Silicon Nanocrystal as a Light Amplification Medium

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Silicon Nanocrystal Material

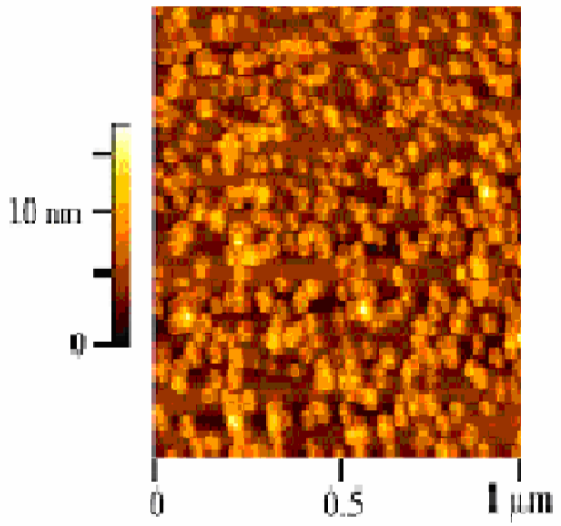
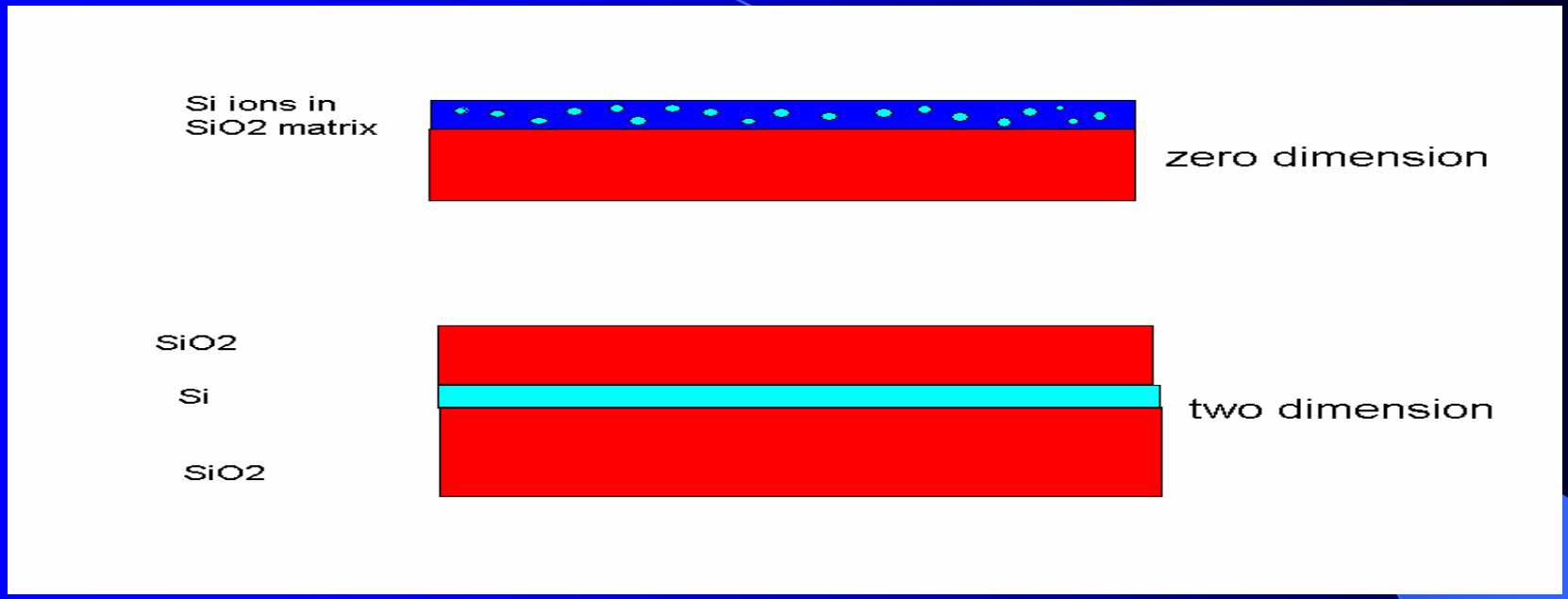


Fig.1 silicon-quantum dots under atomic force microscope

- Nanacrystals are layer and dot in the range of 2 to 50 nm
- Size of nanoparticles play essential roles in the physical properties of materials such as optical, thermal, acoustic and etc.

Formation of Silicon Nanocrystal



- Implantation of Si ions into Si/Si02 followed by annealing,
- High temperature(1000 to 1250 celcius) of Substoichiometric SiOx by PECVD
- Lithography followed by anisotropic etching and oxidation on silicon substrate

Light Emission Mechanisms

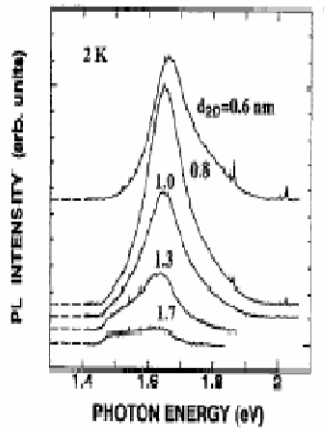


Fig.2 Photoluminescence intensity spectrum VS photon energy

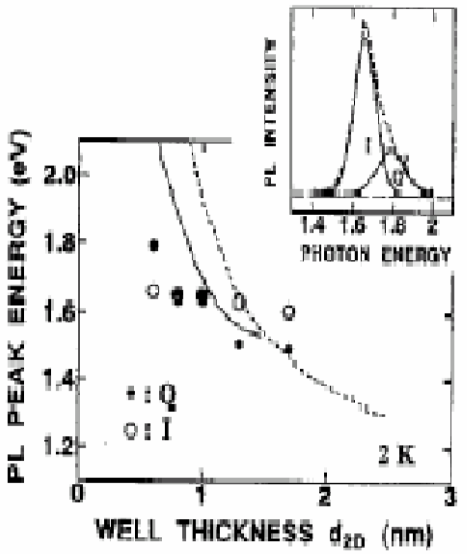


Fig.3 PL peak energy VS well thickness

- Light emission due to irradiative Si-oxide interface and quantum confinement of Si nanocrystal
- Dependence of Light luminescence on the size of the nanocrystals.
- Size dependence of PL of Infared spectrum and well thickness independence of Infared spectrum

Light Emission Mechanisms cont.

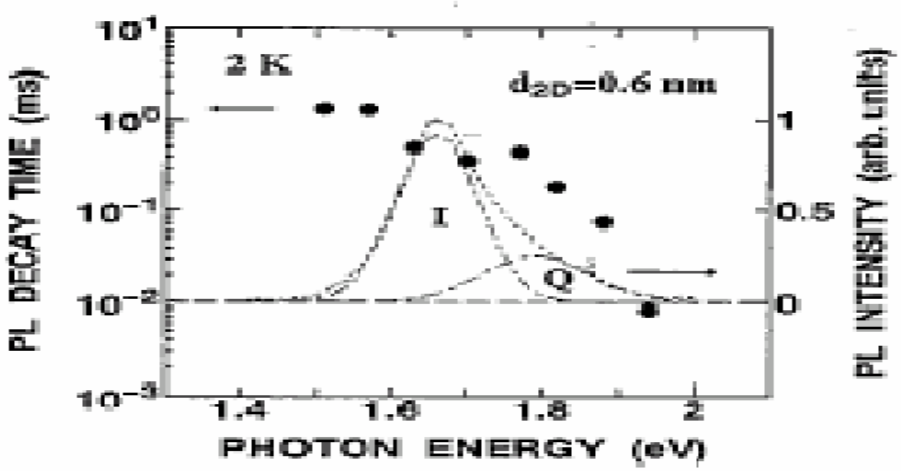


Fig.4 PL decaytime VS photon energy

- I band is due to radioactive nanocrystal-oxide interface
- Q band is due the quantum confinement of the bandgap of the nanocrystal cause the theoretical quantum confinement model matches the peak PL intensity.

Amplification of Silicon nanocrystal

- The coincidence of the absorbance and emission suggests the radioactivity of the oxide-nanocrystal interface
- Amplified spontaneous emission determined by length variation method
- Saturation occurs at 0.06cm

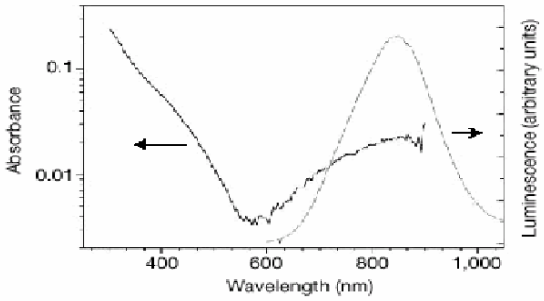


Fig.5 Absorbance and emission spectrum VS wavelength

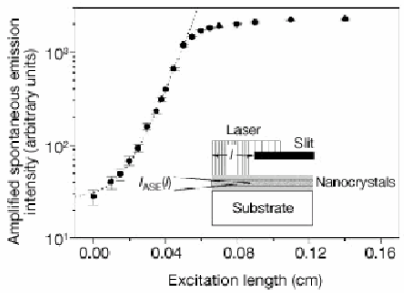


Fig.6 spontaneous emission VS length of silicon nanocrystal

Pump and Probe Method

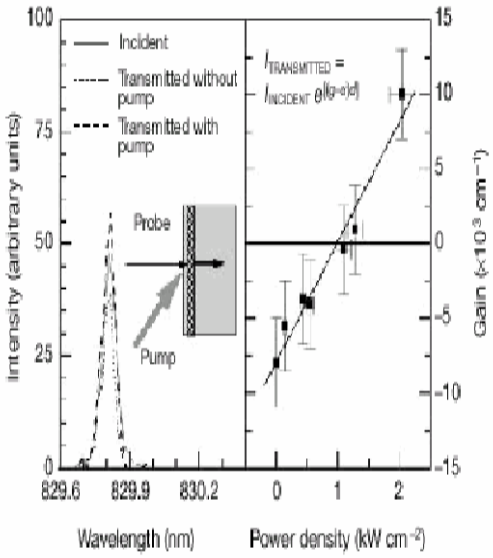


Fig.8 Gain VS pump power density, Intensity for each input and out intensity

- Pump beam at 390nm wave length and probe beam at 800nm
- Gain increases as the pump power increases

Emperical Results of Pump and Probe Method

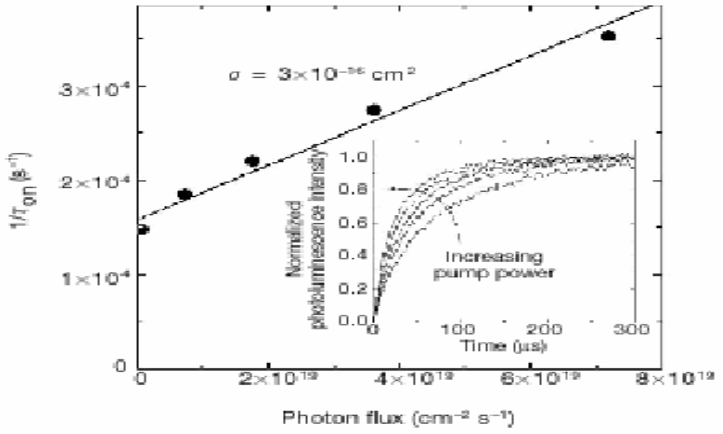


Fig.9 Rise time VS Photon Flux

- The gain cross sectional area and lifetime of nanocrystal can be extracted from the fitted curve.

Equations

$$I(t) = I_0\left\{1 - \exp\left[-\left(\sigma J + \frac{1}{\tau}\right)t\right]\right\} = I_0\left\{1 - \exp\left[-\left(\frac{t}{\tau_{on}}\right)\right]\right\}$$

$$\frac{dN^*}{dt} = \sigma J(N - N^*) - \frac{N^*}{\tau}$$

Three Energy Level System

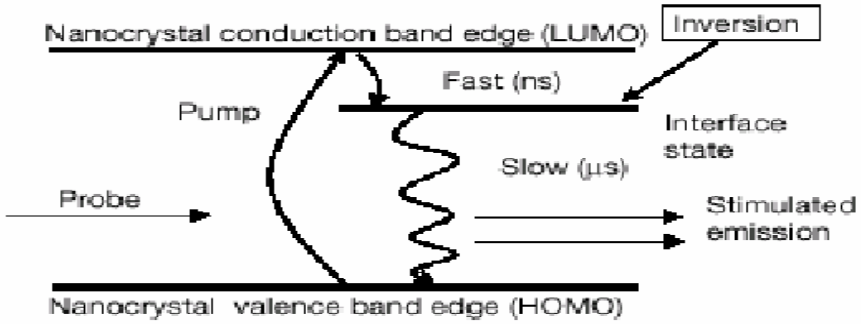


Fig. 10 Energy band diagram for the silicon nano crystals as an amplification mediam

- High density state for electron and hole generation and long excitation lifetime(70us) make the population inversion possible.
- Indirect bandgap nature of the silicon nanocrystal is still present

Conclusion

- Material, formation methods, light emission mechanisms, and light amplification of silicon nanocrystal are presented
- Further research required to precisely control the size of nano-structures.

Bibliography

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