Ph.D. Project Abstracts
AMM&NS Programme

Optical Add/Drop Multiplexer

Student : Agam Prakash Vajpeyi
Thesis Advisor (Singapore) : Prof Chua Soo Jin
Thesis Advisor (MIT) : Prof Eugene A. Fitzgerald

Project Abstract:

Project Abstract:

Photonics crystals are two and three dimensionally periodic structures with high refractive index contrast. The existence of a photonics band gap, a frequency range in which propagation of light is prevented in all directions, makes PBG structures very useful in applications where spatial localization of light is required. In a purely 2 dimensional photonic crystal linear wave-guide, a linear defect is introduced into the crystal creating a localized band that falls within and governed by the photonic band gap. Phontics band gap properties can be tailored by changing -Lattice parameter of the crystal, Radius of pillars or holes, and Material of dielectrics. This makes PBG material very useful for the application. Various scientific and engineering applications, such as control of pontaneous emission, zero-threshold lasing, sharp bending of light, and so on, are expected by using the photonic band gap and the artificially introduced defect states and/or light-emitters. The aim of this project is to fabricate approximately zero threshold current lasers and this project involves FDTD (Finite Difference Time domain) Simulation for optimizing dimension of the device, Fabrication of Laser structure and finally characterization of device Structure.

Copper Reliability

Student : Chang Choon Wai
Thesis Advisors (Singapore) : Assoc Prof Choi Wee Kiong, Assoc Prof Pey Kin Leong
Thesis Advisor (MIT) : Prof Carl V. Thompson

Project Abstract:

Reliability of Cu interconnect trees is evaluated using different types of structures including dotted-I, T-trees and cross structure. The different types of structures are aimed for accurate method for circuit level reliability assessment. The reliability study is focused on electromigration (EM). The Cu interconnect trees were fabricated using Cu/SiO_2 or Cu/low-K metallization scheme with technology ranging from 0.18μm, 0.13μm and 0.09μm channel length. The architecture of the Cu interconnect trees is an important factor in determining EM lifetime as well as the failure mechanism. The difference in dielectric mechanical strength is also expected to have an impact on EM lifetime. The objectives of the project are to identify the critical interconnect length for immortality and failure mechanisms due to EM, study effects of interconnects designs on EM lifetime, model the EM failure for Cu interconnects and eventually suggest design rules for Cu interconnects reliability.

Ge Nanocrystal Growth in Epitaxial Silicon Germanium and its Applications

Student : Eric Kan Wing Hong
Thesis Advisors (Singapore) : Assoc Prof Choi Wee Kiong, Assoc Prof Chim Wai Kin

Ph.D. Project Abstracts
AMM&NS Programme

Thesis Advisor (MIT) : Prof Eugene A. Fitzgerald

Project Abstract:

The observation of visible photoluminescence from indirect band gap materials in the form of nanocrystals has promised many potential applications in optoelectronic devices. There are also proposals that made use of Si or Ge nanocrystals embedded in amorphous silicon oxide films for memory applications. Over the years, research on the formation of Ge nanocrystals embedded in silicon oxide synthesized by the rapid thermal annealing technique has been conducted. Currently, investigation on the possibility of using such nanocrystals for flash memory application is being done.

Ni-Silicidation on SiGe

Student : Jin Lijuan
Thesis Advisors (Singapore) : Assoc Prof Choi Wee Kiong, Assoc Prof Pey Kin Leong
Thesis Advisors (MIT) : Prof Eugene A. Fitzgerald, Prof Dimitri A. Antoniadis

Project Abstract:

One of the problems limiting the performance of Silicon MOSFET is the speed that carries can move from source to drain. Silicon Germanium has been proposed as an alternative material for the fabrication of MOSFET in order to overcome the speed limit. To further reduce the RC delay, self-aligned silicide is formed at the source and drain regions. Ni-silicide has been identified as the next candidate for advanced CMOS Si technology. Previous project shows that the onset temperature for obtaining uniform low resistivity Ni-SiGe is a strong function of the Ge concentration, and some results further prove the current RTA technology has very narrow process window for various Ge concentrations and may not the viable manufacturable technology for fabricating uniform Ni-SiGe.

This project aims to develop robust technology for forming good Ni-SiGe on relaxed SiGe S/D regions and ultimately develop a Ni-Silicidation process for application to future SiGe-based MOSFET devices with high performance. The main study includes: Effect of sputter deposition using rapid thermal annealing (RTA) and in-situ annealing on Ni-SiGe formation; effect of Pt alloy in Ni on the thermal stability of Ni (Pt)-SiGe formation; Effect of dopant in SiGe on the Silicidation. After finishing this part, the most viable process need to be integrated into high performance SiGe MOSFET transistors.

Thin Film Microbatteries for Integration with Microelectronics

Student : Shi Zhifei
Thesis Advisor (Singapore) : Assoc Prof Lu Li
Thesis Advisor (MIT) : Prof Gerbrand Ceder

Project Abstract:

In association with the rapid progress in miniaturization of electronic devices in recent years, there is increasing demand to develop on-chip rechargeable batteries for distributed and back-up power. The ideal batteries for a laptop computer, cell phone, or electric car would be light in weight, low in cost, high in voltage, and w ould lose none of

its power over repeated charging and discharging.Solid state batteries have advantages compared to liquid-electrolyte batteries such as lead-acid batteries or cadmium-nickel cells. These advantages include: ease of utilization, resistance to shocks and vibrations, absence of possible pollution due to liquid electrolyte, thermal stability, absence of self-discharge and possible miniaturization. Li systems are the fastest growing battery technology and have overtaken Ni-Cd and Ni-metal-hydride in terms of market share and potential. In addition, Li batteries can be fabricated completely in the solid state by successive deposition of contacts, electrodes and an oxide electrolyte. This makes them ideal for integration with microelectronics.

In this project a microbattery will consist of the following main components: Pt current collectors on a substrate, $LiCoO_2$ cathode, LiPON electrolyte, Li anode, and protective coating. This project will use pulsed laser deposition (PLD) to develop materials that can lead to batteries with high power capacity and energy density. PLD is a new evaporative thin film deposition technique. Compared to conventional evaporative technologies PLD can preserve the stoichiometries of the target sources, therefore can grow films of constant stoichiometries. During deposition the following process parameters will be under control: laser energy/fluence, laser pulse duration, laser pulse frequency, target composition, background gasses, substrate temperature, target-substrate distance and orientation. The effects of the variations of these parameters will be observed on the parameters of the film: film stoichiometry, film thickness, film structure (grain size, texture), film stress, film phases.

Dislocations and Their Effects on the EL/PL Emmissions of lll-Nitrides

Student : Wang Yadong
Thesis Advisor (Singapore) : Prof Chua Soo Jin
Thesis Advisors (MIT) : Prof Clifton G. Fonstad

Project Abstract:

GaN grown on sapphire inherently incorporates a high density of threading dislocations propagating along the c-axis. Lattice mismatch of GaN on sapphire is 13.8% and the defect density created is on the order of 10^8 cm^{-2}. Although the defect density is high, strong electroluminescence and photoluminescence are obtained. However, these dislocation densities are reduced by several orders of magnitude in epitaxial laterally overgrown (ELO) layers without a corresponding increase in the luminescence. It is postulated that the extended defects affect carrier flow through the generation of depleted zones. If this same phenomenon applies to surfaces, it would mean that even small dimension LEDs could be made to work. Microcavity effects can lead to enhancement of emission. In this project, A new approach with anodic aluminium oxide template is used to fabricate the nano-size GaN and related devices. Electroluminescence and photoluminescence will be studied on the dimensional dependence of the cavity in both high and low density dislocated GaN epilayers.

Structure Evolution of Growth of lll-Nitrides on Silicon

Student : Zang Keyan
Thesis Advisor (Singapore) : Prof Chua Soo Jin
Thesis Advisor (MIT) : Prof Carl V. Thompson

Ph.D. Project Abstracts
AMM&NS Programme

Project Abstract:

Growth of GaN onto silicon substrate offers very attractive potential to incorporate future GaN devices onto silicon-based very large-scale integrated circuits. However, due to the large difference in lattice constant, crystal structure, and thermal expansion coefficient, it is rather difficult to epitaxially grow GaN on Si substrate. The goal of this project is to grow good crystal quality GaN on silicon.The quality of GaN grown on highly mismatched substrates depends strongly on the nature of the crystallites and the dislocations formed by low-angle grain boundaries in the buffer layer. Larger crystallites are found to yield stronger band edge emissions. The growth temperatures, nature of surfactant and V/III ratios largely control the growth conditions but an additional factor that needs to be investigated is the crystal orientation. The formation of terrace and ledges on silicon substrate will be studied and the nucleation pattern of different vicinal planes for GaN layers will be studied using TEM, AFM or STM observation. The optoelectronic properties will be characterized by micro-Roman, PL and X-ray diffraction. Correlate results of stress and dislocation density with the nucleation patterns. Finally, the fabrication of LED will be attempted.

Ph.D. Project Abstracts (2001/2002)
HPCES Programme

A Level Set Method for Biological Flows

Student : Le Duc Vinh
Thesis Advisors (Singapore) : Assoc Prof Khoo Boo Cheong, Prof Nhan Phan Thien
Thesis Advisor (MIT) : Prof Jaime Peraire

Project Abstract:

We propose a numerical method to simulate the deformation of living tissue cells in microfluidic systems described for purifying cells, sorting of cells from the whole fluid. The level set approach for computing solutions to incompressible/compressible multi-phase will be used. We use the level set function to keep track of the cell surface. The zero level marks the location of the surface, while the negative values correspond to the cells' fluid and the positive value correspond to the surrounding fluids such as blood, pathologic fluids. Each fluid satisfies an appropriate mathematical model constructed based on the its properties (elastic modulus, damping ratio, density, Possion's ratio, …). The level set method will allow us to include large density and viscosity ratios as well as surface tension. We also consider applying the Ghost Fluid Method (GFM) to create accurate discretization across the cell surface. The method can be widened to simulate the motion of particles in solid-liquid flows.