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HIGH PRESSURE OPTICAL STUDIES OF SEMICONDUCTORS AND HETEROSTRUCTURES

FINAL REPORT

H.R. Chandrasekhar
Professor
Department of Physics and Astronomy
University of Missouri-Columbia
Columbia, Missouri 65211
Phone: 314-882-6086 or 314-882-3335

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ABSTRACT

We have studied the effects of hydrostatic pressure on the confined transitions in quantum well heterostructures, using lattice matched GaAs/$Al_xGa_{1-x}As$, strained layer narrow band gap GaSb/AlSb and $In_xGa_{1-x}As$/GaAs, and strained layer wide gap $Zn_{1-x}Cd_xSe$/ZnSe as examples. Precise values of the energies, pressure coefficients and band alignments are determined. In strained epilayers the interfacial strains, deformation potential constants and compressibilities are deduced. Strain compensation, structural stability and phase transitions are probed. We have observed a novel type of Fano resonance of excitons in GaAs associated with the Γ conduction band as they hybridize with the X and L continua via electron-phonon coupling. This effect is used to extract the intervalley electron-phonon deformation potential $D_{\Gamma X}$ to be 10.7±0.7 eV/Å. We have observed a new electron trap state in $Al_{0.3}Ga_{0.7}As$ doped with silicon at pressure of 60 kbar. We postulate that this new trap state has a large lattice relaxation with the trap energy well above the X CB. These trap states may be present in all Al_xGa_xAs materials and may be dominant at large x values (0.7<x<1)

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Summary

This report contains a summary of the research performed under the grant No. DE-FG02-89ER45402 from the period of the beginning of this contract in September 1989 upto the termination date of the contract.

This report is organized as follows: Section A describes the graduate students supported by the grant. Section B lists the refereed publications, invited and contributed presentations during the grant period. A short description of each project is presented in Section C which is followed by the reprints and preprints which are appended to this report.

SECTION A: Support and participation of Graduate Students

The following students were either partially or completely supported by the DOE grant and performed research for their Ph.D. dissertation. All of them are citizens of the United States and obtained their undergraduate diplomas from various colleges in the state of Missouri.

Patrick Roach, Ph.D., 1990. Thesis: *Deep levels in semiconductors under hydrostatic pressure..* Dr. Roach is currently employed at the Air Force Office of Scientific Research in San Antonio, Texas.

Benjamin Rockwell, Ph.D., 1991. Thesis: *Pressure effects in Strained Layer Heterojunctions.* Dr. Rockwell is a Research Scientist at the Armstrong Lab. at the Brooks Air Force Base, San Antonio, Texas.

Robert Thomas, Ph.D., August 1994. Thesis: *photomodulation studies of II-VI heterostructures under high pressure.* Dr. Thomas is a Research Fellow of the National Research Council and is presently employed at the Armstrong Lab. at the Brooks Air Force Base, San Antonio, Texas.

Mark Boley, Ph.D., August 1993. Thesis: *Photoluminescence studies of wide gap semiconductors.* Dr. Boley is an assistant professor at the North Eastern Illinois University.

SECTION B:

PUBLICATIONS

1. Spectroscopic studies of strained - layer GaSb - AlSb superlattices, Benjamin

Rockwell, H.R. Chandrasekhar, Meera Chandrasekhar, Fred H. Pollak, H. Shen, L.L. Chang, W.I. Wang and L. Esaki, Surface Science, **228**, 322 (1990).

2. Photoluminescence studies of diluted magnetic semiconductors under hydrostatic pressure: $Cd_{1-x}Mn_xTe$, M. Prakash, M. Chandrasekhar,H.R. chandrasekhar,I. Miotkowski and A.K. Ramdas, Mat.Res.Soc.Symp.Proc.,**161**, 449 (1990).

3. High pressure optical studies of GaSb-AlSb multiple quantum wells, Benjamin Rockwell, H.R. Chandrasekhar, Meera Chandrasekhar, Fred H. Pollak, H. Shen, L.L. Chang, W.I. Wang and L. Esaki, Mat.Res.Soc.Symp.Proc.,**160**, 751(1990).

4. Photoreflectance studies of electronic transitions in quantum well structures under high pressure, H.R. Chandrasekhar and M. Chandrasekhar, SPIE, Modulation Spectroscopy, **1286,** 207 - 220 (1990).

5. Electronic transitions in CdTe under pressure, M. Prakash, Meera Chandrasekhar and H.R. Chandrasekhar, I. Miotkowski and A.K. Ramdas, Phys. Rev.**B42,** 3586(1990 -II).

6. The effect of substrate on the pressure coefficients of GaSb-AlSb quantum wells, Benjamin Rockwell, H.R. Chandrasekhar, M.Chandrasekhar,Fred H. Pollak, L.L.Chang, Leo Esaki, G.J.Gualtieri and G.P.Schwartz, 20th International Conference on the Physics of Semiconductors, Thessaloniki, Greece, Aug.6-10, 1990, ed. E.M. Anastassakis and J.D. Joannopoulos, World Scientific, p. 929-932.

7. Pressure induced Fano resonance of excitons: A new method for the determination of electron-phonon deformation potential, S. Satpathy, M. Chandrasekhar and H. R. Chandrasekhar, 20th International Conference on the Physics of Semiconductors, Thessaloniki, Greece, Aug.6-10, 1990, ed. E.M. Anastassakis and J.D. Joannopoulos, World Scientific, p. 1521-1524.

8. The bound magnetic polaron in $Cd_{1-x}Mn_xTe$ under pressure, M. Prakash, M. Chandrasekhar, H.R. Chandrasekhar, I. Miotkowski, A.K. Ramdas and L.R. Ram-Mohan,.20th International Conference on the Physics of Semiconductors, Thessaloniki, Greece, Aug.6-10, 1990, ed. E.M. Anastassakis and J.D. Joannopoulos, World Scientific, p. 747-750.

9. A new deep center in $Al_{0.3}Ga_{0.7}As$, W.P. Roach, M. Chandrasekhar, H.R. Chandrasekhar and F.A. Chambers, 20th International Conference on the Physics of

Semiconductors, Thessaloniki, Greece, Aug.6-10, 1990, ed. E.M. Anastassakis and J.D. Joannopoulos, World Scientific, p. 674-677.

10. Pressure tuning of magnetic interactions in $Cd_{1-x}Mn_xTe$, M. Prakash, M. Chandrasekhar, H.R. Chandrasekhar, I. Miotkowski, A.K. Ramdas and L.R. Ram-Mohan, Proceedings of the IV International conference on High Pressure in Semiconductor Physics, Porto Carras, Greece, (ed. D.S. Kyriakos and O.E. Valassiades, Aristotle University, Thessaloniki, 1990), p. 258.

11. A new pressure activated center in $Al_{0.3}Ga_{0.7}As$ and $GaAs/Al_{0.3}Ga_{0.7}As$, W.P. Roach, M. Chandrasekhar, H.R. Chandrasekhar, F.A. Chambers, G.P. Devane and K.A. Stair, Proceedings of the IV International conference on High Pressure in Semiconductor Physics, Porto Carras, Greece, (ed. D.S. Kyriakos and O.E. Valassiades, Aristotle University, Thessaloniki, 1990), p. 242.

12. Semiconductor quantum wells and heterostructures under high pressure, H.R. Chandrasekhar and M. Chandrasekhar, Proceedings of the XIII AIRAPT International Conference on High Pressure and Technology, Oct. 7-11, 1991, Bangalore, India.

13. Pressure tuning of strains in semiconductor heterostructures: (ZnSe epilayer/ GaAs epilayer), Benjamin Rockwell, H.R. Chandrasekhar, Meera Chandrasekhar, A.K. Ramdas, M. Kobayashi and R.L. Gunshor, Phys. Rev. **B44**, 11307(1991-II).

14. Pressure - induced resonance broadening of exciton line shapes in semiconductors: Direct determination of intervalley scattering rates in GaAs, S. Satpathy, M. Chandrasekhar, H.R. Chandrasekhar and U. Venkateswaran, Phys. Rev. **B44**, 11339(1991-II).

15. Deep center in $Al_{0.3}Ga_{0.7}As$, W.P. Roach, Meera Chandrasekhar, H.R. Chandrasekhar and F.A. Chambers, Phys. Rev. **B43**, 12126 (1991-I).

16. Electronic transitions in bulk $Al_{0.3}Ga_{0.7}As$ under hydrostatic pressure, W.P. Roach, Meera Chandrasekhar, H.R. Chandrasekhar and F.A. Chambers, Phys. Rev.**B44**, 13404 (1991-II).

17. Electronic transitions in semiconductor quantum wells and epilayers under pressure, Meera Chandrasekhar and H.R. Chandrasekhar, Invited Review article, J. High Pressure Research, vol. 9, 57–82 (1992).

18. Pressure tuning of strain in CdTe/InSb epilayer: a photoluminescence and photomodulated reflectivity study, Mark S. Boley, R.J. Thomas, M. Chandrasekhar and H.R. Chandrasekhar, J. Appl. Phys.**74**, 4136 (1993).

19. Raman and modulated-reflectivity spectra of strained pseudomorphic ZnTe epilayer on InAs under pressure, R.J. Thomas, Mark S. Boley, H.R. Chandrasekhar, M. Chandrasekhar, C. Parks, A.K. Ramdas, J. Han, M. Kobayashi and R.L. Gunshor, Phys. Rev.B**49**, 2181(1994).

20. Optical studies of strained pseudomorphic semiconductor heterostructures under external pressure, Meera Chandrasekhar and H.R. Chandrasekhar, Invited Review article, Philosophical Magazine B**70**, 369 (1994).

5. PRESENTATIONS

INVITED TALKS :

1. Spectroscopic Studies of Strained Layer GaSb-AlSb Superlattices, 36th Midwest Solid State Conference, Oct.10-11,1988, Purdue University, W.Lafayette, Ind.

2. Pressure Studies of Impurity Levels in $Al_xGa_{1-x}As$, Invited participant in a Panel Discussion on "Deep Levels in Semiconductors", International Conference on High Pressure in Semiconductor Physics, Warsaw,Aug.20-21,1988.

3. High Pressure Optical Studies in Semiconducting Superlattices, Materials Science Division, National Aeronautics Laboratory, Bangalore, India. Sept. 1 ,1988.

4. Photoreflectance studies of electronic transitions in quantum well structures under high pressure, International Conference on Modulation Spectroscopy, SPIE, San Diego, Cal.,17-21 March 1990.

5. Semiconductor quantum wells and heterostructures under high pressure, H.R. Chandrasekhar, Invited talk at the XIII AIRAPT International Conference on High Pressure and Technology, Bangalore, India, Oct. 7-11, 1991.

6. Electronic transitions in semiconductor quantum wells and epilayers under pressure, Meera Chandrasekhar and H.R. Chandrasekhar, Invited Presentation at the 29th

European High Pressure Group Meeting, Thessaloniki, Greece, October 21-25, 1991.

7. *High Pressure Techniques and Optical Studies,* Tata Institute of Fundamental Research (TIFR), Bombay, July 20, 1993.

8. *A tutorial on Modulation Spectroscopy of Solids,* Tata Institute of Fundamental Research (TIFR), Bombay, July 21, 1993.

9. *Hetero Structures and Quantum Wells under High Pressure,* Tata Institute of Fundamental Research (TIFR), Bombay, July 22, 1993.

10. *Strained.Layer Structures,* Tata Institute of Fundamental Research (TIFR), Bombay, July 23, 1993.

11. *High Pressure studies of High Temperature Super Conductors,* Tata Institute of Fundamental Research (TIFR), Bombay, July 26, 1993.

12. *Raman Spectroscopy of Semiconductors and Heterostructures under High Pressure*, Bhabha Atomic Research Center, Bombay, July 27, 1993.

13. *Characterization of semiconductors: Modulation Techniques,* Department of Physics, Indian Institute of Science, Bangalore, August 6, 1993.

14. *High Pressure Research at the University of Missouri,* National Aeronautics Laboratories, Bangalore, August 10, 1993.

15. *High Pressure Low temperature studies of Semiconductor Superlattices,* Department of Physics, Indian Institute of Science, Bangalore, August 11, 1993.

16. *High Pressure Optical Studies of Semiconductors and Superconductors,* Solid State and Structural Chemistry Unit and Materials Research Center, Indian Institute of Science, Bangalore, August 12, 1993.

17. *New Materials for future Electronics,* The Bangalore Science Forum, Dr. H.N. Hall, The National College, Bangalore, August 12, 1993.

18. *High Pressure Optical Studies of Semiconductors and Superconductors,* Department of Physics, Indian Institute of Technology, Madras, August 19, 1993.

19. *Heterostructures and Quantum wells under High Pressure,* Department of Physics, Indian Institute of Technology, Delhi, August 27, 1993.

20. *Optical Properties of Superlattices and Quantum well structures under High Pressure,* Department of Physics, Indian Institute of Technology, Kanpur, August 30, 1993.

21. *Strained Layer structures,* Laser Research Center, Department of Physics, Indian Institute of Technology, Delhi, September 1, 1993.

CONTRIBUTED TALKS :

1. Fano Resonance Broadening of Quantum-Well levels in GaAs/AlGaAs. ,S.Satpathy, M.Chandrasekhar and H.R.Chandrasekhar, Bull.Am. Phys.Soc.,**34**,682(1989).

2 A hydrostatic pressure study of Deep Donor States in $Al_{0.3}Ga_{0.7}As$., W.P.Roach, M.Chandrasekhar and H.R.Chandrasekhar, Bull.Am.Phys.Soc.,**34**,683(1989).

3. Photoreflectance Spectroscopy of Strained-layer GaSb-AlSb Superlattices, Bull. Am. Phys. Soc.,**34**,830(1989).

4. Deep Impurity Levels in $Al_xGa_{1-x}As$. A study of D-X related Levels under Pressure, M. Chandrasekhar, W:P.Roach, H.R.Chandrasekhar, F.A.Chambers,B.A.Vojak and J.M.Meese, 19th International Conference on the Physics of Semiconductors, Warsaw, Poland, 16th Aug. 1988.

5. Spectroscopic Studies of $GaAs\text{-}Ga_{1-x}Al_xAs$ Quantum Wells under hydrostatic Pressures, H.R. Chandrasekhar, M. Chandrasekhar, A. Kangarlu, F.A.Chambers, B.A.Vojak and J.M.Meese, 19th International Conference on the Physics of Semiconductors, Warsaw, Poland,16th Aug., 1988.

6. Spectroscopic Studies of Strained-Layer GaSb-AlSb Superlattices, Benjamin Rockwell, H.R. Chandrasekhar and M. Chandrasekhar, 4th International Conference on Modulated Semiconductor Structures, Ann Arbor, Michigan, 17-21 July,1989.

7. Superlattice Structures for Fiber-Optic Applications, H.R. Chandrasekhar, Condensed Matter Seminar, Physics Dept., MU-Columbia, 27 March, 1989.

8. Spectroscopic studies of a strained-layer GaSb-AlSb superlattice in a diamond anvil cell, 37th Annual Midwest Solid State Conference, MU- Rolla, Oct.13-14, 1989.

9. Hydrostatic Pressure Studies of Deep Donor States in $Al_{0.3}Ga_{0.7}As$, 37th Annual Midwest Solid State Conference, MU- Rolla, Oct.13-14, 1989.

10. Photoluminescence studies of diluted magnetic semiconductors under hydrostatic pressure: $Cd_{1-x}Mn_xTe$, 37th Annual Midwest Solid State Conference, MU- Rolla, Oct.13-14, 1989.

11. Does the valence band discontinuity in GaSb-AlSb multiple quantum wells depend on strain: An optical investigation, Bull.Am.Phys.Soc., **35**, 212(1990).

12. Deep donor states in $Al_{0.3}Ga_{0.7}As$ under hydrostatic pressure, Bull.Am.Phys.Soc., **35**, 414 (1990).

13. Photoluminescence studies of diluted magnetic semiconductors under hydrostatic pressure, Bull.Am.Phys.Soc. **35**, 662(1990).

14. The effect of substrate on the pressure coefficients of GaSb-AlSb quantum wells, Benjamin Rockwell, H.R. Chandrasekhar, M.Chandrasekhar,Fred H. Pollak, L.L.Chang, Leo Esaki, G.J.Gualtieri and G.P.Schwartz, 20th International Conference on the Physics of Semiconductors, Thessaloniki, Greece, Aug.6-10, 1990.

15. Pressure induced Fano resonance of excitons: A new method for the determination of electron-phonon deformation potential, S. Satpathy, M. Chandrasekhar and H. R. Chandrasekhar, 20th International Conference on the Physics of Semiconductors, Thessaloniki, Greece, Aug.6-10, 1990.

16. The bound magnetic polaron in $Cd_{1-x}Mn_xTe$ under pressure, M. Prakash, M. Chandrasekhar, H.R. Chandrasekhar, I. Miotkowski, A.K. Ramdas and L.R. Ram-Mohan,.20th International Conference on the Physics of Semiconductors, Thessaloniki, Greece, Aug.6-10, 1990.

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18. Pressure tuning of magnetic interactions in $Cd_{1-x}Mn_xTe$, M. Prakash, M. Chandrasekhar, H.R. Chandrasekhar, I. Miotkowski, A.K. Ramdas and L.R. Ram-Mohan, Proceedings of the 4th International conference on High Pressure in Semiconductor Physics, Porto Carras, Greece, Aug. 1990.

19. A new pressure activated center in $Al_{0.3}Ga_{0.7}As$ and $GaAs/Al_{0.3}Ga_{0.7}As$, W.P. Roach, M. Chandrasekhar, H.R. Chandrasekhar, F.A. Chambers, G.P. Devane and K.A. Stair, Proceedings of the 4th International conference on High Pressure in Semiconductor Physics, Porto Carras, Greece, Aug. 1990.

20. Hydrostatic pressure studies of confined transitions in cubic $Zn_xCd_{1-x}Se$ / ZnSe strained layer quantum wells, R.J. Thomas, H.R. Chandrasekhar, M. Chandrasekhar, N. Samarth, H. Luo and J.K. Furdyna, Bull.Am.Phys.Soc., **37**, 432(1992).

21. Pressure tuning of strains in semiconductor heterostructures: ZnSe epilayer/ GaAs epilayer, Benjamin Rockwell, H.R. Chandrasekhar, Meera Chandrasekhar, A.K. Ramdas, M. Kobayashi and R.L. Gunshor, Bull.Am.Phys.Soc., **37**, 689(1992).

22. Photoluminescence and photoreflectance studies of CdTe/ InSb semiconductor heterostructure under pressure, M.S. Boley, R.J. Thomas, H.R. Chandrasekhar, M. Chandrasekhar, A.K. Ramdas, M. Kobayashi and R.L. Gunshor, Bull. Am. Phys. Soc., **37**, 690(1992).

23. Raman and Photo-modulated reflectivity studies of ZnTe/InAs semiconductor heterostructure under hydrostatic pressure, R.J. Thomas, Mark S. Boley, H.R. Chandrasekhar, M. Chandrasekhar, C. Parks, A.K. Ramdas, J. Han, M. Kobayashi and R.L. Gunshor, Bull. Am. Phys. Soc., **38**, 507(1993).

24. Hydrostatic pressure studies of optical transitions in the photoluminescence spectra of $Zn_{1-x}Cd_xSe$ thick epilayers and $Zn_{1-x}Cd_xSe/ZnSe$ strained layer multiple quantum wells, Mark S. Boley, M. Chandrasekhar, H.R. Chandrasekhar, L.R. Ram-Mohan, N. Samarth, H. Luo and J.F. Furdyna, Bull. Am. Phys. Soc., **38**, 374(1993).

25. Raman and Photo-modulated reflectivity studies of ZnTe/InAs semiconductor heterostructure under hydrostatic pressure, R.J. Thomas, Mark S. Boley, H.R. Chandrasekhar, M. Chandrasekhar, C. Parks, A.K. Ramdas, J. Han, M. Kobayashi and R.L. Gunshor, The Joint AIRAPT/APS conference, Colorado Springs, June 28-July 2, 1993.

26. Hydrostatic pressure studies of the Raman-active phonon modes in the bulk high temperature superconductor $YBa_2Cu_4O_8$, Mark S. Boley, M. Chandrasekhar, H.R. Chandrasekhar, Y. Wu and P. Boolchand, The Joint AIRAPT/APS conference, Colorado Springs, June 28-July 2, 1993.

27. Hydrostatic pressure studies of optical transitions in the photoluminescence spectra of $Zn_{1-x}Cd_xSe$ thick epilayers and $Zn_{1-x}Cd_xSe/ZnSe$ strained layer multiple quantum wells, Mark S. Boley, M. Chandrasekhar, H.R. Chandrasekhar, L.R. Ram-Mohan, N. Samarth, H. Luo and J.F. Furdyna,The Joint AIRAPT/APS conference, Colorado Springs, June 28-July 2, 1993.

28. Polarized photomodulated reflectivity and photoluminescence studies of ordered $InGaP_2$ under pressure, R.J. Thomas, H.R. Chandrasekhar, M. Chandrasekhar, E.D. Jones and R.P. Schneider, Jr., Sixth International Conference on "High Pressure Semiconductor Physics", August 22-24, 1994, Vancouver, B.C., Canada.

29. A comparative study of ordered alloy and random alloy quantum wells of Zn Cd Se/ZnSe under pressure, E.M. Baugher, M. Chandrasekhar, H.R. Chandrasekhar, H. Luo, J.K. Furdyna and l.r. Ram-Mohan, Sixth International Conference on "High Pressure Semiconductor Physics", August 22-24, 1994, Vancouver, B.C., Canada.

30. Raman Scattering studies of Yb-124 single crystals and Y-124 superconductors under high pressure, D.J. Payne, E.M. Baugher, R.J. Thomas, Mark S. Boley, M. Chandrasekhar, H.R. Chandrasekhar, Y. Wu and P. Boolchand, Bull. Am. Phys. Soc., **39**, 728(1994).

SECTION C: A brief outline of the research performed. A copy of each publication is appended.

1. Strained Layer Heterostructures:

Strained layer heterostructures are of considerable interest due to the vast possibilities they offer in band gap engineering. The ability to grow pseudomorphic epilayers on substrates with very different lattice constants is central to this problem. The questions of accommodation of strains at the interface, stability and the critical dimensions beyond which misfit dislocations occur, need careful examination. The evaluation of valence band discontinuity is complicated by the strains due to lattice mismatch which shift and split the light and heavy hole valence bands. If these structures are grown on a substrate with a different compressibility, under external pressure, the in-plane deformation is governed by the substrate. This results in an additional biaxial stress in the MQW. This stress could either enhance or compensate the lattice mismatch induced strain as evidenced by the following systems.

a) GaSb-AlSb MQW's grown on different substrate materials. Accurate values of the pressure coefficients of ground and excited subbands are measured. The strain dependence of valence band discontinuity is deduced from a careful analysis of the data.

b) $In_xGa_{1-x}As$ quantum wells which are of importance due to their potential for applications in optical fibers.

c) Epilayers of wide gap semiconductors such as $Zn_xCd_{1-x}Se$ on GaAs. These materials have a potential for the fabrication of lasers in the blue part of the electromagnetic spectrum. Our studies have shown that the lattice mismatch strain can be completely cancelled by the pressure induced strain for ZnSe epilayer grown on GaAs at 36.2 kbars and 300K. This is an accurate method to measure microscopic strains and to deduce important parameters such as the deformation potential constants and compressibilities.

2. The diluted magnetic semiconductors

The diluted magnetic semiconductors are of importance due to their novel magnetic properties such as giant Faraday rotation and large effective g-factors. The wide band gap is exploited in blue-green lasers, modulators, nonlinear devices and optical memories. The large internal magnetic fields lead to giant Zeeman splittings with possible applications in the far infrared. Alloying with manganese alters the band gap of CdTe but also changes the magnetic properties. The competing band structure and magnetic effects can be sorted out by the application of pressure on a sample of given Mn concentration. Pressure alters the band structure only.

We have studied the acceptor bound magnetic polaron in $Cd_{1-x}Mn_xTe(Sb)$ for x=0, 0.05 and 0.15. The sp-d exchange interaction between the spins of the hole and the Mn^{2+} ions causes a magnetic binding energy which, unlike Coulombic binding energies, has unusual characteristics. The decrease in binding energy with increasing temperature is one such and is due to the the loss of spin alignment. The BMP binding energy decreases with pressure for low Mn concentration and the reverse is true for high Mn concentration. Various contributions to the binding energy due to the lattice and magnetic parts leads to this anomaly. Detailed theoretical calculations are presently under way.

3. Pressure-induced Fano resonance of excitons in semiconductors

We have observed a novel type of Fano resonance of excitons in GaAs associated with the Γ CB as they hybridize with the X and L continua via electron-phonon coupling. This effect is used to extract the electron-phonon deformation potential. The PL line shape shows the characteristic broadening and asymmetry as the hybridization is continuously tuned via pressure. The line width of the exciton is proportional to the density of states, $\rho(\varepsilon)$, in the continuum. Since the energy of the continuum band changes linearly with pressure, and since $\rho(\varepsilon)$ is proportional to $\sqrt{\varepsilon}$, the line width of the exciton PL should show a $\sqrt{(P-P_c)}$ dependence where P_c is the pressure at which the Γ and X band edges cross. The effect is dramatically seen for high quality MBE grown GaAs QWH. This effect should be observable in other semiconductors and provides a novel way to deduce the electron-phonon interaction.

4. A new pressure activated deep trap in III–V semiconductors:

Deep donor levels have been known to play an important role in the electrical and optical properties of $Al_xGa_{1-x}As$. The DX center, in particular, acts as an efficient trap for electrons and severely affects devices that us $Al_xGa_{1-x}As$ with $x>0.3$. In our studies, we use hydrostatic pressure to change the position of the Γ,L and X bands relative to one another in a manner that is similar to changing the aluminum mole fraction x. The obvious advantage is that all the studies are performed on the same sample, and no new defects are introduced.

We have observed a new electron trap state in $Al_{0.3}Ga_{0.7}As$ doped with silicon at pressure of 60 kbar. We observe it via photoluminescence (PL) in a diamond anvil cell at 15K. PL from deep donor states becomes observable for pressures over 10 kbar at which the direct (Γ) conduction band(CB) crosses the X CB along (100) direction. The PL intensity remains constant upto 50 kbar beyond which it drops steeply and disappears at 70 kbar. Surprisingly, when the pressure is reduced, the intensity of the deep levels does not recover fully until very low pressures are reached. The hysteresis in the radiative efficiency suggests a trap rather than a level crossing. The behaviour is reminiscent of the temperature cycling necessary to depopulate the DX center. In our case we have to pressure cycle to depopulate this center. We postulate that this new trap state has a large lattice relaxation with the trap energy well above the X CB. As the pressure is increased the thermal capture barrier decreases and at 70 kbar, the carriers transfer to the trap state and quench the PL. In the down stroke, the recovery does not take place until the emission barrier is crossed leading to a hysteresis. A similar feature is observed in the PL intensity of staggered transitions in several GaAs/AlGaAs quantum well structures. These trap states may be present in all Al_xGa_xAs materials and may be dominant at large x values $(0.7<x<1)$

reprints removed and cycled separately —