GaAs quantum dot molecules (QDM). The optical emission wavelength of the LDE GaAs QDs is tunable by the hole filling-level and their small exciton peak line width, low neutral exciton fine-structure splitting, and clear single-photon emission suggests the LDE dots for quantum information applications. Vertically stacked QDs forming a QDM are created by hole filling with more complex heterostructures. Here, gate-voltage dependent photoluminescence measurements exhibit indirect excitons with electron and hole in different dots. Furthermore, anti-crossings between direct and indirect excitons are a clear proof for delocalized charge carriers with binding and anti-binding states and, thus, a molecule resonance. Highly asymmetric QDMs allow studies of coupling also for excited-state charge carriers where we assume a long lifetime stabilized by a phonon bottleneck.

BIO:

Dr. Christian Heyn was born 1960 in Germany. He studied and obtained his PhD in physics. Since 1995 he has been a senior researcher and head of a laboratory for molecular beam epitaxy (MBE) at the Institute for Applied Physics (now Center for Hybrid Nanostructures, CHyN) at the University of Hamburg.

Expertise: Design and fabrication of various types of MBE heterostructures with focus on self-assembly and droplet-based techniques. Modelling of epitaxial growth and self-assembly processes. Measurements of the structural, electrical, and optical properties of the created quantum structures. Modelling of their quantized energy states.