HL 78: Quantum dots: Preparation and characterization

Time: Wednesday 16:30–18:45 Location: POT 251

HL 78.1 Wed 16:30 POT 251

Nonvolatile memory characteristics of Ge nanocrystals embedded in TaZrO2 — •David Lehninger[1], Peter Seidel[1], Frank Schneider[1], Volker Klemm[2], Johannes von Borany[3], and Johannes Heitmann[1] — [1]Institut für Angewandte Physik, TU Bergakademie Freiberg, D-09596 Freiberg — [2]Institut für Werkstoffwissenschaft, TU Bergakademie Freiberg, D-09596 Freiberg — [3]Institut für Ionenstrahlphysik und Materialforschung, HZDR, D-01314 Dresden

NVM devices with charge storage in discrete nanocrystals (NCs) offer the chance for better scalability and to operate at lower voltages compared to continuous floating gate (FG) flash devices. Using Ge NCs instead of Si NCs is expected to further improve the memory performance due to the smaller bandgap of Ge compared to Si.

In this work, Ge NCs embedded in a high-k control oxide have been fabricated by magnetron sputtering of Ge-TaZrO2/TaZrO2 layers on a p-type Si-Wafer covered by a 5 nm thermal oxide. The formation of spherically shaped Ge NCs in amorphous TaZrO2 is demonstrated by cross-sectional TEM. C-V measurements exhibit a counter clockwise hysteresis indicating the tunneling of holes through the SiO2 and their subsequent trapping in the Ge NCs. The memory window widens with both, sweep voltage range and programming time. The discharging kinetic is examined by the constant capacity method and shows a long time stabile state after an initial logarithmic decay. It could be shown, that MIS structures comprising Ge NCs in amorphous high-k TaZrO2 show promising NVM characteristics.

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Atomic structure of InGaAs/GaAs quantum dots in a GaP(001) matrix — •Holger Eisele, Christopher Prohl, Andrea Lenz, Dominik Roy, Gernot Stracke, Andre Strittmatter, Udo W. Pohl, Dieter Bimberg, and Mario Daehne — Institut für Festkörperphysik, Technische Universität Berlin, Hardenbergstr. 36, 10623 Berlin

Due to the comparably low lattice mismatch, GaP is a promising material for the direct integration of optical III-V-semiconductor applications into silicon-based technology. Therefore, the development of epitaxially grown nanostructures—like quantum dots—on GaP(001) substrates for opto-electronic devices is an interesting new task. Furthermore, In(Ga)As/GaP quantum dots are also promising for new nano-memory cells due to an expected high hole localization energy at the quantum dots, as compared with InAs/GaAs quantum dots, resulting in reasonable long storage times. In order to understand the growth and capping of quantum dots in this new material system, we analyzed InGaAs/GaAs/GaP nanostructures on the atomic scale, using scanning tunnelling microscopy (XSTM).

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Crystallization phenomena of germanium nano crystals in ZrO_2 — •Maximilian Geyer[1], Peter Seidel[1], David Lehninger[1], Volker Klemm[2], Gerhard Schreiber[2], and Johannes Heitmann[1] — [1]TUBAF, Institut für Angewandte Physik — [2]TUBAF, Institut für Werkstoffwissenschaften

Due to the heightened interest of semiconductor nanocrystals in high-κ matrices the crystallization of germanium in ZrO_2 was investigated. Germanium was especially interesting because of its smaller band gap and higher Bohr-radius then silicon and ZrO_2 shows superior high-κ and dielectric properties and is of interest for optical and electrical applications.

All samples were prepared by a co-sputtering process of a superlattice containing pure ZrO_2 and mixed Ge/ZrO_2 layers. First different annealing processes combined with different capping layers to prevent the oxidation of germanium due to the oxygen conductivity of the matrix were tested. A Capping layer of SiO_2 combined with a RTP annealing process gives the best results. Raman and photoluminescence spectroscopy show characteristic peaks after this processing which are connected to nanocrystalline structures.

Furthermore we found that a interface layer of silicon nitride in contrast to the natural silicon oxide transmits the crystal information of our silicon substrate to the layers of our superlattice and makes a continuous crystallization of germanium possible.

Further research will investigate different layer compositions and the possibility of lateral conductivity through the nano crystalline layers.

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Fabrication of a charge-tunable GaAs/AlGaAs strain-free quantum dot device suitable for single dot spectroscopy — •Fabian Langer, David Plischke, Martin Kamp, and Sven Höfling — Technische Physik and Wilhelm Conrad Röntgen Research Center for Complex Material Systems, University of Würzburg, Am Hubland, D-97074 Würzburg, Germany

Stranski-Krastanov growth has been the method of choice for the fabrication of high-quality self-assembled quantum dots in a variety of material systems. The difference in lattice constants that drives the self-organization of the dots is absent in the GaAs/AlAs material system. Therefore, other approaches like modified droplet epitaxy (MDE)[1] have to be used for producing GaAs QDs on AlGaAs. This process creates QDs without significant material intermixing and allows the investigation of exciton fine-structure splitting or nuclear spin dynamics without the influence of strain or piezoelectric effects. In this contribution we report on the fabrication of a charge-tunable GaAs/AlGaAs QD device containing QDs deposited by MDE. We achieved a QD density in the low 10^9 1/cm^2 range, enabling the use of single dot spectroscopy without any additional patterning. The observed linewidths are as small as 40 μeV. We were able to charge a single QD with up to four electrons in devices with a Schottky gate. The QD character of the photoluminescence (PL) emission was proven by photon antibunching and cross-correlation measurements yielding a $g^{(2)}(0)$ value of 0.05.

[1] Watanabe, K.; Nobuyuki, K.; Gotoh, Y. Jpn. J. Appl. Phys., Vol. 39, L79-L81, 2000

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GaAs quantum dots in shallow and deep nanoholes fabricated by local droplet etching — •Christian Heyn, Achim Küster, David Sonnenberg, Andreas Graf, Arne Ungeheuer, and Wolfgang Hansen — Institute of Applied Physics, University of Hamburg, D-20355 Hamburg, Germany

We fabricate GaAs quantum dots (QDs) by filling of nanoholes drilled in an AlGaAs substrate utilizing local droplet etching (LDE) [1]. The etching process takes place in a self-assembled fashion during molecular beam epitaxy (MBE) without the need of additional equipment. Using Al droplets as etchant, the nanohole depth d can be varied from less than 10 to more than 100 nm in a controlled fashion. Optical studies of single LDE GaAs QDs show clear excitonic features [2]. Here, we compare the single-dot photoluminescence emission of low-density ($N \simeq 10^7$ cm^{-2}) QDs formed by partial filling of either shallow ($d \simeq$ 10 nm) or deep (d = 70 - 100 nm) holes.

[1] Ch. Heyn, A. Stemmann, T. Köppen, Ch. Strelow, T. Kipp, S. Mendach, and W. Hansen, Appl. Phys. Lett. **94**, 183113 (2009).

[2] Ch. Heyn, Ch. Strelow, and W. Hansen, New Journal of Physics **14**, 053004 (2012).

HL 78.6 Wed 17:45 POT 251

Charge carrier localization by Sb-assisted growth of InAs/GaAs sub-monolayer stacks — •David Quandt, Jan-Hindrik Schulze, Manuel Gschrey, Ronny Schmidt, Sven Rodt, Andre Strittmatter, Udo W. Pohl, and Dieter Bimberg — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstraße 36, D-10623 Berlin

Quantum dots (QDs) grown in the sub-monolayer (SML) growth mode result in dense arrays of 3D charge carrier localization centers which enable high-gain active regions in laser devices. InAs/GaAsSML QDs grown by MOVPE typically exhibit very high island densities which, due to lateral electronic coupling, provide only weak carrier localization. Using Sb as additional species during growth of InAs/GaAs SML QDs, the electronic confinement properties can be effectively tuned to strong carrier localization. This is evidenced by spatially resolved cathodoluminescence spectroscopy revealing individual sharp lines in the ensemble luminescence. The amount of supplied Sb controls also the ensemble broadening which is very attractive for mode-locking applications in laser devices.

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Growth, structure and spectroscopy of $In_{0.50}Ga_{0.50}As$ quantum dots grown by MOVPE on GaP(001) — •Elisa Maddalena Sala, Gernot Stracke, Manuel Gschrey, Christopher Prohl, Andrei Schliwa, Holger Eisele, André Strittmatter, and Dieter Bimberg — Institut für Festkörperphysik, Technische Universität Berlin Hardenbergstr. 36 10623 Berlin, Germany

InGaAs quantum dots (QDs) on GaP have recently attracted great attention for application in nano memory cells and monolithic III/V on silicon photonics. $In_{0.50}Ga_{0.50}As$ QDs on GaP(001) grown by metalorganic vapor phase epitaxy exhibit truncated inverted pyramidal shape and strong indium agglomeration at QD tops. For injection of electrons into the QDs, indirect bandgap of GaP with lowest conduction band states at the X-point has to be taken into account. 8-band k·p theory predicts a QD size- and strain- dependent transition from indirect to direct optical emission. By preparing QD ensemble of ultra-low density, detection of luminescence from individual InGaAs/GaP QDs is enabled for the first time. Narrow emission lines with FWHM of 52 μmeV showing no spectral jitter suggest that no electrical active defects are present in the QD vicinity. Temperature-dependent cathodoluminescence investigations allow to study the electronic structure of InGaAs/GaP QDs since thermally induced strain alters the electronic structure of the QDs allowing to research for the transition from indirect-to-direct optical emission.
Towards QD positioning, initial studies on buried stressor formation by selective lateral oxidation of thin AlP layers will be presented.

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GaN quantum dots grown on AlN by MOVPE — •Farsane Tabataba-Vakili, Konrad Bellmann, Tim Wernicke, Stefan Kalinowski, André Strittmatter, and Michael Kneissl — Technische Universität Berlin, Institut für Festkörperphysik, Hardenbergstr. 36, 10623 Berlin, Germany

GaN quantum dots (QDs) embedded in an AlN matrix enable single and entangled photon emitters operating at room temperature, which are key elements in quantum information science. Stranski-Krastanow (SK) growth of GaN QDs by metal organic vapor phase epitaxy (MOVPE) is subject to a multi-dimensional parameter space of which we have studied the effects of temperature, V/III ratio, and growth interruption (GRI). Desorption effects have a large impact on surface morphologies. Performing a GRI without ammonia supply transforms two dimensional GaN grown under a high V/III ratio into three dimensional islands with a few nm in height and 50-90 nm in diameter. Narrow emission lines of 10 meV from individual islands are observed in μ-PL experiments. Experiments with different V/III ratios during GaN deposition show that a SK-growth mode transition can be achieved for low V/III ratios during GaN deposition. Thereby, QDs with an average height of 4.5 nm and 26 nm in diameter are obtained at densities of $10^{10}\,cm^{-2}$.

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Growth and characterisation of InGaN quantum dots on AlGaN-Templates — •Carsten Laurus[1], Timo Aschenbrenner[1], Elahe Zakizadeh[1], Stephan Figge[1], Detlef Hommel[1], JunJun Wang[2], and Ferdinand Scholz[2] — [1]Institute of Solid State Physics, University of Bremen, Otto-Hahn-Allee, 28359 Bremen, Germany — [2]Institut für Optoelektronik, Universität Ulm, Albert-Einstein-Allee 45, 89081 Ulm, Deutschland

InGaN quantum dots (QDs) are of great interest to realize single photon emitters. Single photon emission (SPE) up to 50 K was achieved utilizing spinodal phase decomposition for QD formation. In order to improve the confinement of charge carriers in QDs and thus the temperature stability of the emission the introduction of barrier-layers with a higher bandgap energy is reasonable. However, each interface might introduce defects. Using an other template (buffer-layer) material might turns out to be a good compromise. Using InGaN as active layer, AlGaN is a promising material for templates because of its higher bandgap. Samples using GaN- and AlGaN-Templates were grown by MOVPE. For structural analysis by SEM samples without capping layer were used, whereby μ-PL investigations were made with capped samples. Based on SEM data all samples regardless from the template show a meander-like structure of different size in line with the model spinodal decomposition. Furthermore, the capping of InGaN QDs with GaN or AlGaN and its influence on the confinement will be discussed by reference to μ-PL measurements. In addition, sharp μ-PL emission lines could be traced up to 65K for samples grown on AlGaN templates.