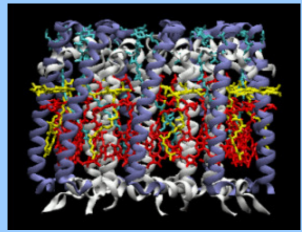
Optyka nanostruktur



Sebastian Maćkowski

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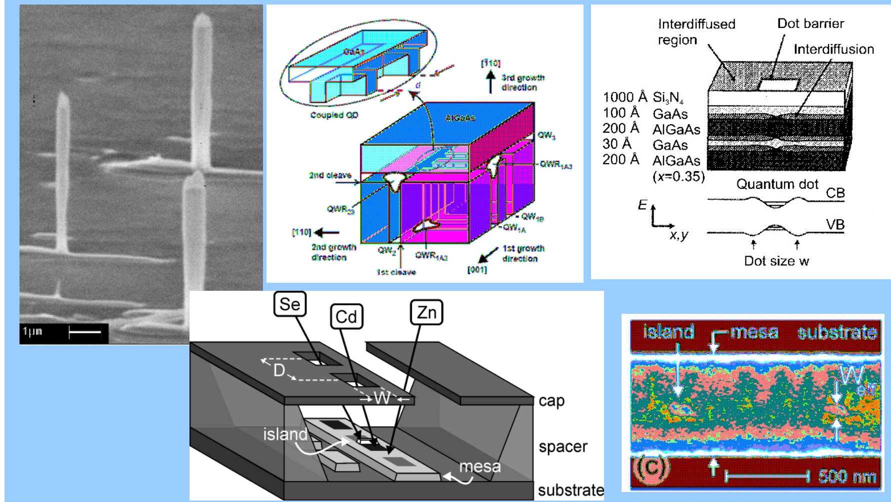
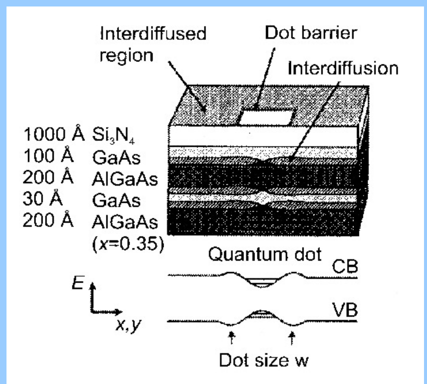
Biuro: **365**, telefon: **611-3250**

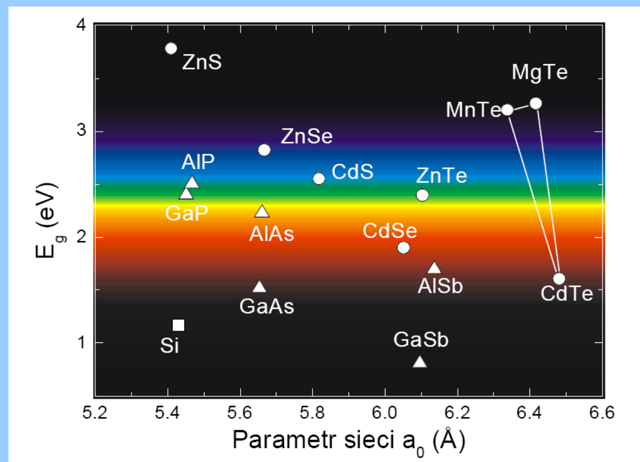
„Pierwsze" kropki kwantowe



Kropka wygrzewana



Przerwa energetyczna



Mody wzrostu

Frank van der Merwe	Stranski-Krastanov	Volmer-Weber

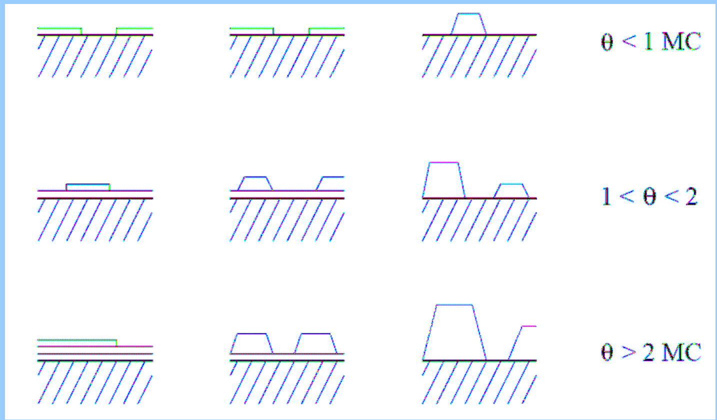
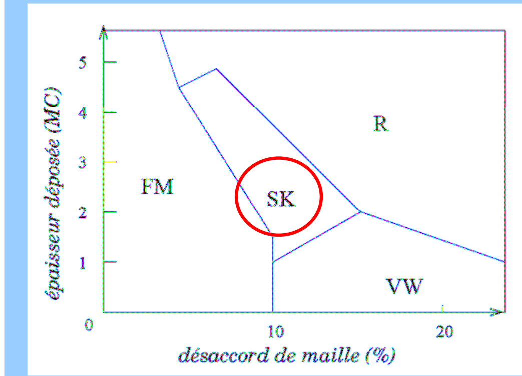


Diagram fazowy



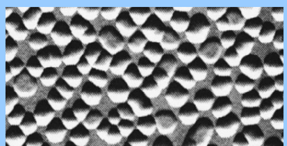
Composés	Désaccord de maille (%)
$InAs/GaAs$	7,2
$CdSe/ZnSe$	6,8
GaN/AlN	2,4(c); 2,7(h)
$Si_{0,7}Ge_{0,3}/Si$	1,2
CdTe/ZnTe	6,2

tak powstają kropki kwantowe

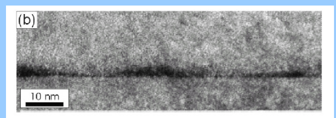
Kropki samorosnące

self-assembled, self-organized quantum dots

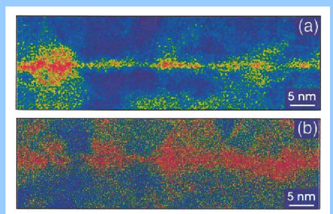
InAs/GaAs QDs



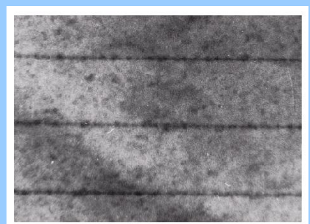
Si/Ge QDs



CdSe/ZnSe QDs

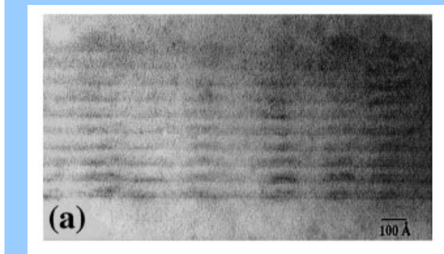


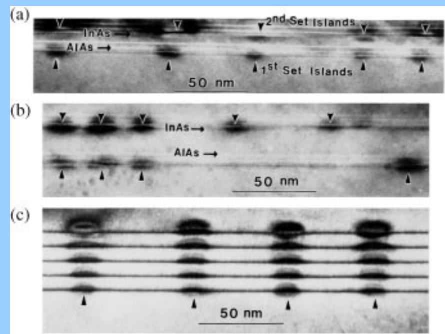
CdTe/ZnTe QDs



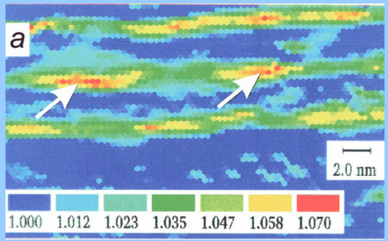
Korelacje przestrzenne

InAs/GaAs QDs



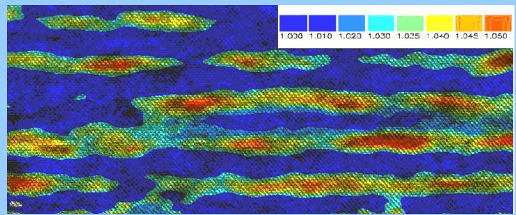


Korelacje przestrzenne

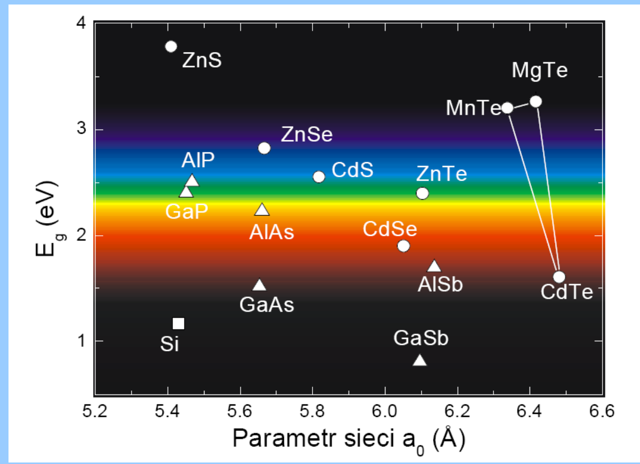


CdSe/ZnSe QDs

CdTe/ZnTe QDs



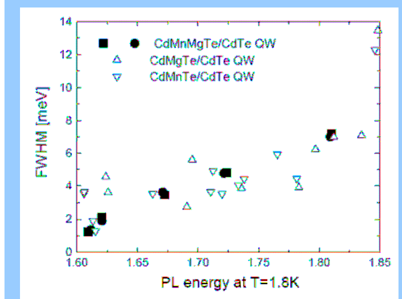
Dopasowane studnie kwantowe

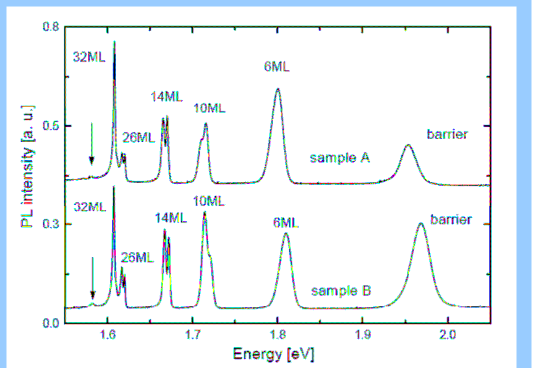


np.:
CdTe/CdMnMgTe

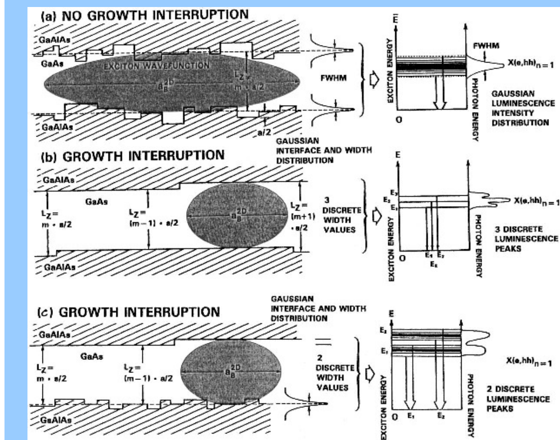
Dopasowane studnie kwantowe

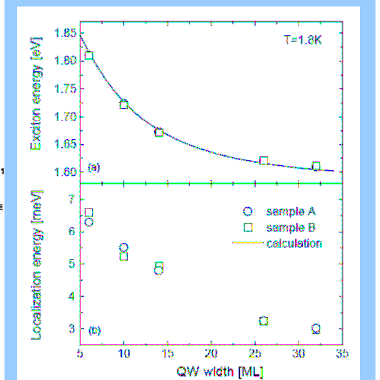
szerokość linii rośnie dla węższych studni kwantowych



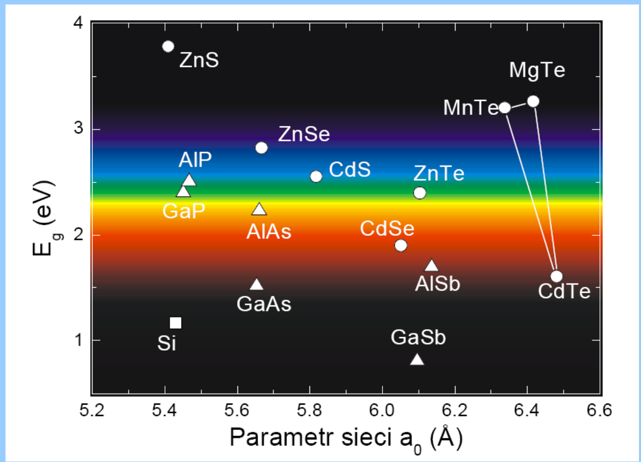


Wpływ fluktuacji szerokości



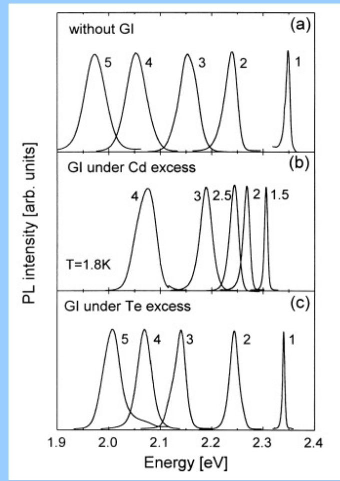


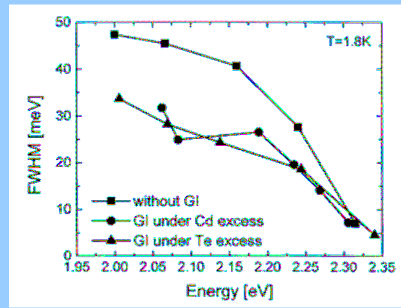
Naprężone studnie kwantowe



np.: CdTe/ZnTe

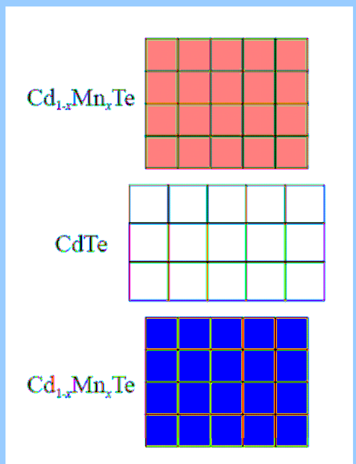
Widma luminescencji

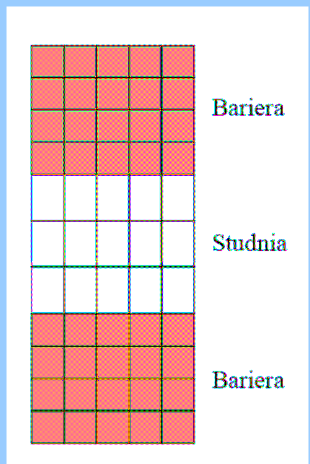




szerokość linii rośnie dla szerszych studni kwantowych

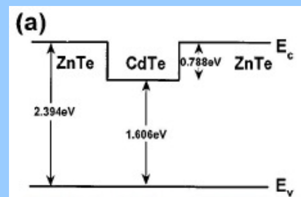
Grubość krytyczna



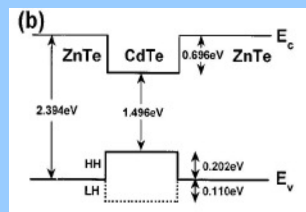


naprężenie ściskające

„Common anion” rule



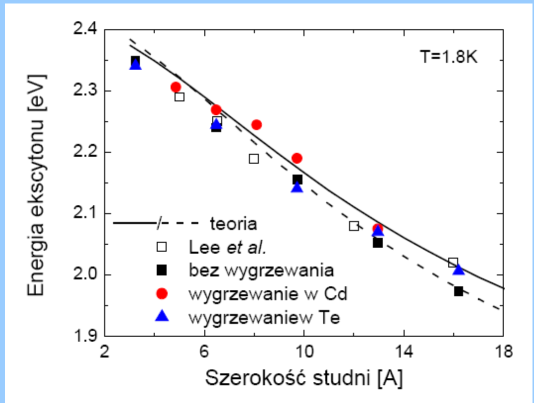
bez uwzględnienia naprężeń -> nie ma lokalizacji dziur



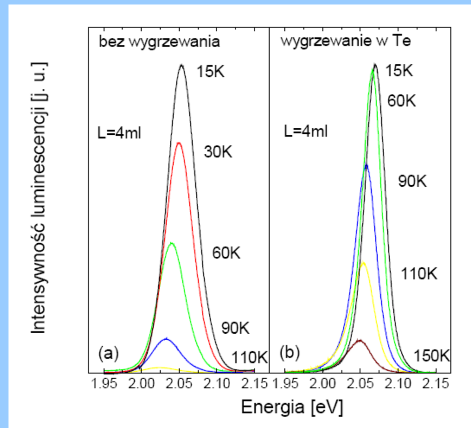
z uwzględnieniem naprężeń -> potencjał dla dziur

„Common anion” rule

opis zależności energii emisji od szerokości studni wymaga uwzględnienia naprężeń



Naprężone studnie kwantowe



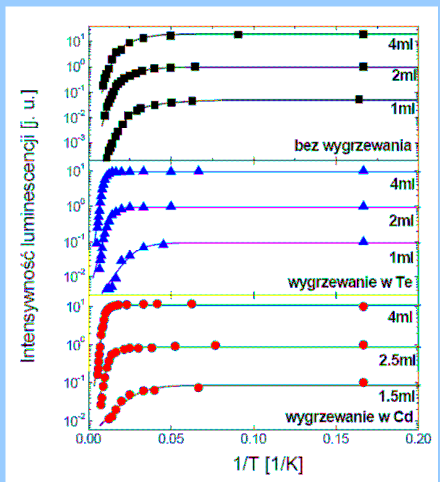
wygrzewanie poprawia własności optyczne naprężonych studni kwantowych

opis ilościowy przy użyciu energii aktywacji

$$I(T) = \frac{I_0}{1 + Ce^{-\frac{E_A}{k_B T}}}$$

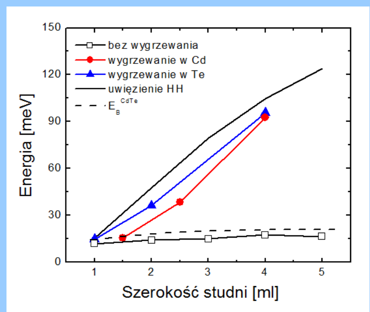
mechanizm rekombinacji bezpromienistej

Intensywność vs. temperatura

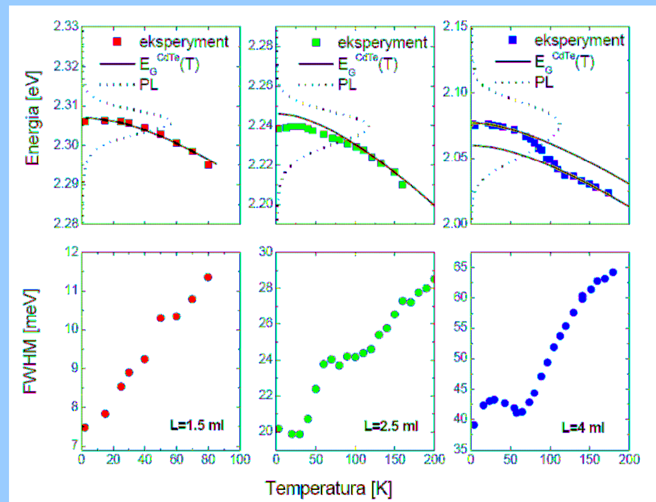


bez wygrzewania: brak zależności od szerokości studni

dla studni wygrzewanych: silna zależność od szerokości studni



Lokalizacja w studni



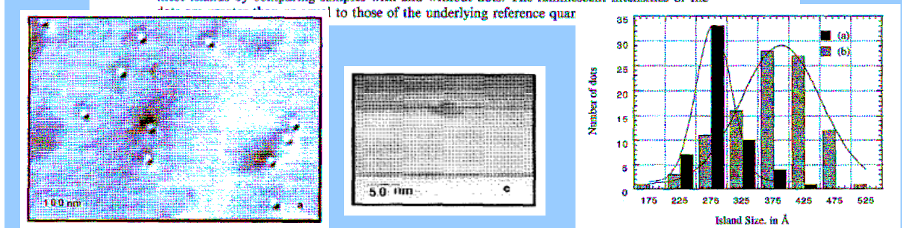
Kropki samorosnące

Direct formation of quantum-sized dots from uniform coherent islands of InGaAs on GaAs surfaces

D. Leonard, M. Krishnamurthy, C. M. Reaves, S. P. Denbaars, and P. M. Petroff
Materials Department and QUEST, University of California, Santa Barbara, California 93106

(Received 2 July 1993; accepted for publication 27 September 1993)

The 2D–3D growth mode transition during the initial stages of growth of highly strained InGaAs on GaAs is used to obtain quantum-sized dot structures. Transmission electron micrographs reveal that when the growth of $In_{0.5}Ga_{0.5}As$ is interrupted exactly at the onset of this 2D–3D transition, dislocation-free islands (dots) of the InGaAs result. Size distributions indicate that these dots are ~300 Å in diameter and remarkably uniform to within 10% of this average size. The areal dot densities can be varied between 10^9 and 10^{11} cm^{-2}. The uniformity of the dot sizes is explained by a mechanism based on reduction in adatom attachment probabilities due to strain. We unambiguously demonstrate photoluminescence at ~1.2 eV from these islands by comparing samples with and without dots. The luminescent intensities of the ... to those of the underlying reference quar



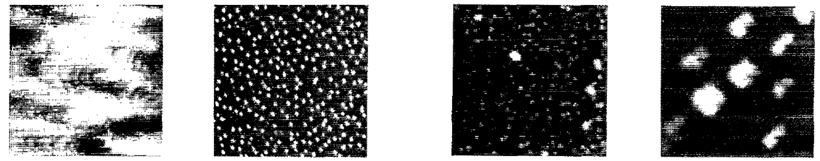
Kropki samorosnące

Self-organized growth of regular nanometer-scale InAs dots on GaAs

J. M. Moison, F. Houzay, F. Barthe, and L. Leprince
France Telecom, Centre National d'Etudes des Télécommunications Paris B, Laboratoire de Bagneux,[a) 196 Avenue Henri Ravera B.P. 107 F-92225 Bagneux Cedex, France
E. André and O. Vatel
France Telecom, Centre National d'Etudes des Télécommunications, Centre Norbert Segard, Chemin du Vieux Chêne BP 98 F-38243 Meylan Cedex, France

(Received 27 April 1993; accepted for publication 1 November 1993)

The deposition of InAs on GaAs proceeds first by two-dimensional (2D) growth and above a 1.75 monolayer coverage by the formation of single-crystal dots on a residual 2D wetting layer. By atomic force microscopy measurements, we show that the first dots formed are in the quantum size range (height 30 Å, half-base 120 Å), that the dispersion on their sizes is remarkably low (±10%), and that they are located fairly regularly (interdot distance 600 Å). Upon further growth, density and shapes do not change but sizes increase up to double values before coalescence occurs. Self-organized growth in strained structures is then shown to be a simple and efficient way of building regular quantum dots.



(a) Θ = 1.7 ml, 1μm x1μm x 25Å (b) Θ = 2.3 ml, 1μm x1μm x 175Å (c) Θ = 3 ml, 1μm x 1μm x 220Å (d) Θ = 6 ml, 1μm x 1μm x 550Å

Kropki samorosnące

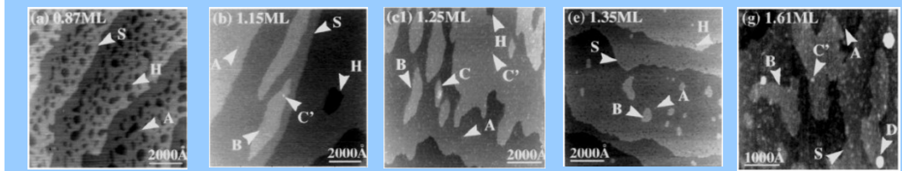
VOLUME 78, NUMBER 21 PHYSICAL REVIEW LETTERS 26 MAY 1997

Observation of Reentrant 2D to 3D Morphology Transition in Highly Strained Epitaxy: InAs on GaAs

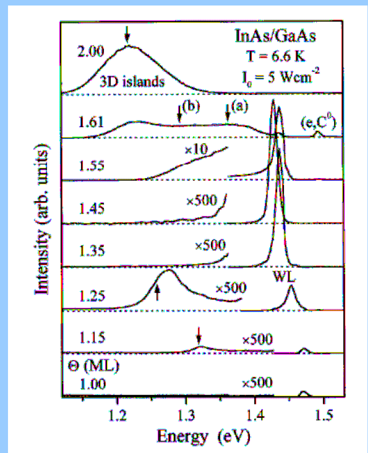
R. Heitz, T. R. Ramachandran, A. Kalburge, Q. Xie, I. Mukhametzhanov, P. Chen, and A. Madhukar
Photonic Materials and Devices Laboratory, Department of Materials Science and Physics, University of Southern California, Los Angeles, California 90089-0241
(Received 19 September 1996)

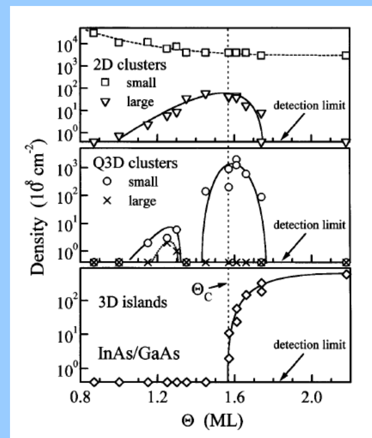
The two-dimensional (2D) to three-dimensional (3D) transition in highly strained growth of InAs of GaAs(001) is investigated using *in situ* scanning tunneling microscopy and photoluminescence spectroscopy. Remarkably, InAs structural features up to five monolayers (ML) high appear at ~1.25 ML, disappear, and reappear prior to the onset of well-developed 3D islands at 1.57 ML, thus manifesting a hitherto unrecognized reentrant behavior in the formation of 3D islands. The results provide new insights into the long-standing problem of the kinetic aspects of 2D to 3D morphology change not embodied in the widely encountered Stranski-Krastanow growth mode. [S0031-9007(97)03235-3]

PACS numbers: 68.35.Bs, 61.16.Ch, 78.66.Fd



Kropki samorosnące





Kropki samorosnące

PHYSICAL REVIEW B VOLUME 58, NUMBER 4 15 JULY 1998-II

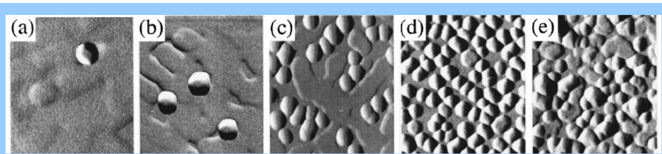
Structural and radiative evolution in quantum dots near the $In_xGa_{1-x}As/GaAs$ Stranski-Krastanow transformation

R. Leon*
Research School of Physical Sciences, Australian National University, Australian Capital Territory 0200, Australia

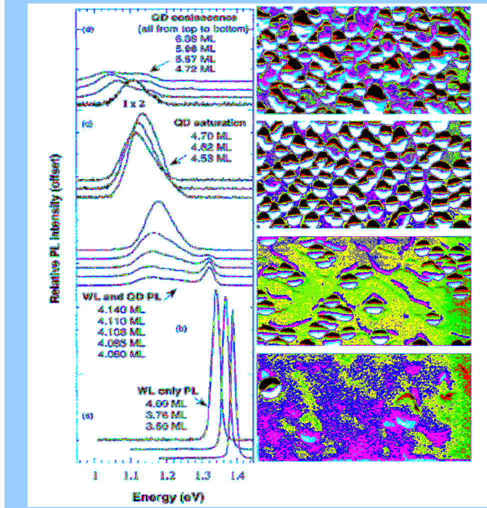
S. Fafard
Institute for Microstructural Sciences, National Research Council, Ottawa, Ontario, Canada K1A 0R6

(Received 27 January 1998)

The evolution of Stranski-Krastanow (SK) quantum-dot (QD) formation in ternary $In_{0.6}Ga_{0.4}As/GaAs$ was studied with graded structures grown via organometallic vapor-phase epitaxy. Surface-probe microscopy showed island evolution between 3.5- and 6.5-monolayer (ML) deposition. Island densities increased exponentially (over three decades with 0.2-ML deposition) before saturation ~4.7 ML. Photoluminescence (PL) of capped structures show that the wetting-layer PL energy does not shift beyond the onset of the SK transition. PL intensities increased with QD concentration but not in proportion to QD density. After saturation, a sharp drop in PL intensity was observed, which we attribute to island coalescence and incoherent island formation. Excitation power dependence of the luminescence at different stages of QD evolution indicates a concentration dependence of optical saturation in self-forming $In_xGa_{1-x}As$ QD's. [S0163-1829(98)50828-4]



Morfologia a luminescencja

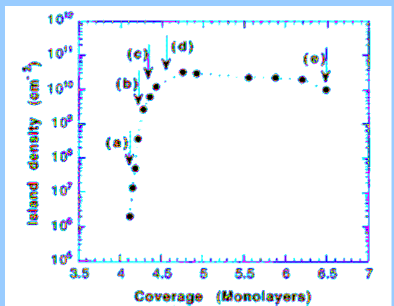


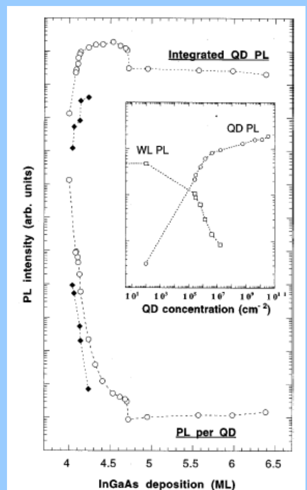
brak emisji z WL
słaba intensywność emisji
z kropek kwantowych

dwie linie:
WL – stała energia, wąska linia
QDs – zmienna energia, szeroka linia

energia przesuwa się ze wzrostem grubości warstwy InGaAs

Morfologia a luminescencja





dla układu InAs/GaAs wzrost kropek kwantowych bardzo dobrze zgadza się z modem wzrostu Stanskiego-Krastanova

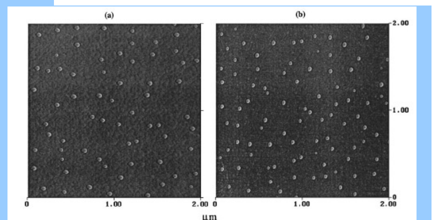
Kropki kwantowe CdSe/ZnSe

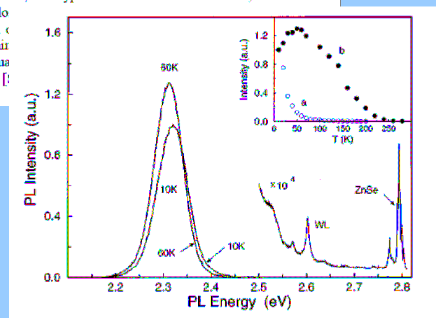
Formation of self-assembling CdSe quantum dots on ZnSe by molecular beam epitaxy

S. H. Xin,[a] P. D. Wang,[b] Aie Yin,[a] C. Kim,[a] M. Dobrowolska,[a] J. L. Merz,[b] and J. K. Furdyna[a]
University of Notre Dame, Notre Dame, Indiana 46556

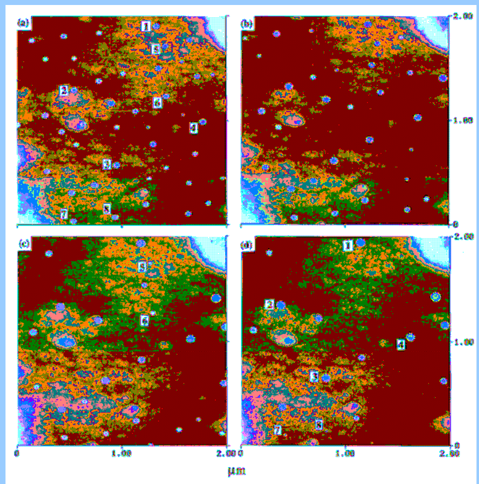
(Received 20 June 1996; accepted for publication 16 October 1996)

We report the formation of self-assembling CdSe quantum dots during molecular beam epitaxial growth on ZnSe and ZnMnSe. Atomic force microscopy measurements on samples with uncapped dots show relatively narrow dot size distributions, with typical dot diameters of 40±5 nm, and with a diameter-to-height ratio consistently very clo with time: their density was observed to drop by an evidence of ripening observed for some dots. Photolumi localization much stronger than in ZnCdSe/ZnSe qua confinement. © 1996 American Institute of Physics. [





Kropki kwantowe CdSe/ZnSe



Oswald rippening ?

Kropki kwantowe CdSe/ZnSe

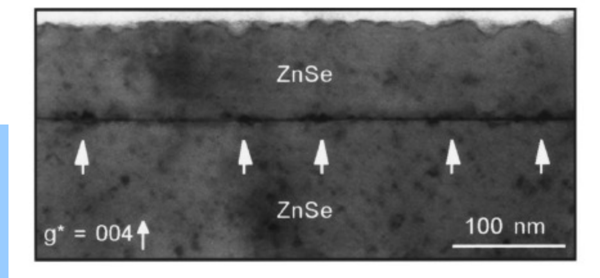
APPLIED PHYSICS LETTERS VOLUME 72, NUMBER 11 16 MARCH 1998

Transmission electron microscopy investigation of structural properties of self-assembled CdSe/ZnSe quantum dots

H. Kirmse, R. Schneider, M. Rabe, W. Neumann,[a] and F. Henneberger
Humboldt-Universität Berlin, Institut für Physik, Invalidenstrasse 110, D-10115 Berlin, Germany

(Received 8 December 1997; accepted for publication 14 January 1998)

CdSe quantum dots on ZnSe, grown by molecular beam epitaxy and formed during reorganization of an initially uniform film by thermal activation, are microstructurally elucidated in cross section



Kropki kwantowe CdTe/ZnTe

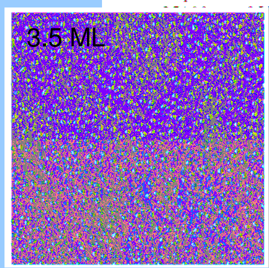
APPLIED PHYSICS LETTERS VOLUME 73, NUMBER 25 21 DECEMBER 1998

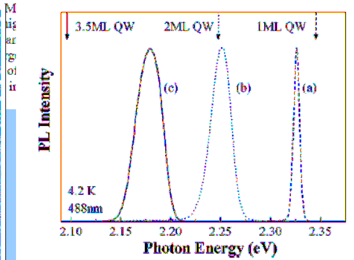
Zero-dimensional excitonic properties of self-organized quantum dots of CdTe grown by molecular beam epitaxy

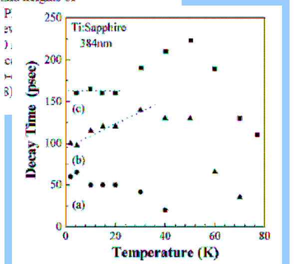
Yoshikazu Terai, Shinji Kuroda,[a] and Kōki Takita
Institute of Materials Science, University of Tsukuba, Tsukuba, Ibaraki 305-8573, Japan
Tsuyoshi Okuno and Yasuaki Masumoto
Institute of Physics, University of Tsukuba, Tsukuba, Ibaraki 305-8571, Japan

(Received 22 June 1998; accepted for publication 18 October 1998)

The successful growth of self-organized quantum dots (QDs) of CdTe on ZnTe (100) surface by molecular beam epitaxy is reported. Atomic force microscope measurements on the uncapped samples revealed the formation of CdTe QDs with typical dot diameters of 20±2 nm and heights of







Kropki kwantowe CdTe/ZnTe

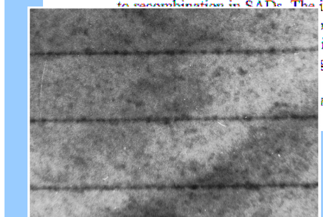
APPLIED PHYSICS LETTERS VOLUME 74, NUMBER 20 17 MAY 1999

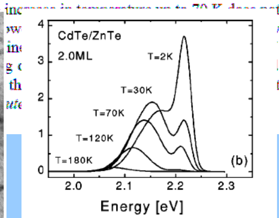
Photoluminescence study of CdTe/ZnTe self-assembled quantum dots

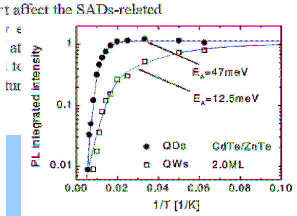
G. Karczewski,[a] S. Maćkowski, M. Kutrowski, T. Wojtowicz, and J. Kossut
Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, 02-668 Warsaw, Poland

(Received 19 August 1998; accepted for publication 26 March 1999)

We report on optical properties of CdTe self-assembled quantum dots (SADs) grown by molecular beam epitaxy on ZnTe. Formation of SADs was achieved by deposition of 1.5–2.5 monolayers of CdTe at a substrate temperature of 420 °C and by applying growth interrupts for few seconds in Cd flux. The resulting dots have a typical diameter of 2 nm and a sheet density of 10^{12} cm^{-2}. At T=2 K the photoluminescence (PL) spectra consist of two emission lines. The high-energy line originates from excitonic recombination in a wetting layer while the low-energy emission PL band is assigned







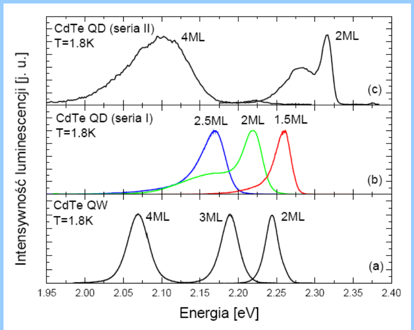
Kropki kwantowe CdTe/ZnTe

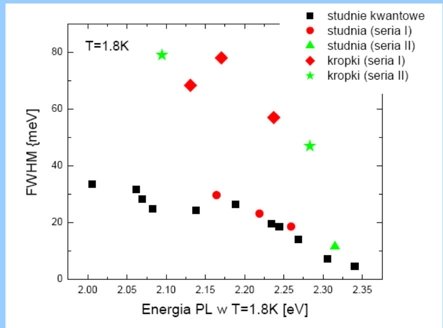
APPLIED PHYSICS LETTERS VOLUME 74, NUMBER 20 17 MAY 1999

Photoluminescence study of CdTe/ZnTe self-assembled quantum dots

G. Karczewski,[a] S. Maćkowski, M. Kutrowski, T. Wojtowicz, and J. Kossut
Institute of Physics, Polish Academy of Sciences, Al. Lotników 32/46, 02-668 Warsaw, Poland

(Received 19 August 1998; accepted for publication 26 March 1999)





Korelacje przestrzenne

VOLUME 75, NUMBER 13 PHYSICAL REVIEW LETTERS 25 SEPTEMBER 1995

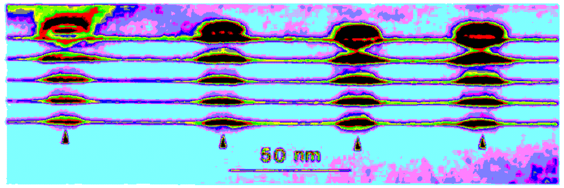
Vertically Self-Organized InAs Quantum Box Islands on GaAs(100)

Qianghua Xie, Anupam Madhukar, Ping Chen, and Nobuhiko P. Kobayashi
Photonic Materials and Devices Laboratory, Departments of Materials Science and Physics, University of Southern California, Los Angeles, California 90089-0241

(Received 6 April 1995)

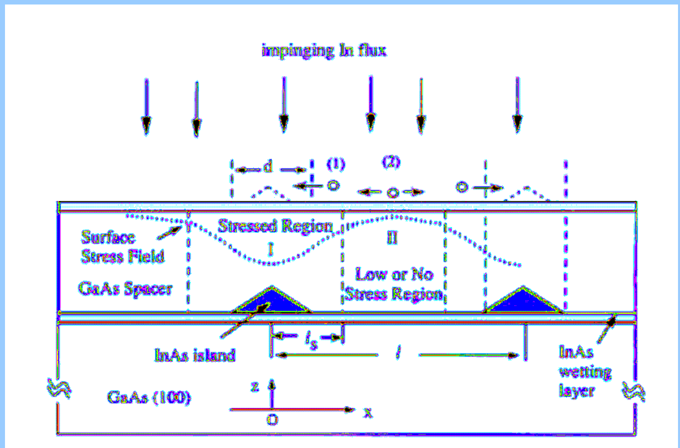
Coherent InAs islands separated by GaAs spacer layers are shown to exhibit self-organized growth along the vertical (i.e., growth) direction. The driving force for such vertically self-organized growth is shown to be the interacting strain fields induced by the islands which give rise to a preferred direction for In migration. A model analysis accounting for the mechanochemical surface diffusion gives an island average size and average separation dependent characteristic spacer layer thickness z_0 below which a vertically self-organized growth occurs.

(c)



Δ=36ML

Korelacje przestrzenne



brak informacji optycznej

Korelacje przestrzenne

VOLUME 76, NUMBER 6 PHYSICAL REVIEW LETTERS 5 FEBRUARY 1996

Vertically Aligned and Electronically Coupled Growth Induced InAs Islands in GaAs

G. S. Solomon,[1] J. A. Trezza,[1] A. F. Marshall,[2] and J. S. Harris, Jr.[1]
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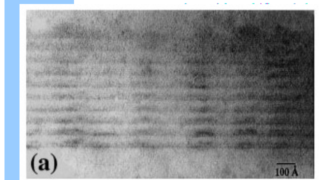
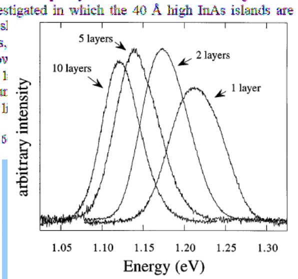
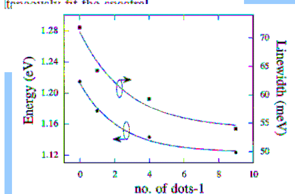
[2]*Center for Materials Research, Stanford University, Stanford, California 94305*

(Received 5 June 1995)

Multilayer, vertically coupled, quantum dot structures are investigated using layers composed of InAs islands grown by molecular beam epitaxy in the Stranski-Krastanov growth mode. Single, 2, 5, and 10 InAs island layers are investigated in which the 40 Å high InAs islands are separated by 56 Å GaAs spacer layers. The InAs isl ... seudomorphic. Between 1 and 10 layers of islands, ... in PL linewidth, and a peak shift of 92 meV to low ... force microscopy show the island size in different l ... ed to electronic coupling between islands in the colur ...







Korelacje przestrzenne

PHYSICAL REVIEW B VOLUME 60, NUMBER 12 15 SEPTEMBER 1999-II

Control of the electronic properties of CdSe submonolayer superlattices via vertical correlation of quantum dots

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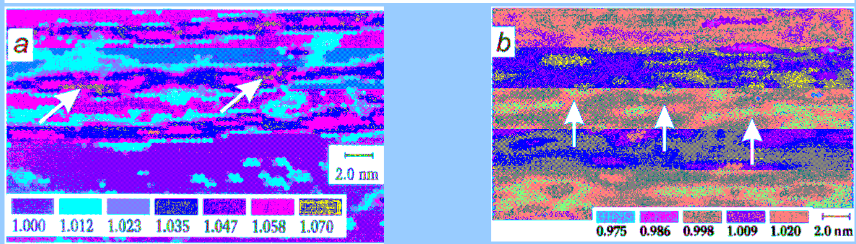
Laboratorium für Elektronenmikroskopie der Universität Karlsruhe, Kaiserstrasse 12, Postfach 6980, 76128 Karlsruhe, Germany

(Received 5 August 1998)



Kryształ z kropek

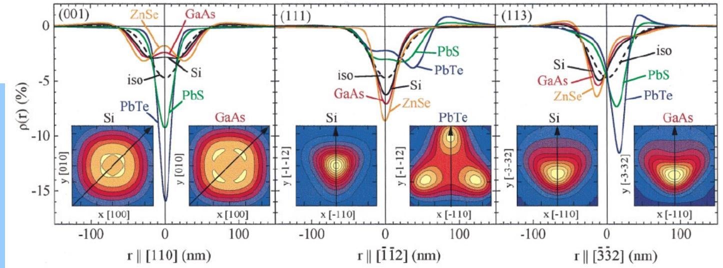
VOLUME 83, NUMBER 2 PHYSICAL REVIEW LETTERS 12 JULY 1999

Strain Induced Vertical and Lateral Correlations in Quantum Dot Superlattices

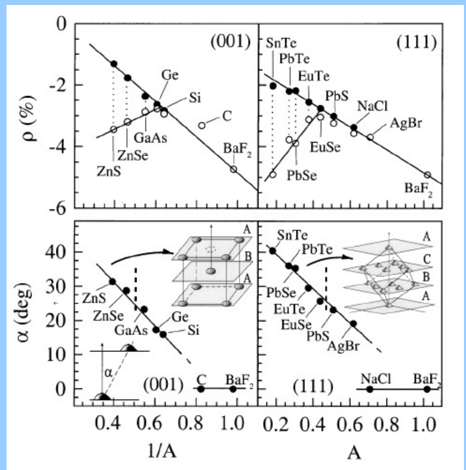
V. Holý,[1,2] G. Springholz,[1,*] M. Pinczolits,[1] and G. Bauer[1]
[1]Institut fuer Halbleiterphysik, Johannes Kepler Universität, A-4040 Linz, Austria
[2]Laboratory for Thin Films and Nanostructures, Masaryk University, 61137 Brno, Czech Republic

(Received 17 February 1999)

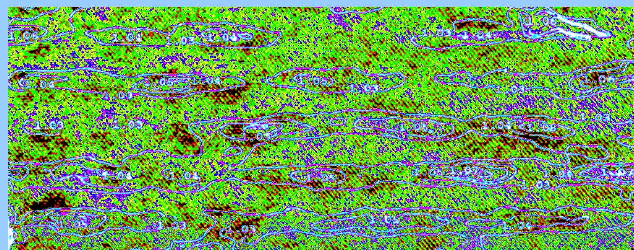
Vertical and lateral ordering of quantum dots in superlattices is shown to be determined by the elastic



Kryształ z kropek

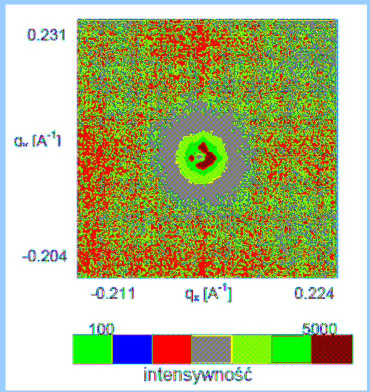


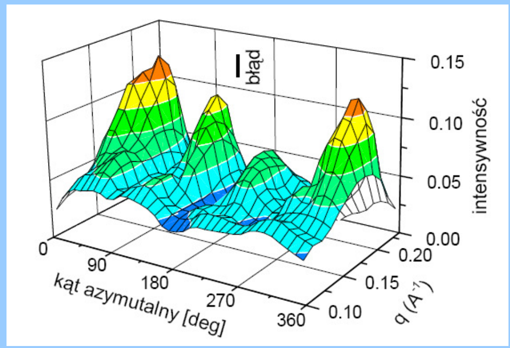
Kryształ z kropek CdTe



dla przekładki 10 ML – antykorelacja położeń kropek w kolejnych warstwach

Kryształ z kropek CdTe





kropki w kolejnej warstwie tworzą się w czterech minimach energii elastycznej

Kryształ z kropek PbSe

VOLUME 84, NUMBER 20 PHYSICAL REVIEW LETTERS 15 MAY 2000

Tuning of Vertical and Lateral Correlations in Self-Organized $PbSe/Pb_{1-x}Eu_xTe$ Quantum Dot Superlattices

G. Springholz,[1,*] M. Pinczolits,[1] P. Mayer,[1] V. Holy,[2] G. Bauer,[1] H. H. Kang,[3] and L. Salamanca-Riba[3]
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(Received 8 December 1999)