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Study on Nanocrystals

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ABSTRACT

A nanocrystal (NC) is a single crystal having a diameter of a few nanometers. A NCQD is a nanocrystal that has a smaller band gap than the surrounding material. The easiest way to produce NCQDs is to mechanically grind a macroscopic crystal. Currently NCQDs are very attractive optical applications because their color is directly determined by their dimensions. The size of the NCQDs can be selected by filtering a larger collection of NCQDs or by tuning the parameters of a chemical fabrication process.

1. Introduction

Cadmium selenide (CdSe) and zinc selenide (ZnSe) NCQDs are approximately spherical crystallites with either wurtzite or zinc-blend structure. The diameter ranges usually between 10 and 100 A^0. CdSe NCQDs are prepared by standard processing methods. $Cd(CH_3)_2$ is added to a stock solution of selenium (Se) powder dissolved in tributylphosphine oxide (TBP). This stock solution is prepared under N_2 in a refrigerator, while tri-n-octylphosphine oxide (TOPO) is heated in a reaction flask to 360^0C under argon (Ar) flow. The stock solution is then quickly injected into the hot TOPO, and the reaction flask is cooled when the NCQDs of the desired size is achieved. The final powder is obtained after precipitating the NCQDs with methanol, centrifugation, and drying under nitrogen flow. The room-temperature quantum yield and photostability can be improved by covering the CdSe NCQDs with, e.g., cadmium sulphide (CdS). By further covering the CdSe NCQDs by CdS, for example, the room temperature quantum yield and photostability can be increased. The almost ideal crystal structure of a NCQD can be seen very clearly in the TEMs .

2. Explanation

Silicon Nanocrystals

Silicon/Silicon dioxide (Si/SiO_2) NCQDs are Si clusters completely embedded in insulating SiO_2. They are fabricated by ion-implanting Si atoms into either ultrapure quartz or thermally grown SiO_2. The Ncs are the formed formed from the implanted atoms under thermal annealing. The exact structure of the resulting NCQDs is not known. Pavesi et al. reported successful fabrication of NCQDs with a diameter around 3 nm and a NCQDs with a diameter around 3 nm and a NCQDs density of 2x 10^{19} cm^{-3}. The high-density results in an even higher light wave amplification ($100cm^{-1}$) than for seven stacks of InAs QDs (70 to 85 cm^{-1}). The main photoluminescence peak was measured at ʎ=800 nm. The radiative recombination in these QDs is not very well understood, but pavesi et al. suggested that the radiative recombinations take place through interface states. Despite the very high modal gain, it is very difficult to fabricate an electrically pumped laser structure of Si NCDQs due to the insulating SiO_2.

Lithographically Defined Quantum Dots

Vertical quantum dots A vertical quntum dots (VQD) is formed by either etching out a pillar from a QW or a double barrier heterostructure (DBH). The main steps in the fabrication process of a VQD. The AIGaAs/InGaAs/AIGaAs DBH was grown epitaxially, after which a cylindrical pillar was etches through the DBH. Finally, metallic contacts were made for electrical control of the QD. Typical QD dimensions are a diamenter of about 500 nm and a thickness of about 50nm. The confinement potential due to the AIGaAs barroers is about 200 meV. The optical quality of VQDs is usually fairly poor due to the etched boundries .

Si Quantum Dots

Si QDs discussed here are lithographically de.ned Si islands either completely isolated by SiO2 or connected to the environment through narrow Si channels. Si QDs can be fabricated using conventional CMOS technology on a silicon – oninsulator (SOI) wafer. The SOI wafer enables complete electrical isolation from the substrate. A narrow wire is etched using electron beam lithography from the topSi layer. The QD is then formed in the wire by thermal oxidation. The oxidation rate is sensitive to the local O2 influx and the local strain field. Both depend strongly on the geometry and, as a result, the cemter of the Si wire is oxidised very slowly compared to the rest. Therefore, the oxidation process gives rise to constrictions pinning off the wire from the leads, resulting in a Si QD in the center of theh wire. This technique has been developed further to fabricate double QDs and even memory and logical gate devices. The main advantage of this technique is the easy integration to CMOS circuits. Si QDs do also have the potential to operate at room temperature due to very high carrier confinement ($V_c \approx 3$ eV) and small size. However, these Si QDs cannot be used for optical applications due to the low quantum efficiency of Si.

Field-Effect Quantum Dots

In a FEQD, the charge carriers are confined into a 2D electron gas (2DEG) by a modulation_droped heterojunction. Within the 2DEG plane, the charges are electrostatically confined by external gates. The ohmic contacts represent any kind of electric contacts to the Qd. The effective potential of

FEQD is very smooth and within the plane of the 2DEG, its shape is close to a parabola depending on the gates.

Self – Assembled Quantum Dots

In self assembly of QDs, one makes use of an island formation in epitaxial growth. The effect is similar to the formation of water droplets on a well-polished surface. The islands can either be Qds themselves or induce Qds in a nearby QW. The major self-assembly growth techniques are vapour phase epitaxy (VPE) and MBE. Generally, the epitaxial growth proceeds in atomic layer-by-layer mode. However, islands are formed if there is a large lattice mismatch between the materials and/or if the surface energy of the deposited material is different from that of the substrate. In the Stranski-Krastanow (S-K) mode, the growth starts in layer by layer mode and proceeds into the island mode after exceeding a critical thickness. Dislocation-free S – K growth has been observed in , e.g., InAs on GaAs and InP on GaAs. Typical island densities are 10^9 to 10^{12} cm^{-2}, depending on the growth conditions.

Quantum Dot Island

The self-assembled island is QD itself if the island is embedded in a material with a larger band gap than that of the island material. An example is provided by InAs islands in GaAs. Qd islands schematically and high resolution scanning tunnelling micrograph of a true InAs island. Very promising laser structures have been fabricated using these types of quantum dots by stacking several island layers on top of each other. Typical QD heights range from 5 to 15 nm and width range 15 to 25 nm. This means that there are very electrons and holes per QD. The total charhe confinement is a combination of strain, piezoelectric fields, and material interface effects. For a dot 13.6 nm height, the calculated confinement energy of the electron ground state is about 180 meV.

Strain-Induced Quantum Dots

Strain is always present in self- assembled islands as well as in the substrate close to the island. The magnitude of the strain depends on the lattice contacts and elastic moduli of the materials. If there is QW close to the Quantum dot, the strain field penetrates it also and affects its energy bands. The island can therefore induce a lateral carrier confinement in the QW. This result in a total QD confinement in the QW. Typically stressor island heights range from 12 to 18 nm and the QW thickness is around 10 nm. The lateral strain-induced confinement is very smooth and has shape of a parabola. The strain-induced electron confinement is very about 70 meV deep. The resulting QD is pretty large and contais in general tens of electron-hole pairs.

References

1. M. A. Kastner, Physics Today 24 – 31, January (2001).
2. R. C. Ashoori, Nature 379, 413 (1996).
3. K. Chang and J.B. Xia, Phys. Rev. b 57, 16 (1998).
4. G. C. John and V.A. Singh, Comments Cond. Matt. Phys. 18, 163 (1997).
5. M. Singh, V. Ranjan, and V.A. Singh, Intnl. J. Mod. Phys. B14, 1753 (2000), and the references therein.
6. M. S. Hybertsen, Mat. Res. Soc. Symp. Proc. 256, 179 (1992).
7. P. Borse, N. Deshmukh and S.K. Kulkarni, Physics Education, January-March (1998).
8. L. E. Brus, J. Phys. Chem. 90, 2555 (1986).
9. Y. Wang and N. erron, J. Phys. Chem. 95, 252 (1991)
10. G. C. John and V. A. Singh, Phys. Rep. 263, 93 (1995).
11. L. T. Canbam, Appl. Phys. Lett. 57, 1046 (1990).
12. S. M. reimann, M. Mannien, Rev. Mod. Phys. 74, 1283 (2002).