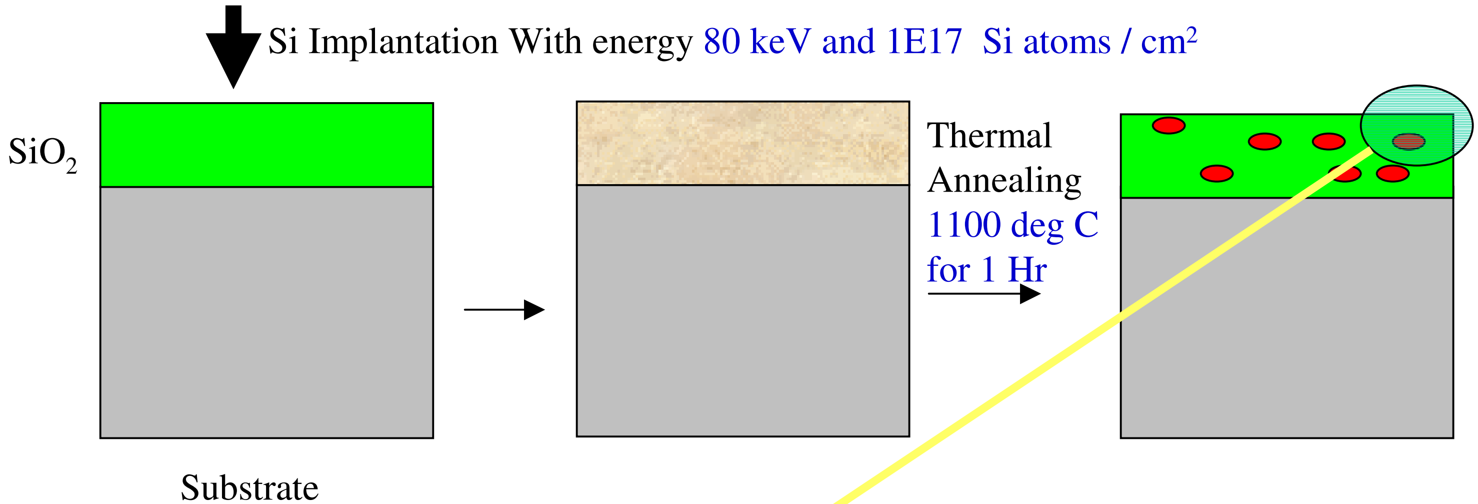
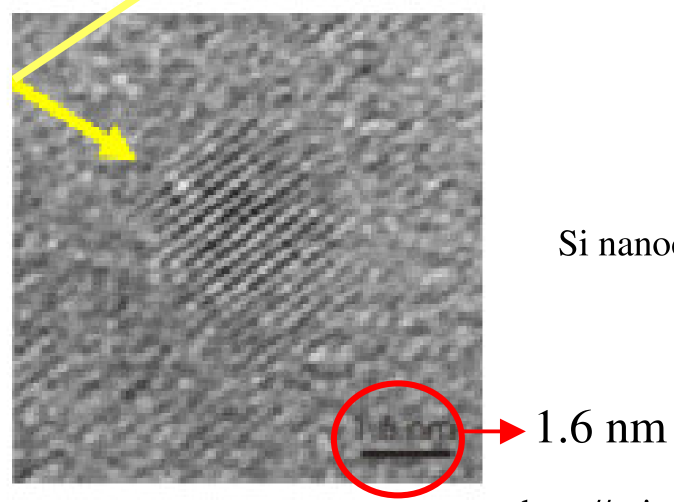
Pavesi's approach

Ion Implantation Method



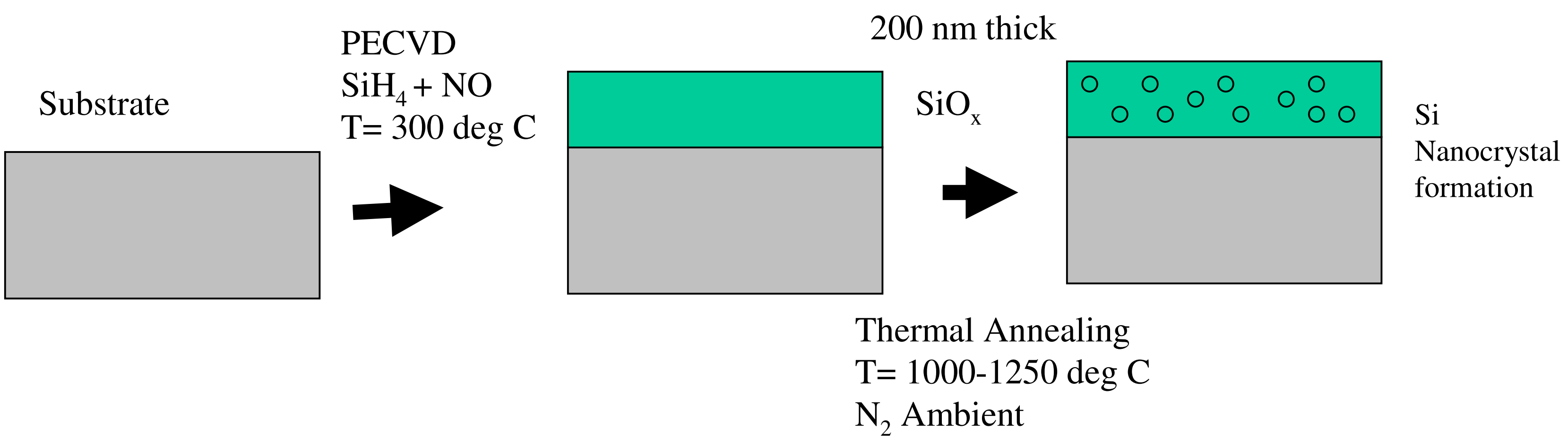


Si nanocrystal

http://science.unitn.it/~semicon/

PECVD Method

plasma enhanced chemical vapor deposition



Ion implantation Vs PECVD

Si NC	Net Modal gain (cm^{-1})	Net material gain (X 10^4 cm^{-1})	Dot density (cm^{-3})	Active layer Thickness (nm)	Filling Factor (X 10^4)	Gain cross section per dot (x 10^{-16} cm^2)
Ion Implanted	100	1	2 X 10^{19}	100	970	0.5-5
PECVD	60	0.1	4.6 X 10^{18}	250	8000	0.1-0.8

gain cross section $\gamma_{\text{ASE}} = \dfrac{g}{(f_c - f_v)N\Gamma}$

Γ = optical filling factor

Population inversion $f_c - f_v = 1$

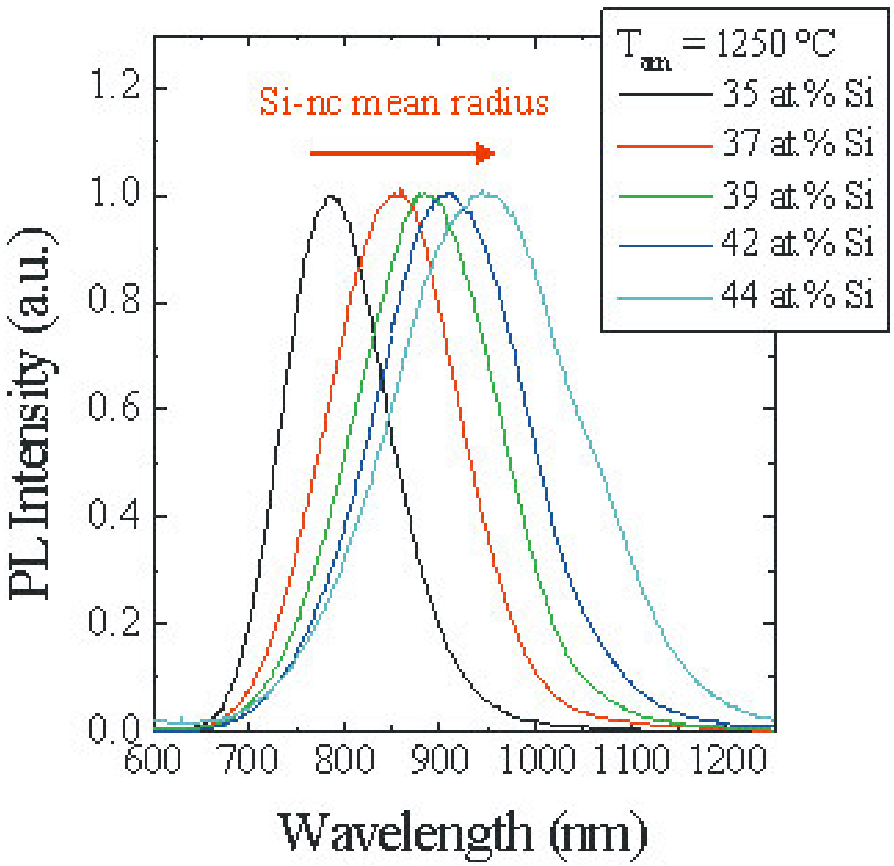
absorption confinement factors, $\Gamma_{\text{gain}}, \Gamma_{\text{abs}}$

Net Modal Gain $\Delta g = \Gamma_{\text{gain}} g - \Gamma_{\text{abs}} \alpha_{opt} - \alpha_{loss}$

$g, \alpha_{opt}, \alpha_{loss}$ are Material optical gain, absorption and Modal losses

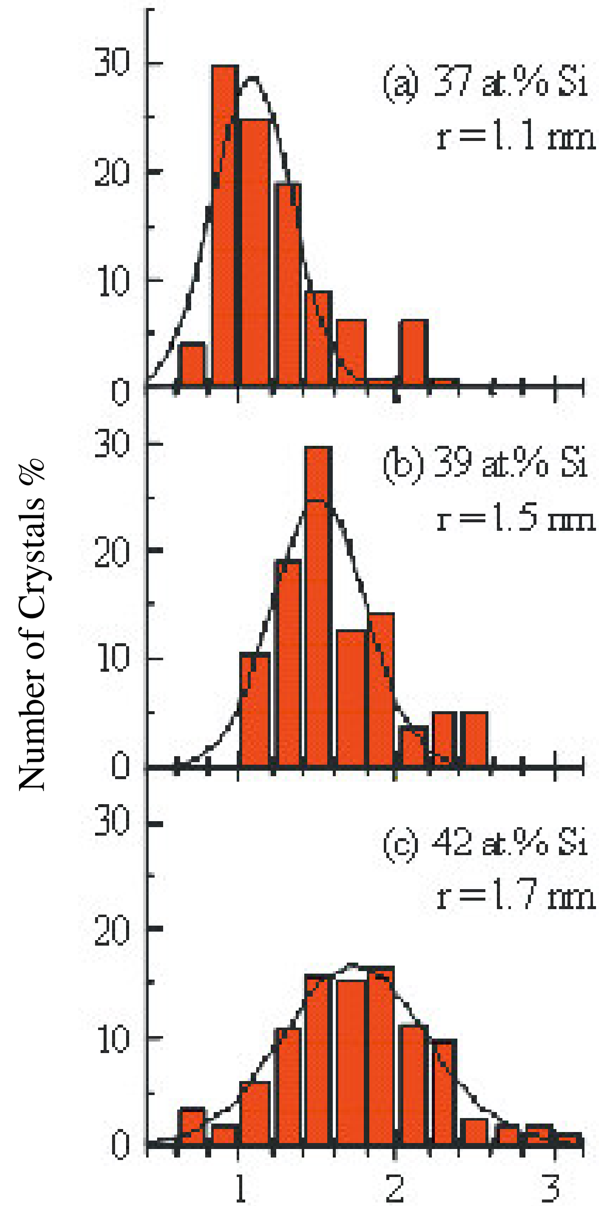
Internal quantum efficiency of Si NC is above 0.1%

PL Dependence on Si NC mean radius



Control of Si NC mean size

T=1250 deg C



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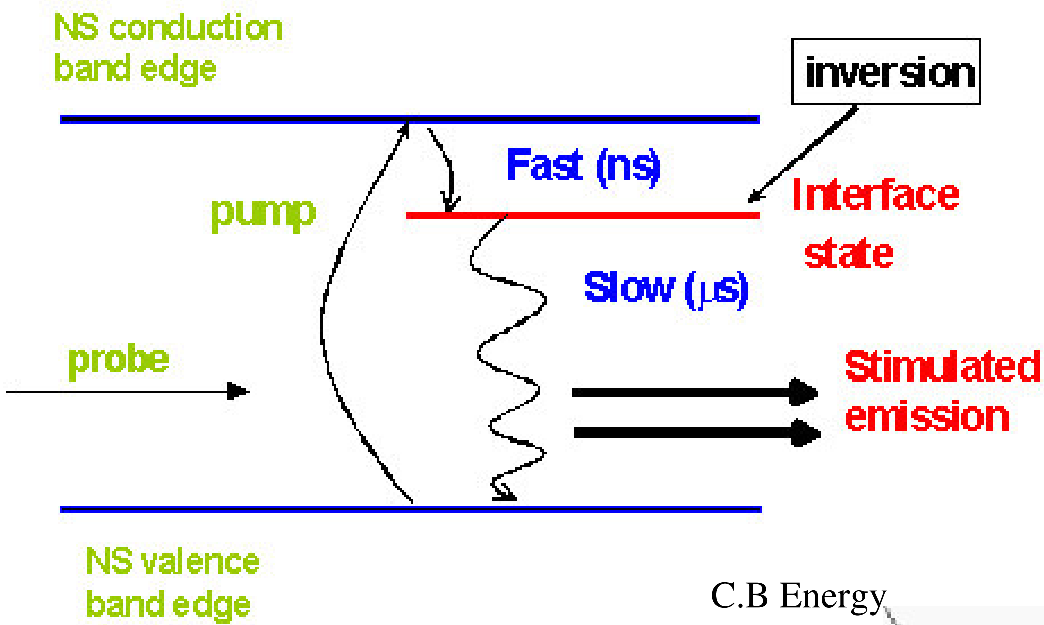
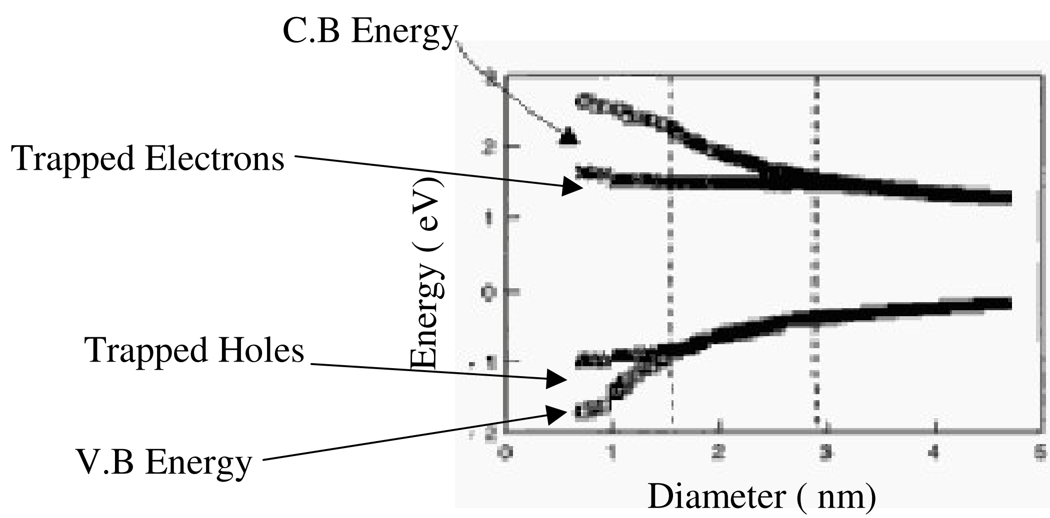
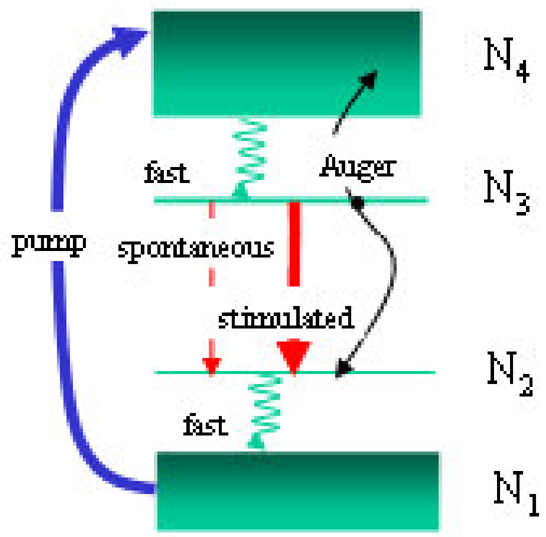
Three Level model of gain in Si nc







Rate Equation Model

$$\frac{dN_1}{dt} = -\sigma_P \phi_P(t) N_1 + \Gamma_{21} N_2$$

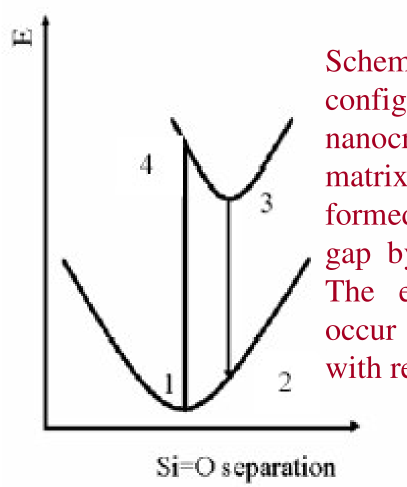
$$\frac{dN_2}{dt} = \frac{N_3}{\tau} - \Gamma_{21} N_2 + B n_{ph} (N_3 - N_2) + (C_{A1} + C_{A2}) N_3^2$$

$$\frac{dN_3}{dt} = -\frac{N_3}{\tau} - B n_{ph} (N_3 - N_2) + \Gamma_{43} N_4 - C_A N_3^2$$

$$\frac{dN_4}{dt} = C_{A1} N_3^2 + \sigma_P \phi_P(t) N_1 - \Gamma_{43} N_4$$

$$\frac{dn_{ph}}{dt} = V_a B n_{ph} (N_3 - N_2) - \frac{n_{ph}}{\tau_{ph}} + \beta \frac{N_3}{\tau_R}$$

Stimulated Emission life Time



Schematic of the energy configuration diagram of the silicon nanocrystals in an oxygen rich matrix. Localised radiative states are formed inside the nanocrystal band-gap by the interface oxygen atoms. The excited nanocrystal state can occur at a different lattice coordinate with respect to the ground state.

$$\tau_{se} = \frac{1}{B n_{ph}} = \frac{4}{3} \pi R_{nc}^{\ 3} \frac{1}{\xi \sigma c n_{ph}}$$

Auger life Time

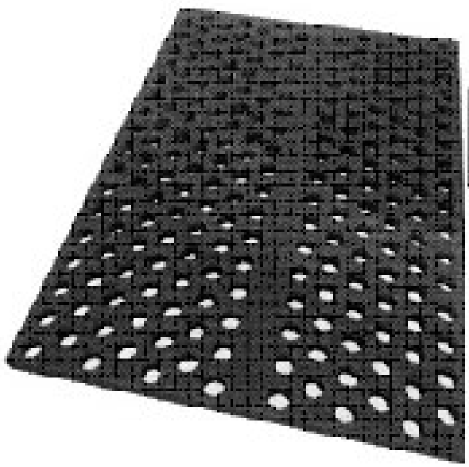
$$\tau_A = \frac{1}{2 C_A N_3}$$

if $\tau_{se} \le \tau_A$, then stimulated emission occurs

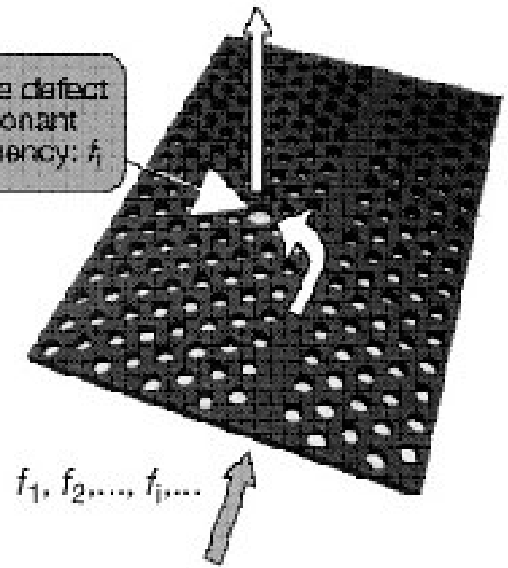
EEL 6935-007 System On a Chip; Fall 2002;
Lasing in Silicon
Ashok Rangaswamy (directed by Dr.Jain, USF)

STIMULATED EMISSION IN SILICON NANOCRYSTALS
Gain measurement and rate equation modelling, L.Pavesi, to be published in Towards the First Silicon Laser, Kluwer academic Publishers

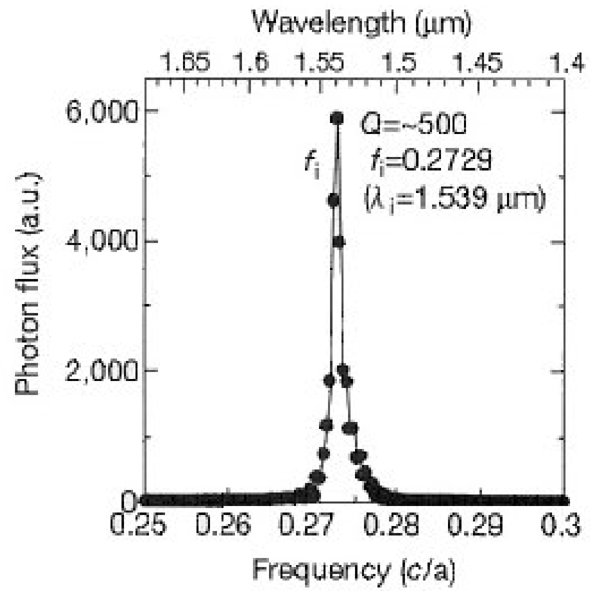
Trapping and emission of photons by a single defect in a photonic bandgap (PBG)



2D triangular lattice slab
radius of hole 0.29a, thickness 0.6a
(a is the lattice constant)



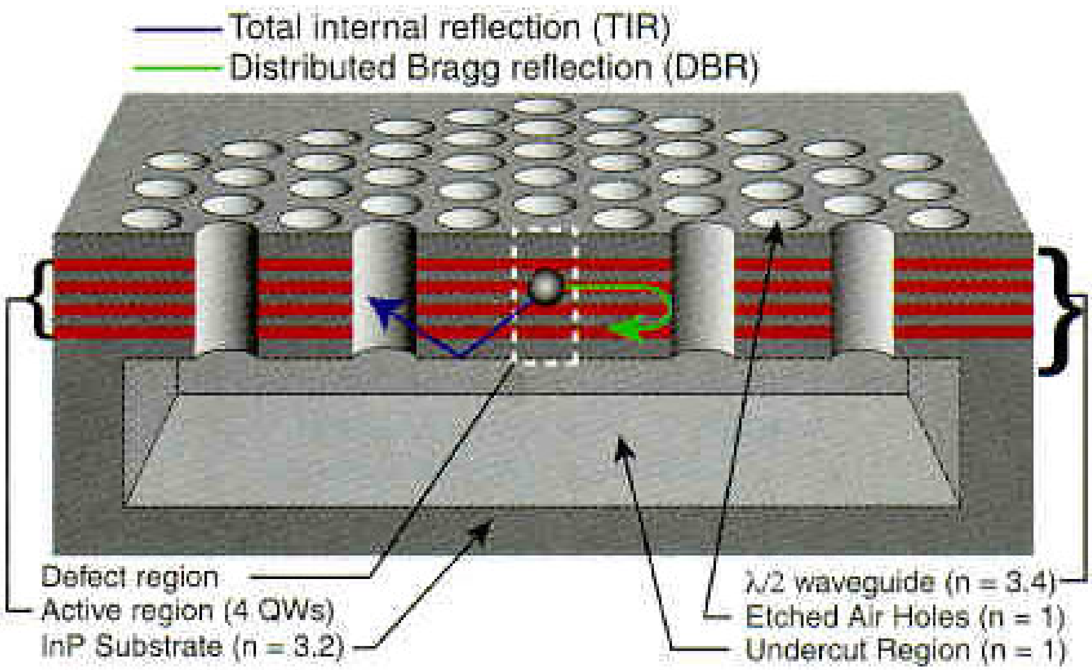
Single defect with radius = 0.56 a



For a = 0.42 ì m

Noda: Nature, Volume 407(6804).October 5, 2000.608-610

Photonic crystal microcavity

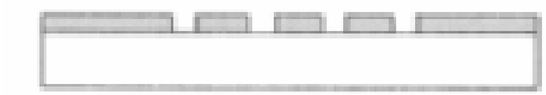


The combination of Bragg reflection from the 2D photonic crystal and TIR from the low-index cladding (air) results in a three-dimensionally confined optical mode.

Painter: Science, Volume 284(5421).June 11, 1999.1819-1821

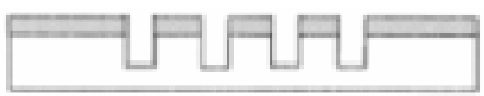
2D Photonic crystals in Silicon

n-type (100) silicon

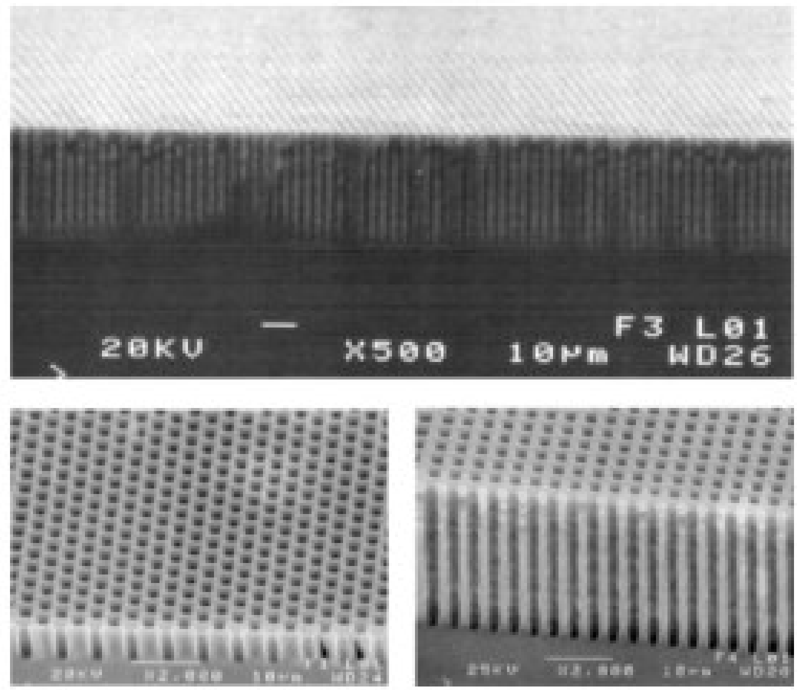


SiN deposition and sputtering

Initial Pit Formation with KOH



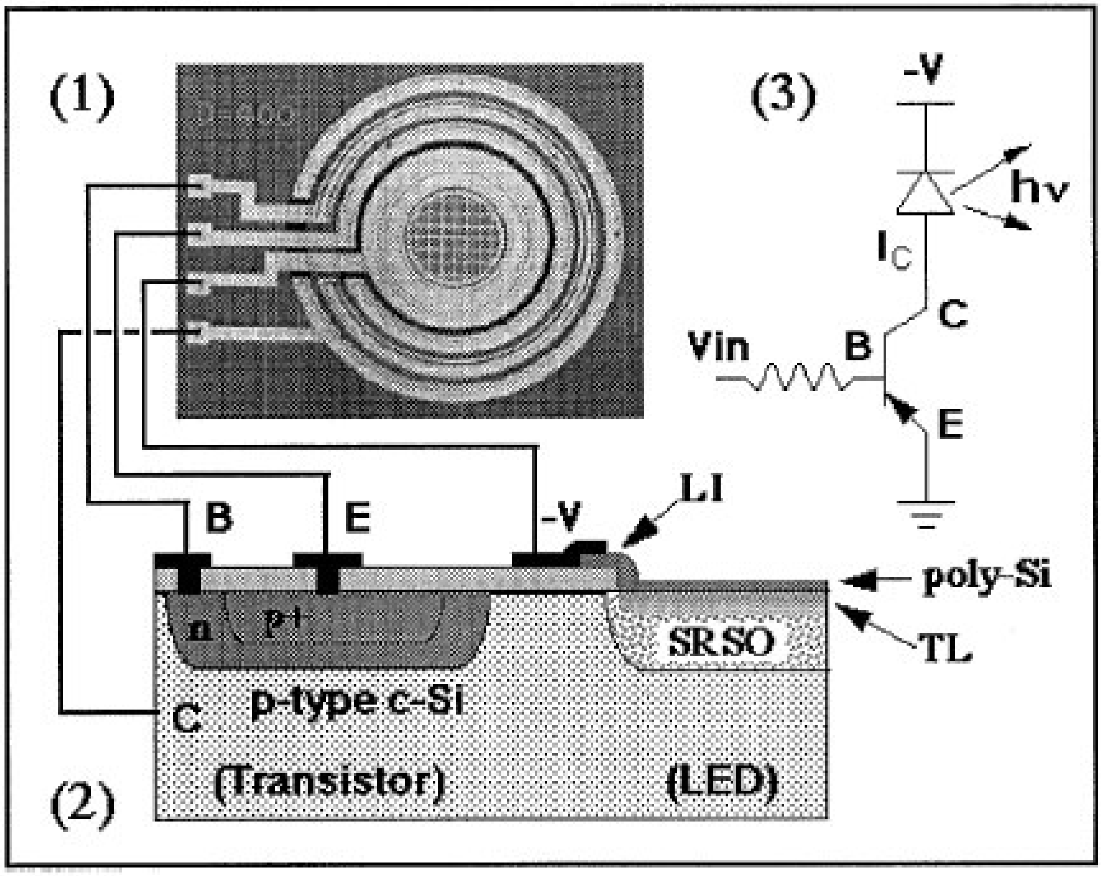
Vertical wall formation using electrochemical etching



Ordered Structures with Lithography

http://science.unitn.it/~semicon/

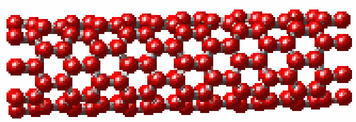
Integration with microelectronics



The integration of nanoscale porous silicon light emitters,M.Fauchet, Journal of Luminescence,80 1999 53-64

Carbon Nanotube[1]

a molecule made from carbon atoms connected into a tube and sealed at both ends by a structure that is like half a buckyball. The tubes may be as long as a few millimeters. Also called "buckytubes".



Nanotube[2]:
A one dimensional fullerene (a convex cage of atoms with only hexagonal and/or pentagonal faces) with a cylindrical shape. Strictly speaking, any tube with nanoscale dimensions, but generally used to refer to carbon nanotubes (a commonly mentioned non-carbon variety is made of boron nitride). nanotubes exhibit varying electrical properties (depending on the way the graphite structure spirals around the tube, and other factors), and can be insulating, semiconducting or conducting (metallic).

1. http://www.cem.msu.edu/~cem181h/glossary.html
2. http://nanotech-now.com/nanotechnology-glossary-M-O.htm