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Article

To Develop Nobel Prize "QUANTUM DOT" Theory By Verilog Programming & Verify by Test Programming

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ABSTRACT

Quantum dot is a generating technique to generate quantum dot of different time interval by change the wave length of different type radiation wave. To develop quantum dot equation by Verilog programming. In order to develop the equation into a programming language define the all the parameter in Verilog system. All the bits of the input and output are fix bit. All the interfacing parameter between equations into the Verilog syntex is fixing. Interfacing between Verilog programming and Test bench programming is verify the Verilog programming of the equation by the test bench programming. Electronic Design Automation software is used to get the output of Verilog programming. Electronic Design Automation software is used to get the output of Test bench programming. The output of Verilog programming and the output of the test bench programming is verifying the programming of the equation quantum dot.Both output of Verilog and test bench programming shown in wave form on the software.

Keywords: Quantum dot, Verilog Programming, Test Bench Programming, Software, Verification, Epwave form

INTRODUCTION

Quantum dots also called semiconductor nanocrystals are semiconductor particles a few nanometers in size, having optical and electronic properties that differ from those of larger particles as a result of quantum. They are a central topic in nanotechnology and materials science. When the quantum dots are illuminated by UV light, an electron in the quantum dot can be excited to a state of higher energy. In the case of a semiconducting quantum dot, this process corresponds to the transition of an electron from the valence band to the conductance band. The excited electron can drop back into the valence band releasing its energy as light. This light emission (photoluminescence) is illustrated in the

figure on the right. The color of that light depends on the energy difference between the conductance band and the valence band, or the transition between discrete energy states when the band structure is no longer well-defined in qds.Nanoscale semiconductor materials tightly confine either electrons or electron holes. The confinement is similar to a three-dimensional particle in a box model. The quantum dot absorption and emission features correspond to transitions between the discrete quanta mechanically allowed energy levels in the box that are reminiscent of atomic spectra. For these reasons, quantum dots are sometimes referred to as artificial atoms, emphasizing their bound and discrete electronics states the like naturally occurring atoms Or molecules. It was shown that the electronic wave functions in quantum dots resemble the ones in real atoms.By coupling two or more such quantum dots, an artificial molecule can be made, exhibiting hybridization even at room temperature. Precise assembly of quantum dots can form super lattices that act as artificial solid-state materials that exhibit unique optical and electronic properties. Quantum dots have properties intermediate between bulk semiconductors and discrete atoms or molecules.

Their optoelectronic properties change as a function of both size and shape. Larger qds of 5–6 nm diameters emit longer wavelengths, with colors such as orange, or red. Smaller qds (2–3 nm) emit shorter wavelengths, yielding colors like blue and green. However, the specific colors vary depending on the exact composition of the QD.Potential applications of quantum dots include single-electron-transistors, solar cell leds cells, lasers, sources,second,computing,cell,research,microscopy,and me dical imaging Their small size allows for some qds to be suspended in solution, which may lead to their use in inkjet printing, and spin coating. They have been used in Langmuir–Blodgett films. These processing techniques result in less expensive and less time-consuming methods of semiconductor

fabrication. Quantum dots are particularly promising for optical applications due to their high extinction coefficient and ultrafast optical nonlinearities with potential applications for developing all-optical systems.They operate like a single-electron transistor and show the Coulomb blockade effect. Quantum dots have also been suggested as implementations of qubits for quantum information processing,andas active elements for thermoelectrics.Tuning the size of quantum dots is attractive for many potential applications. For instance, larger quantum dots have a greater spectrum shift toward red compared to smaller dots and exhibit less pronounced quantum properties. Conversely, the smaller particles allow one to take advantage of more subtle quantum effects.A device that produces visible light, through energy transfer from thin layers of quantum wells to crystals above the layers.

Being zero-dimensional, quantum dots have a sharper density of states than higher-dimensional structures. As a result, they have superior transport and optical properties. They have potential uses in diode lasers, amplifiers, and biological sensors.[67] Quantum dots may be excited within a locally enhanced electromagnetic field produced by gold nanoparticles, which then can be observed from the surface plasmon resonance in the photo luminescent excitation spectrum of (cdse)zns nanocrystals. High-quality quantum dots are well suited for optical encoding and multiplexing applications due to their broad excitation profiles and narrow/symmetric emission spectra. The new generations of quantum dots have far-reaching potential for the study of intracellular processes at the single-molecule level, high-resolution cellular imaging, long- term in vivo observation of cell trafficking, tumor targeting, and diagnostics.Cdse nanocrystals are efficient triplet photosensitizers.

Laser excitation of small cdse nanoparticles enables the extraction of the excited state energy from the quantum dots into bulk solution, thus opening the door to a wide range of potential applications such as photodynamic therapy, photovoltaic devices, molecular electronics, and catalysis. Interfacing between equation of quantum dot and Verilog programming. It is never develop any type of programming language of this equation and never verify by test bench programming. My object to develop the Verilog programming of this equation and verify by test bench programming. The scope of this research is interfacing of multiple programming language and conversion from one domain to another domain.

LITERATURE REVIEW

Glassmakers were able to make colored glass by adding different dusts and powders elements such as silver, gold and cadmium and then played with different temperatures to produce shades of glass. In the 19th century, scientist started to understand how glass color depended on elements and heating-cooling techniques. It was also found that for the same element and preparation, the color depended on the dust particles' size. Naturally occurring obsidian glass was used by Stone Age societies as it fractures along very sharp edges, making it ideal for cutting tools and weapons. Glassmaking dates back at least 6000 years, long before humans had discovered how to smelt iron. Archaeological evidence suggests that the first true synthetic glass was made in Lebanon and the coastal north Syria, Mesopotamia or ancient Egypt. The earliest known glass objects, of the mid-third millennium BC, were beads, perhaps initially created as accidental by-products of metalworking (slags) or during the production of faience, a pre-glass vitreous material made by a process similar to glazing. Early glass was rarely transparent and often contained impurities and imperfections, and is technically faience rather than true glass, which did not appear until the 15th century BC. However, red-orange glass beads excavated from the Indus Valley Civilization dated before 1700 BC (possibly as early as 1900 BC) predate sustained glass production, which appeared around 1600 BC in Mesopotamia and 1500 BC in Egypt. During the Late Bronze Age there was a rapid growth in glass making technology in Egypt and Western Asia. Archaeological finds from this period include coloured glass ingots, vessels, and beads. Much early glass production relied on grinding techniques borrowed from stone working, such as grinding and carving glass in a cold state. Dichroic glass has one or several coatings in the nanometer-range (for example metals, metal oxides, or nitrides) which give the glass dichroic optical properties. Also the blue appearance of some automobile windshields is caused by dichroic.

The Vavilov State Optical Institute in St Petersburg, Russia (named after Sergey Ivanovich Vavilov) is a research institute in optics in Russia. It works both in pure and applied optics. It was established in 1918 along the lines of a proposal by the physicist Dimitri Rozhdestvensky, who was the first director, a post he held until 1932.It is part of the Shvabe holding. It designs optical systems for many applications, including .Russian reconnaissance satellites. It publishes the Journal of Optical Technology Alexander Lwowitsch Efros is a Russian physicist. Efros is the co- discoverer of semiconducting nanocrystals known as quantum dots.Efros graduated as a physical engineer in 1973 from the Leningrad Technological Institute and received his doctorate there in 1978. He was a scientist at the Ioffe Institute in Leningrad from 1981 to 1990, at which time he moved to the West. In the 1980s, Alexey Ekimov, Alexei A. Onuschenko and Efros, discovered semiconductor nanocrystals while studying doped glasses. They correctly determined the quantum mechanical origin of the size- dependent optical properties of nanocrystals. He was at the Technical University of Munich from 1990 to 1992, at

the Massachusetts Institute of Technology as visiting scientist from 1992 to 1993. Since 1993 he has been an advisor at the Laboratory. IN 2001, Efros became a Fellow of the American Physical Society. He received the R. W. Wood Prize in 2006 along with Ekimov and Louis E. Brus. In the Alexander von Humboldt Prize in 2008 for his work on quantum dots.

In 2013, he received the E. F. Gross Medal of the Russian Optical society for pioneering nanocrystal researched coined the term quantum dots, for demonstrating the first zero-dimensional electronic device that had fully quantized energy states. Reed did research in electronic transport in nanoscale and mesoscopic systems, artificially structured materials and devices, molecular electronics, biosensors and bioelectronic systems, and nanofluidics. He was the author of more than 200 publications, had given over 75 plenary and over 400 invited talks, and held 33 U.S. and foreign patents on quantum effect, heterojunction, and molecular devices. He was the editor in chief of the journal Nanotechnology (2009–2019) and of the journal Nano Futures, and held numerous other editorial and advisory board positions. Reed received his Ph.D. From Syracuse University in 1983. He worked at Texas Instruments from 1983 to 1990, where he demonstrated the first quantum dot device. He had been at Yale School of Engineering and Applied Science since 1990, where he held the Harold Hodgkin son Chair of Engineering and Applied Science. Notable work there included the first conductance measurement of a single molecule, the first single molecule transistor, and the development of CMOS nanowire biosensors.

METHODOLOGY

Quantum dot equation is interfacing with Verilog programming. All the parameter of the equation is mapping by Verilog parameter. Data bits of parameter are fixing accordance with Verilog parameter bit. Interconnection between Verilog programs and test

bench programming. All this parameter is fixing by both domain bits in distinguish ways. Parameter of quantum dot and test bench programming language is determined by its own domain. The output of the Verilog programming is display on the Electronic design automation software in the Epwave form .Similarly the output of the test bench is shows on Electronic design automation software in the Epware form. Verification of the equation programming in Verilog and test bench programming is match with each other after that display the output. Output of the quantum dot is multiple wave form and multiple signal form.

FINDING

Output of the verification of Verilog programming and test bench programming in binary digit and hexa digit by the software is given below:
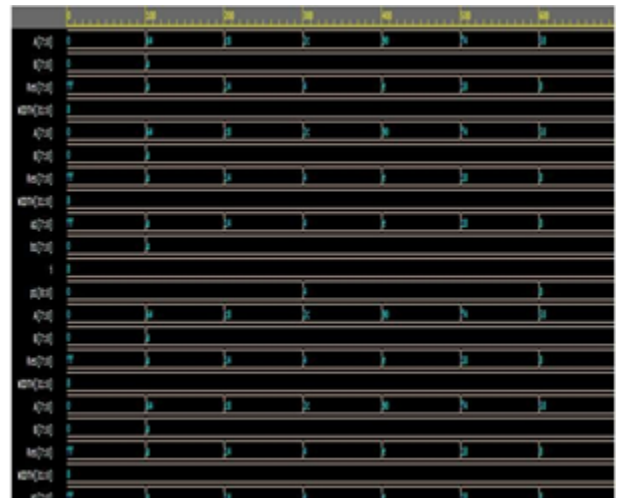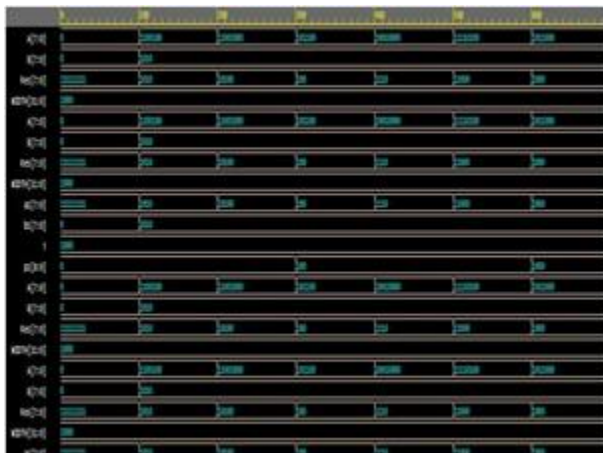

Fig1: Hexa Bit output

Fig.2 Binary-bit output

DISCUSSION

Epwave form generated the output of Verilog programming of the equation in the proper bit format in the form of the binary digit and hexa decimal digit. Verification of both programming of the equation is display in definite time interval .Output of the bit in shows in various time duration.

CONCLUSION

The study undertaken contributes the positive outcome of the Epwave form of the Verilog programming and test bench programming and development of the equation of the quantum dot verified by the output of the software of the electronic design automation.

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REFERENCES

1. ^ Turchetti, Marco; Homulle, Harald; Sebastiano, Fabio; Ferrari, Giorgio; Charbon, Edoardo; Prati, Enrico (2015). "Tunable single hole regime of a silicon field effect transistor in standard CMOS technology". Applied Physics Express. 9 (11):014001. doi:10.7567/APEX.9.014001. S2CID 124809958.

2. ^ Lee, S. W.; Mao, C.; Flynn, C. E.; Belcher, A. M. (2002). "Ordering of quantum dots using genetically engineered viruses". Science. 296 (5569): 892–895. Bibcode:2002Sci...296..892L. doi:10.1126/science.1068054. PMID 11988570. S2CID 28558725.

3. ^ Whaley, S. R.; English, D. S.; Hu, E. L.; Barbara, P. F.; Belcher, A. M. (2000). "Selection of peptides with semiconductor binding specificity for directed nanocrystal assembly". Nature. 405 (6787): 665–668. Bibcode:2000Natur.405..665W. doi:10.1038/35015043. PMID 10864319. S2CID 4429190.

4. ^ Jawaid, A. M.; Chattopadhyay, S.; Wink, D. J.; Page, L. E.; Snee, P. T. (2013). "Cluster-Seeded Synthesis of Doped CdSe:Cu4 Quantum Dots". ACS Nano. 7 (4): 3190–3197. doi:10.1021/nn305697q. PMID 23441602.

5. ^ Soutter, Will (30 May 2013). "Continuous Flow Synthesis Method for Fluorescent Quantum Dots". AZo Nano. Retrieved 19 July 2015.

6. ^ Quantum Materials Corporation and the Access2Flow Consortium (2011). "Quantum materials corp achieves milestone in High Volume Production of Quantum Dots". Archived from the original on 10 February 2015. Retrieved 7 July 2011.

7. ^ "Nanoco and Dow tune in for sharpest picture yet". The Times. 25 September 2014. Retrieved 9 May 2015.

8. ^ MFTTech (24 March 2015). "LG Electronics Partners with Dow to Commercialize LGs New Ultra HD TV with Quantum Dot Technology". Archived from the original on 18 May 2015. Retrieved 9 May 2015.

9. ^ Hauser, Charlotte A. E.; Zhang, Shuguang (2010). "Peptides as biological semiconductors". Nature. 468

(7323): 516–517. Bibcode:2010Natur.468..516H. doi:10.1038/468516a. P MID 21107418. S2CID 205060500.

10. ^ Jump up to:a b Hardman, R. (2006). "A Toxicologic Review of Quantum Dots: Toxicity Depends on Physicochemical and Environmental Factors". Environmental Health Perspectives. 114 (2): 165– 172. doi:10.1289/ehp.8284. PMC 1367826. PMID 16451849.

11. ^ Jump up to:a b Pelley, J. L.; Daar, A. S.; Saner, M. A. (2009). "State of Academic Knowledge on Toxicity and Biological Fate of Quantum Dots". Toxicological Sciences. 112 (2): 276–296. doi:10.1093/toxsci/kfp188. PMC 2777075. PMID 19684286.

12. ^ Jump up to:a b c d Tsoi, Kim M.; Dai, Qin; Alman, Benjamin A.; Chan, Warren C. W. (19 March 2013). "Are Quantum Dots Toxic? Exploring the Discrepancy Between Cell Culture and Animal Studies". Accounts of Chemical Research. 46 (3):662–671. doi:10.1021/ar300040z. PMID 22853558.

13. ^ Derfus, Austin M.; Chan, Warren C. W.; Bhatia, Sangeeta N. (January 2004). "Probing the Cytotoxicity of Semiconductor Quantum Dots". Nano Letters. 4 (1): 11–18. Bibcode:2004NanoL...4...11D. doi:10.1021/nl0347334. P MC 5588688. PMID 28890669.. doi:10.1021/jp025698c.

14. Silbey, Robert J.; Alberty, Robert A.; Bawendi, Moungi G. (2005). Physical Chemistry (4th ed.). John Wiley & Sons. p. 835.

15. ^ Ashoori, R. C. (1996). "Electrons in artificial atoms". Nature. 379 (6564): 413–419. Bibcode:1996Natur.379..413A. doi:10.1038/379413 a0. S2CID 4367436.

16. ^ Kastner, M. A. (1993). "Artificial Atoms". Physics Today. 46 (1): 24–31. Bibcode:1993PhT....46a..24K. doi:10.1063/1.881393.

17. ^ Banin, Uri; Cao, YunWei; Katz, David; Millo, Oded (August 1999). "Identification of atomic-like electronic states in indium arsenide nanocrystal quantum dots". Nature. 400 (6744): 542–544. Bibcode:1999Natur.400..542B. doi:10.1038/22979. I SSN 1476-4687. S2CID 4424927.

18. ^ Cui, Jiabin; Panfil, Yossef E.; Koley, Somnath; Shamalia, Doaa; Waiskopf, Nir; Remennik, Sergei; Popov, Inna; Oded, Meirav; Banin, Uri (16 December 2019). "Colloidal quantum dot molecules manifesting quantum coupling at room temperature". Nature Communications. 10 (1):5401. arXiv:1905.06065. Bibcode:2019NatCo..10.5401C. doi:10.1038/s41467-019-13349-1. ISSN 2041-1723. PMC 6915722. PMID 31844043.

19. Cherniukh, Ihor; Rainò, Gabriele; Stöferle, Thilo; Burian, Max; Travesset, Alex; Naumenko, Denys; Amenitsch, Heinz; Erni, Rolf; Mahrt, Rainer F.; Bodnarchuk, Maryna I.; Kovalenko, Maksym V. (May 2021). "Perovskite-type superlattices from lead halide perovskite nanocubes". Nature. 593 (7860): 535–542. Bibcode:2021Natur.593..535C. doi:10.1038/s41586-021-03492-5. ISSN 1476-4687. PMID 34040208. S2CID 235215237.

20. ^ Septianto, Ricky Dwi; Miranti, Retno; Kikitsu, Tomoka; Hikima, Takaaki; Hashizume, Daisuke; Matsushita, Nobuhiro; Iwasa, Yoshihiro; Bisri, Satria Zulkarnaen (23 May 2023). "Enabling metallic behaviour in two- dimensional superlattice of semiconductor colloidal quantum dots". Nature Communications. 14 (1):2670. Bibcode:2023NatCo..14.2670S. doi:10.1038/s41467-023-38216-y. ISSN 2041-1723. PMC 10220219. PMID 37236922.

21. ^ Jump up to:a b Murray, C. B.; Kagan, C. R.; Bawendi, M.G. (2000). "Synthesis and Characterization of Monodisperse Nanocrystals and Close-Packed Nanocrystal Assemblies". Annual Review of Materials Research. 30

(1): 545–610. Bibcode:2000AnRMS..30..545M. doi:10.1146/annur ev.matsci.30.1.545.

22. ^ Brus, L. E. (2007). "Chemistry and Physics of Semiconductor Nanocrystals" (PDF). Retrieved 7 July 2009.

23. ^ "Quantum Dots". Nanosys – Quantum Dot Pioneers. Retrieved 4 December 2015.

24. ^ Huffaker, D. L.; Park, G.; Zou, Z.; Shchekin, O. B.; Deppe, D. G. (1998). "1.3 µm room-temperature GaAs-based quantum-dot laser". Applied Physics Letters. 73 (18): 2564–2566. Bibcode:1998ApPhL..73.2564H. doi:10.1063/1.122534. ISSN 0003-6951.

25. ^ Lodahl, Peter; Mahmoodian, Sahand; Stobbe, Søren (2015). "Interfacing single photons and single quantum dots with photonic nanostructures". Reviews of Modern Physics. 87 (2): 347–400. arXiv:1312.1079. Bibcode:2015RvMP...87..347L. doi:10.1103/RevModPhys.87.347. ISSN 0034-6861. S2CID 118664135.

26. ^ Eisaman, M. D.; Fan, J.; Migdall, A.; Polyakov, S. V. (2011). "Invited Review Article: Single-photon sources and detectors". Review of Scientific Instruments. 82 (7): 071101. Bibcode:2011RScI...82g1101E. doi:10.1063/1.3610677. ISSN 0034-6748. PMID 21806165.

27. ^ Senellart, Pascale; Solomon, Glenn; White, Andrew (2017). "High-performance semiconductor quantum-dot single-photon sources". Nature Nanotechnology. 12 (11):1026–1039. Bibcode:2017NatNa..12.1026S. doi:10.1038/nnano .2017.218. ISSN 1748-3387. PMID 29109549.

28. ^ Loss, Daniel; DiVincenzo, David P. (1998). "Quantum computation with quantum dots". Physical Review A. 57 (1): 120–126. arXiv:cond- mat/9701055. Bibcode:1998PhRvA..57..120L. doi:10.1103/PhysRevA.57.120. ISSN 1050-2947.

29. ^ Jump up to:a b Michalet, X.; Pinaud, F. F.; Bentolila, L.A.; Tsay, J. M.; Doose, S.; Li, J. J.; Sundaresan, G.; Wu, A. M.; Gambhir, S. S.; Weiss, S. (2005). "Quantum Dots for Live Cells, in Vivo Imaging, and Diagnostics". Science. 307 (5709): 538–544. Bibcode:2005Sci...307..538M. doi:10.1126/science.1104274. PMC 1201471. PMID 15681376.

30. ^ Wagner, Christian; Green, Matthew F. B.; Leinen, Philipp; Deilmann, Thorsten; Krüger, Peter; Rohlfing, Michael; Temirov, Ruslan; Tautz, F. Stefan (6 July 2015). "Scanning Quantum Dot Microscopy". Physical Review Letters. 115 (2):026101. arXiv:1503.07738. Bibcode:2015PhRvL.115b6101W. doi:10.1103/PhysRevLett.115.026101. ISSN 0031-9007. PMID 26207484. S2CID 1720328.

31. ^ Ramírez, H. Y.; Flórez, J.; Camacho, A. S. (2015). "Efficient control of coulomb enhanced second harmonic generation from excitonic transitions in quantum dot ensembles". Physical Chemistry Chemical Physics. 17 (37): 23938–23946. Bibcode:2015PCCP...1723938R. doi:10.1039/C5CP03349G. PMID 26313884. S2CID 41348562.

32. ^ Coe-Sullivan, S.; Steckel, J. S.; Woo, W.-K.; Bawendi, M.G.; Bulović, V. (July 2005). "Large-Area Ordered Quantum-Dot Monolayers via Phase Separation During Spin-Casting". Advanced Functional Materials. 15 (7):1117–1124. doi:10.1002/adfm.200400468. S2CID 94993172.

33. ^ Xu, Shicheng; Dadlani, Anup L.; Acharya, Shinjita; Schindler, Peter; Prinz, Fritz B. (2016). "Oscillatory barrier-assisted Langmuir–Blodgett deposition of large- scale quantum dot monolayers". Applied Surface Science. 367: 500–506. Bibcode:2016ApSS..367..500X. doi:10.1016/j.apsusc.2016.01.243.

34. ^ Gorbachev, I. A.; Goryacheva, I. Yu; Glukhovskoy, E. G. (June 2016). "Investigation of Multilayers Structures Based on the Langmuir-Blodgett Films of CdSe/ZnS Quantum Dots". BioNanoScience. 6 (2): 153–156. doi:10.1007/s12668-016-0194-0. ISSN 2191-1630. S2CID 139004694.

35. ^ Achermann, Marc; Petruska, Melissa A.; Crooker, Scott A.; Klimov, Victor I. (December 2003). "Picosecond Energy Transfer in Quantum Dot Langmuir-BlodgeΣ Nanoassemblies". The Journal of Physical Chemistry B. 107 (50): 13782–13787. arXiv:cond- mat/0310127. Bibcode:2003cond.mat.10127A. doi:10.1021/jp036497r. ISSN 1520-6106. S2CID 97571829.

36. ^ Protesescu, Loredana; et al. (2015). "Nanocrystals of Cesium Lead Halide Perovskites (CsPbX3, X=Cl, Br, and/or I): Novel Optoelectronic Materials Showing Bright Emission with Wide Color Gamut Profiling". Nano Letters. 15 (6): 3692–3696. doi:10.1021/nl5048779. PMC 4462997. PMID 25633588.

37. ^ Mangolini, L.; Thimsen, E.; Kortshagen, U. (2005). "High-yield plasma synthesis of luminescent silicon nanocrystals". Nano Letters. 5 (4): 655–659. Bibcode:2005NanoL...5..655M. doi:10.1021/nl050066y. PMID 15826104.

38. ^ Knipping, J.; Wiggers, H.; Rellinghaus, B.; Roth, P.; Konjhodzic, D.; Meier, C. (2004). "Synthesis of high purity silicon nanoparticles in a low Pressure microwave reactor". Journal of Nanoscience and Nanotechnology. 4 (8): 1039–1044. doi:10.1166/jnn.2004.149. PMID 15656199. S2CID2461258.

39. ^ Sankaran, R. M.; Holunga, D.; Flagan, R. C.; Giapis, K. P. (2005). "Synthesis of blue luminescent Si nanoparticles using atmospheric-pressure microdischarges" (PDF). Nano Letters. 5 (3): 537–541. Bibcode:2005NanoL...5..537S. doi:10.1021/nl0480060. PMID 15755110.

40. ^ Kortshagen, U (2009). "Nonthermal plasma synthesis of semiconductor nanocrystals". Journal of Physics D: Applied Physics. 42 (11):113001. Bibcode:2009JPhD...42k3001K. doi:10.1088/0022-3727/42/11/113001. S2CID 121602427.

41. ^ Pi, X. D.; Kortshagen, U. (2009). "Nonthermal plasma synthesized freestanding silicon–germanium alloy nanocrystals". Nanotechnology. 20 (29):295602. Bibcode:2009Nanot..20C5602P. doi:10.1088/0957-4484/20/29/295602. PMID 19567968. S2CID 12178919.

42. ^ Pi, X. D.; Gresback, R.; Liptak, R. W.; Campbell, S. A.; Kortshagen, U. (2008). "Doping efficiency, dopant location, and oxidation of Si nanocrystals" (PDF). Applied Physics Letters. 92 (2):123102. Bibcode:2008ApPhL..92b3102S. doi:10.1063/1.2830828. S2CID 121329624.

43. ^ Ni, Z. Y.; Pi, X. D.; Ali, M.; Zhou, S.; Nozaki, T.; Yang, D. (2015). "Freestanding doped silicon nanocrystals synthesized by plasma". Journal of Physics D: Applied Physics. 48 (31):314006. Bibcode:2015JPhD...48E4006N. doi:10.1088/0022-3727/48/31/314006. S2CID 118926523.

44. ^ Torres Torres, C.; López Suárez, A.; Can Uc, B.; Rangel Rojo, R.; Tamayo Rivera, L.; Oliver, A. (24 July 2015). "Collective optical Kerr effect exhibited by an integrated configuration of silicon quantum dots and gold nanoparticles embedded in ion-implanted silica". Nanotechnology. 26 (29):295701. Bibcode:2015Nanot..26C5701T. doi:10.1088/0957-4484/26/29/295701. ISSN 0957-4484. PMID 26135968. S2CID 45625439.

45. ^ Loss, D.; DiVincenzo, D. P. (January 1997). "Quantum computation with quantum dots". Physical Review A (published 1998). 57:

120. arXiv:cond- mat/9701055. doi:10.1103/PhysRevA.57.120.

46. ^ Yazdani, Sajad; Pettes, Michael Thompson (26 October 2018). "Nanoscale self-assembly of thermoelectric materials: a review of chemistry-based approaches". Nanotechnology. 29 (43):432001. Bibcode:2018Nanot..29Q2001Y. doi:10.1088/1361-6528/aad673. ISSN 0957-4484. PMID 30052199.

47. ^ Bux, Sabah K.; Fleurial, Jean-Pierre; Kaner, Richard B. (2010). "Nanostructured materials for thermoelectric applications". Chemical Communications. 46 (44): 8311–8324. doi:10.1039/c0cc02627a. ISSN 1359-7345. PMID 20922257.

48. Zhao, Yixin; Dyck, Jeffrey S.; Burda, Clemens (2011). "Toward high-performance nanostructured thermoelectric materials: the progress of bottom-up solution chemistry approaches". Journal of Materials Chemistry. 21 (43):17049. doi:10.1039/c1jm11727k. ISSN 0959-9428.

49. ^ Achermann, M.; Petruska, M. A.; Smith, D. L.; Koleske, D. D.; Klimov, V. I. (2004). "Energy-transfer pumping of semiconductor nanocrystals using an epitaxial quantum well". Nature. 429 (6992): 642–646. Bibcode:2004Natur.429..642A. doi:10.1038/nature02571. PMID 15190347. S2CID 4400136.

50. ^ Chern, Margaret; Kays, Joshua C.; Bhuckory, Shashi; Dennis, Allison M. (24 January 2019). "Sensing with photoluminescent semiconductor quantum dots". Methods and Applications in Fluorescence. 7 (1):012005. Bibcode:2019MApFl...7a2005C. doi:10.1088/2050-6120/aaf6f8. ISSN 2050-6120. PMC 7233465. PMID 30530939.

51. ^ Mongin, C.; Garakyaraghi, S.; Razgoniaeva, N.; Zamkov, M.; Castellano, F. N. (2016). "Direct observation of triplet energy transfer from semiconductor nanocrystals". Science. 351 (6271): 369–372. Bibcode:2016Sci...351..369M. doi:10.1126/science.a ad6378. PMID 26798011.

52. ^ Jump up to:a b Trafton, Anne (18 December2019). "Storing medical information below the skin's surface". MIT News.

53. ^ Jump up to:a b Jaklenec, Ana; McHugh, Kevin J.; Langer, Robert S. "Microneedle tattoo patches and use thereof". No. US20190015650A1. US Patent and Trademark Office.

54. ^ Jump up to:a b Walling, M. A.; Novak, Shepard (February 2009). "Quantum Dots for Live Cell and In Vivo Imaging". International Journal of Molecular Sciences. 10 (2): 441–491. doi:10.3390/ijms10020441. PMC 2660663. PMID 19333416.

55. ^ Stockert, Juan Carlos; Blázquez Castro, Alfonso (2017). "Chapter 18: Luminescent Solid-State Markers". Fluorescence Microscopy in Life Sciences. Bentham Science Publishers. pp. 606–641. ISBN 978-1-68108-519-7. Archived from the original on 14 May 2019. Retrieved 24 December 2017.

56. ^ Marchuk, K.; Guo, Y.; Sun, W.; Vela, J.; Fang, N. (2012). "High-Precision Tracking with Non-blinking Quantum Dots Resolves Nanoscale Vertical Displacement". Journal of the American Chemical Society. 134 (14): 6108–6111. doi:10.1021/ja301332t. PMID 22458433.