Edited by

Chua Soo Jin

Teng Jinghua

Aaron Danner

COMPOUND SEMICONDUCTOR PHOTONICS

Materials, Devices and Integration

Proceedings of Symposium O of the International Conference on Materials for Advanced Technologies (ICMAT) 2009

Synthesis of ZnS (II-VI) Nanostructures for Gas Sensors and Effect of Growth Conditions 139
M. Hafeez, U. Manzoor and A. S. Bhatti

Recent Development of Nanophotonic Integrated Devices and Materials 142
Y. Sugimoto, N. Ikeda, D. Tsuya, H. Oda, K. Inoue, A. Miura, D. Inoue, T. Nomura, H. Fujikawa, K. Sato, N. Ozaki, S. Ohkouchi, Y. Watanabe, Y. Koide and K. Asakawa

Study of Strain Effects in Multi-Quantum Well Structures of AlGaInP-Based Light Emitting Diodes 145
Hwa-Sub Oh, Jee-Hue Joo, Jin-Hong Lee, Joon-Seop Kwak and Jong-Hyeob Baek

A Si-doped GaAs/AlGaAs Solar Cell on (311) A GaAs Substrate 149
Ong-Arj Tangmettajitakul, Supachok Thainoi, Somsak Panyakeow and Somchai Rathanathamapan

InGaAs Ring-shaped Nanostructures Grown by Droplet Epitaxy 152
Naraporn Pankaow, Somsak Panyakeow and Somchai Ratanathammaphan

Mesoporous TiO_2 Film for Solar Cell Application 155
Shweta Agarwala, Ho Ghim Wei and G. K. Dalapati

Effect of Substrate Temperature on $In_{0.15}Ga_{0.85}As$/GaAs (001) Nanohole Templates Grown by Droplet Molecular Beam Epitaxy 158
P. Boonpeng, S. Panyakeow and S. Ratanathammaphan

Dependency of In Thickness on the Properties of Self-Assembled InP Ring-Shaped Nanostructures Grown by Droplet Molecular Beam Epitaxy 161
W. Jewasuwan, S. Panyakeow and S. Ratanathammaphan

Properties of Dilute InPN Alloys Grown by Liquid Phase Epitaxy 164
Tushar Dhabal Das, Sunanda Dhar and Brij Mohan Arora

Determinants of Bandgap Energies in Semiconductor Nanoalloys 167
C. C. Yang and S. Li

Fabrication of Iron Silicide Photonic Crystals and Properties of Light Propagation 170
Yoshihito Maeda and Yoshikazu Terai

Multilayered Structures of Doped and Undoped ZnO 173
Saraswathi Chirakkara and S. B. Krupanidhi

Effect of Thickness of GaP Ultra-thin Insertion Layer on the Structural and Optical Properties of InP Quantum Dots 176
Soe Soe Han, Somsak Panyakeow, Somchai Rathanathamapan

Determination of Electron Trap Density in Dilute Nitride GaNAs and InGaNAs Semiconductors 179
H. Eshghi and M. Ameri

Fabrication and Properties of Non-Stoichiometric Nickel Oxide Films by Radio Frequency Sputtering 183
S. C. Chen, T. Y. Kuo, W. H. Hong, Y. R. Lin and P. C. Kuo

Nanoheteroepitaxy of GaN on Nanoporous Sapphire Substrate 186
K. Y. Zhang, Y. D. Wang and S. J. Chua

Role of Hydrogen in Optical Properties of CdTe/Mn Bilayer Thin Films of Diluted Magnetic Semiconductor 192
S. P. Nehra, M. K. Jangid, M. Singh and Y. K. Vijay

X-ray Photoelectron Spectroscopy Analysis of Plasma-Treated n-GaN Surfaces in Relation to Ohmic Contact Formation 195
L. K. Li, L. S. Tan and E. F. Chor

Application of Fourier Transform-based K·P Method to Semiconductor Supperlattices 198
Q. J. Zhao, X. G. Tu and T. Mei

Nonlinear Properties and Optical Limiting Performance of Sulforhodamine-B Doped Silica and Polymeric Matrices 201
Sunita Sharma, Devendra Mohan, S. K. Ghoshal and Umesh Gupta

White Light Emitting from $Ba_3MgSi_{2-x}Al_xO_8$: yEu^{2+}, zMn^{2+} Phosphor 207
Changyu Shen, Yi Yang and Shangzhong Jin

Quantum Dot Laser Diodes with Native Oxide Injection Current Confinement: Static and Dynamic Properties 210
H. X. Zhao, R. Wang, Q. Cao, C. Y. Liu, C. Z. Tong, S. M. L. Nai, J. Wei and S. F. Yoon

EFFECT OF THICKNESS OF GaP ULTRA-THIN INSERTION LAYER ON THE STRUCTURAL AND OPTICAL PROPERTIES OF InP QUANTUM DOTS

SOE SOE HAN, SOMSAK PANYAKEOW AND SOMCHAI RATHANATHAMAPAN
Semiconductor Device Research Laboratory (Nanotec Center of Excellence)
Department of Electrical Engineering, Chulalongkorn University, Bangkok 10330, Thailand. e-mail: rsomchai@chula.ac.th

Abstract

A systematic study of thickness of GaP insertion layers on the structural properties of InP quantum dots (QDs) was investigated. All samples were grown by conventional solid-source molecular beam epitaxy using a GaP decomposition cell was used as P_2 source for P-based materials. The density of InP QDs directly grown on $In_{0.48}Ga_{0.52}P$ layer is 4.8×10^{10} cm^{-2}, and decrease to 2.4-3.9×10^{10} cm^{-2} on GaP layers which depends on the thickness of GaP layer. The effect of GaP insertion layer on the size distribution of InP QDs is also studied in this work.

Introduction

Self-assembled quantum dots (QD) have been widely applied to laser diodes [1] and high efficiency QD intermediate solar cells (QDSCs) [2]. In particular, in order to achieve the predicted high efficiencies in QDSCs, QDs must be uniform in size and periodically distributed in all three-dimensions which lead to the formation of an intermediate band or miniband rather than a multiplicity of discrete quantized levels. Stranski-Krastanov (SK) growth is the prevalent method for the formation of quantum dots (QDs). The most popular technique of stacked QDs is to take advantage of spontaneous self-assembly of coherent three-dimension islanding in lattice-mismatched epitaxy. However, this technique usually results internal strain due to misfit dislocation. The lattice mismatch between InP and $In_{0.48}Ga_{0.52}P$ (lattice matched to GaAs) of 3.8% provides sufficient strain to allow to form QDs via the SK mechanism. Advantageous of QD-based optoelectronic devices is the formation of defect-free, ordered arrays of uniform quantum dots, conditions realized in the InP/ $In_{0.48}Ga_{0.52}P$ system. Recently, the strained-compensation technique is an approach for an enhancement of quality of multi-stacked layers of QDs [3]. Here, the GaP is used as strain-compensated layer for InP/ $In_{0.48}Ga_{0.52}P$.

In this paper, we report the structure characteristics of InP QDs due to the use of different 0-4 ML GaP insertion layers on GaAs substrate by molecular beam epitaxy. QD properties are characterized by atomic force microscopy (AFM).

Experimental Procedure

Quantum dots composed of InP within an InGaP matrix were elaborated by molecular beam epitaxy on semi-insulating (100) oriented GaAs substrates using a Riber 32P system via Stranski-Krastanow growth mode. The growth process was monitored by using 15kV reflection high-energy electron diffraction (RHEED) system. The removal of native oxide was performed by heating the substrate under As_4 beam at 600°C until the streaky pattern appeared. The subsequent growth was 300 nm GaAs buffer layer at 450°C and followed by a 200 nm $In_{0.48}Ga_{0.52}P$ grown at 480 °C. Then GaP insertion layers with 0-4 monolayers were grown before the growth of QDs. Finally, the high density QDs were fabricated by deposited 3ML InP with temperature of 450°C at growth rate 0.5 ML/s. The surface morphology was studied ex situ by atomic force microscope (AFM).

Results and Discussion

InP QD on $In_{0.48}Ga_{0.52}P$ has a high density of about $2\text{-}5\times10^{10}$ cm^{-2}. Figures 1 (a)-(e) show images of high density InP quantum dots grown without and with 1-4 ML GaP that have been characterized by atomic force microscopy.

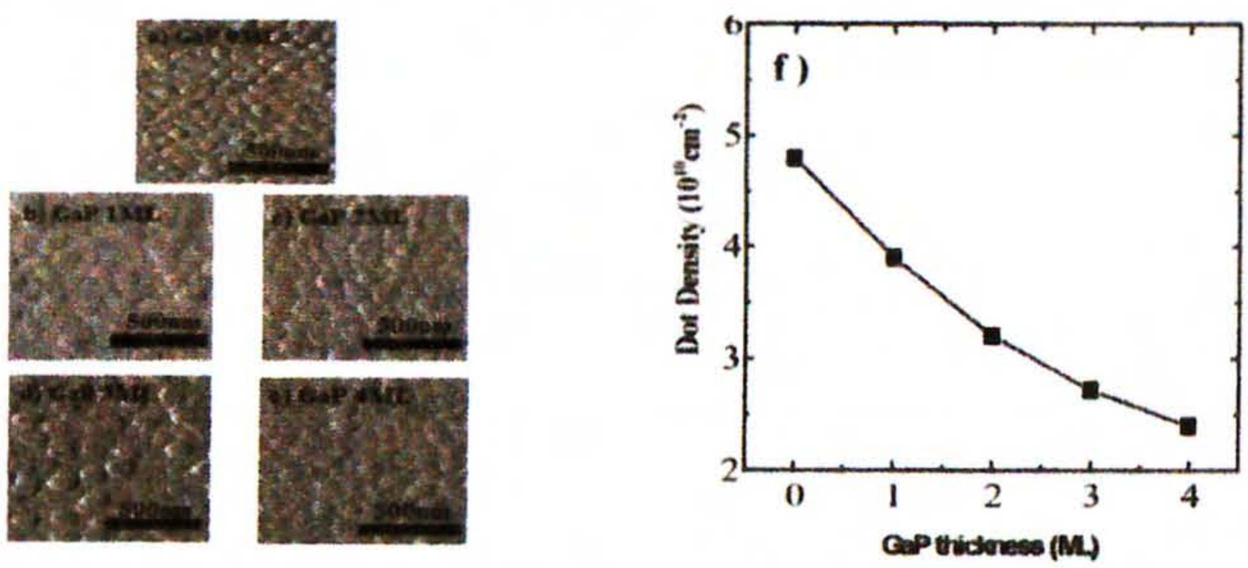

Figure.1 Typical AFM images of InP QDs on (a) 0 ML (b) 1 ML (c) 2 ML (d) 3 ML (e) 4 ML GaP layers and (f) InP QDs density plotted as a function of 0-4 ML GaP thickness.

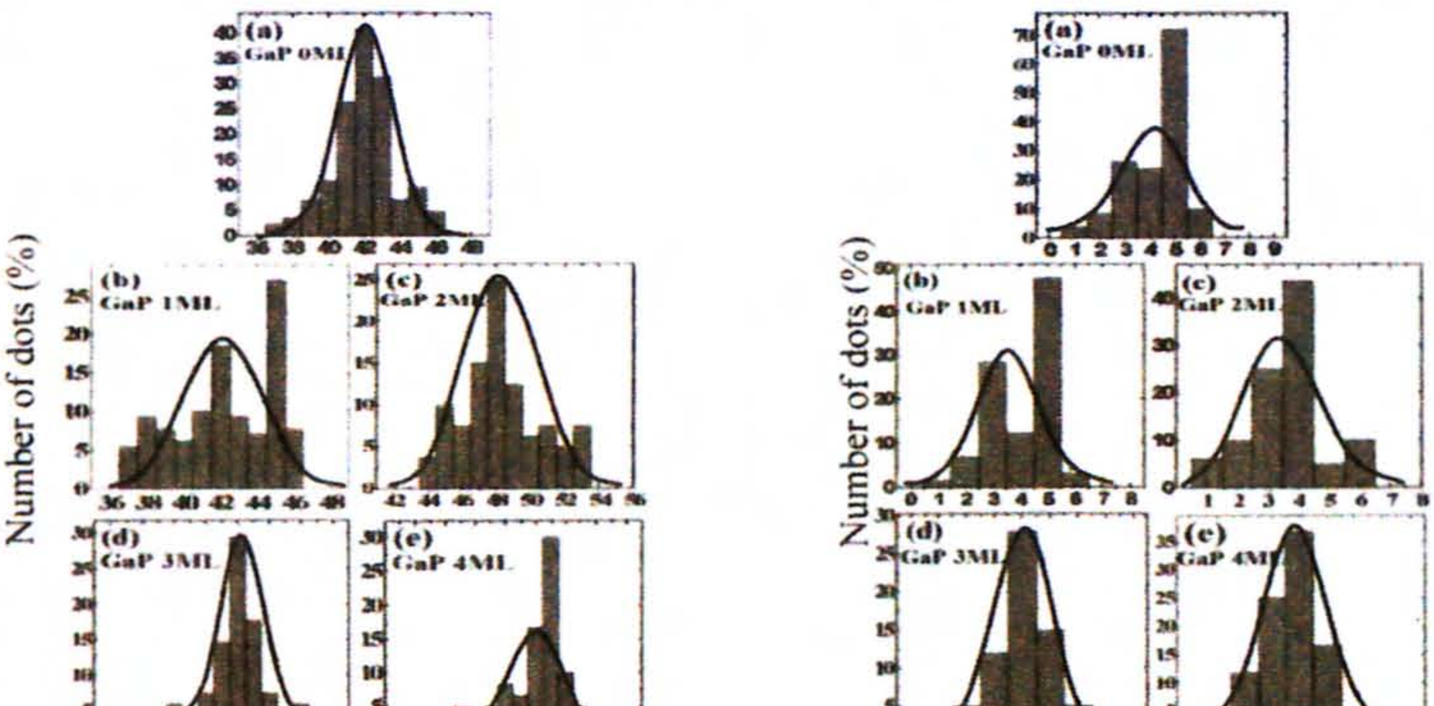

Figure.2 Size (diameter) and height distribution histograms of InP QDs on 0 ML (b) 1 ML (c) 2 ML (d) 3 ML and (e) 4 ML GaP layers.

The dot density decreases approximately from 4.8×10^{10} cm^{-2} to 2.7×10^{10} cm^{-2} due to the insertion of 0-4 ML GaP layers. Figure 1 (f) shows the relation of dot density of InP QDs as a function of the GaP insertion layer thickness. The density of 3ML InP QDs depends on GaP thickness because the diffusion length of In atoms on GaP layer is shorten when increasing these parameters [4]. Figure 2 shows the size and height distributions of the nanostructures with varying deposition thickness of 0-4 MLs GaP layers. It is observed that with increasing GaP thickness, the QDs density decreases and the height and diameter increase. This is also an expected result and is due to an decreased supersaturation at the onset of nucleation which leads to a lower nucleation density. Since the QDs growth conditions are the same, the bigger QD height and diameter and reduced density for the sample grown with the InGaP interlayer indicates that the insertion of the 0-4 MLs GaP layer results in more incorporation of the material. The incorporation efficiency of In during the deposition of an GaP layer reduces as strain increases [5]. During the growth of InP QDs, the segregated indium atom may react with P bond and forms additional InP which increases the QD size and its uniformity.

Conclusion

Dependence on growth parameters of structural properties of MBE grown InP quantum dots (QDs) has been studied by using atomic force microscopy. We have demonstrated the fabrication of InP quantum dots on $In_{0.48}Ga_{0.52}P$ layer with GaP insertion layers. The Insertion of GaP improve the uniformity when the GaP thickness is over 3 ML.

Acknowledgements

The author wishes to thank ASEAN University Network/Southeast Asia Engineering Education Development Network (AUN/SEED-Net), Asian Office of Aerospace Research and Development(AOARD), Thailand Research Fund (TRF), National Nanotechnology Center (NANOTEC) and Chulalongkorn University for support of this research work. The author also wants to thank Ms. Wipakornji Jewasuwan, Mr. Poonyasiri Boonpeng and Ms. Naraporn Pankaow for being mentor and their technical assistance.

References

[1] Y. Arakawa, H. Sakaki, Appl. Phys Lett. 40 (1982) 939.

[2] A. Luque, A. Marti, Phys. Rev. Lett. 78 (1997) 5014.

[3] Ryuji Oshima, Yasushi Shoji, Ayami Takata, Yoshitaka Okada, J. Cryst. Growth, 311 (2009) 1770.

[4] M.K. Zundel, P. Specht, K.Eberl, N.Y. Jin-Phillipp, F. Phillipp, Appl. Phys. Lett., 71(2972), 1997.

[5] V.M Ustinov, N.A. Maleev, A.E. Zhukov, A.R. Kovsh, A. Yu. Egorov, A.V. Lunev, B.V. Volovik, I.L. Krestnikov, Yu.G. Musikhin, N.A. Bert, P.S. Kop'ev, Z.h.I. Alferov, N.N. Ledentsov, D. Bimberg, Appl. Phys. Lett., 74(2815), 1999.