# S.M. Project Abstracts (2003/2004)

## *AMM&NS programme*

**Complex Low-Pass Integrated Active Filter for Direct-Conversion Transceiver for WCDMA**

Student : Abhishek Kumar Khare
SMA Supervisor : Dr Wu Ping
Company Supervisor : Ms Khoo Ee Sze (Institute of Microelectronics)

Project Abstract :
Direct-Conversion is an alternative wireless transceiver architecture to the well-established super heterodyne, particularly for highly integrated, low power terminals. Direct-Conversion transceivers suffer from the imbalance of the I and Q paths. By using a complex low-pass filter topology instead of a conventional pair of real low-pass filters, this imperfection can be reduced. In this thesis, design of a 3.3V, fifth order complex Chebyshev $g_m$-C low-pass filter for WCDMA transceiver is presented. The filter has a 3-dB cutoff frequency of 2.5 MHz and has been designed in 0.35µm CMOS technology. The designed filter has high input and output linearity, and good noise performance. On–chip automatic frequency tuning circuit has been designed to keep the filter frequency response immune to supply voltage, process and temperature variations. The designed frequency tuning circuit has a tuning error of less than 2%.

**CMOS Transistor Channel Straining by SiGe Heterostructures**

Student : Ang Kah Wee
SMA Supervisor : Assoc Prof Chim Wai Kin
Company Supervisor : Dr Jagar Singh (Institute of Microelectronics)

Project Abstract :
Metal oxide semiconductor field effect transistor (MOSFET) is currently the device of choice for the state-of-the-art digital electronics. Advanced silicon (Si) processing technology has allowed MOSFETs to be scaled to deep sub-micron dimensions, realising incredible gains in performance and integration. However aggressive scaling is reaching its physical constraints that will hinder the continued device performance enhancement. Thus, it is imperative to introduce new materials or device structures to boost the transistor's performance at a preferably low additional costs incurred.

Enhancing the carrier mobility in the channel of a Si MOSFET has the potential to extend the performance limits of existing MOS technology. Theoretical calculations indicate that strain in the Si channel causes crystal symmetry distortion and lead to band structure modification. The strain-induced splitting of degeneracies at the conduction and valence bands minima contributes to suppression of interband phonon scattering and reduction in effective transport mass that produces an overall carrier mobility enhancement. In this study, we report the significant drive current enhancement achieved by the first of its kind p-MOSFET featuring a lateral $Si_{1-x}Ge_x$ stressor in the source-drain region. An astounding improvement of >50% in linear drive current is attainable with transistor gate length $L_g = 50nm$ and potentially to reach 100% enhancement for a 40% Ge content. The observed drive current improvement is attributed to the enhanced carrier mobility due to suppressed interband phonon scattering and reduced effective transport mass as a consequence of hole quantization effects.

Using the existing 0.18µm CMOS process baseline, an n-MOSFET with variation in transistor gate length is fabricated on pseudomorphic strained Si/relaxed $Si_{1-x}Ge_x$ substrate and characterised. More than 94% enhancement in saturation drive current is observed in short channel devices with 15% Ge content. However a degraded subthreshold characteristic is observed when Ge content is increased. With no optimization of HALO and threshold-adjust implants, the drain-induced barrier lowering effect (DIBL) of short channel strained Si device is significantly degraded and resulted in high leakage current. Local lattice strain analysis using Cumulative Sum of Deviation (CUSUM) method reveals that compressive strain in [001] direction is gradually built up towards the $Si/SiO_2$ interface which is a possible explanation for enhanced electron mobility under strong inversion bias.

**Smart Materials as Integrated Actuators for Micro Electromechanical**

Student : Christian Kusuma
SMA Supervisor : Assoc Prof Du Hejun
Company Supervisor : Dr Yao Kui (Institute of Materials Research and Engineering)

Project Abstract :
This project seeks to evaluate ferroelectric thin film materials in term of their photovoltaic properties. The ferroelectric thin films with strong photovoltaic effects are deposited on silicon substrate; hence it opens a new window for integration towards opto-electronic application.

The effects of film thickness and light intensity on the ferroelectric film were investigated in this project by characterizing the photovoltaic properties, including photocurrent and photovoltage under UV light illumination. The dynamic responses of photocurrent and photovoltage of the ferroelectric film were also studied to understand how fast these materials could respond to illumination. Our experiments showed that both the photovoltage and photocurrent strongly depended on the film thickness, wavelength and intensity of the UV light. The photocurrent was found to increase with the decrease in film thickness. A model was proposed to describe the thickness dependence of the photocurrent.

**Development of Drop-Test Simulation and Reliability Characterization for IC Packages**

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| Student | : | Edi Anto |
| SMA Supervisor | : | Assoc Prof Wong Chee Cheong |
| Company Supervisor | : | Dr Zhou Wei (Micron Semiconductor Asia Pte Ltd) |

Project Abstract :

Drop impact induced failure, one of the most dominant failure modes for portable electronic products, can cause housing damage, components failure and interconnects cracking. It is common that failure modes exist with the damage of the inside small components or tiny structures within the product. The solder joint interconnects have been identified as one of the weakest points within IC packages in these products. Due to small in dimension of these solder joints, it makes it difficult, costly, and time-consuming to conduct drop impact test to investigate the failure mechanism and identify their drop impact behaviors. A board-level drop impact test simulation methodology has been established to assess the solder joints reliability on 2$^{nd}$ level packaging. Implementation of the methodology in BGA package with different pad designs and unconventional polymer core-enhanced solder ball had been carried out. It was found that the SMD design tends to result in higher stress concentration at the solder joints. NSMD design could demonstrate higher reliability compared to SMD design; seemingly because of the advantages of the three-dimensional form encapsulating the pad with the solder. Polymer core-enhanced solder ball had also been shown to have no effect on reducing drop impact induced stresses. Extended studies on the effects of drop height, PCB thickness, package thickness, and solder diameter had also been carried out. The stresses induced at the solder joints increases with drop height, PCB thickness, package thickness, and solder size.

**Preparation Techniques and Characterization of Molecular Devices**

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| Student | : | Gao Hai |
| SMA Supervisor | : | Assoc Prof Chim Wai Kin |
| Company Supervisor | : | Dr Sean O'Shea (Institute of Materials Research and Engineering) |

Project Abstract :

"Mono-molecular" electronics, in which a single molecule will integrate the elementary functions and interconnections required for computation, is a very promising research area in the semiconductor industry. However, the economic fabrication of one molecular device and complete circuits at the molecular level remains challenging. In this paper, preparation techniques for some key steps of a molecular electronics test device are discussed, especially the preparation of Au (111) surface, self assemble monolayers, template-stripped gold surfaces and control of gold particle attachment. Atomic Force Microscopy (AFM) was used to characterize surface structure. The template-stripped gold surfaces prepared by a stripping procedure seem to have some advantages over Au (111) surfaces.

**Microfluidic Assembly of Carbon Nanotubes into Functional Networks**

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| Student | : | Le Cao Hoai Nam |
| SMA Supervisor | : | Assoc Prof Lu Li |
| Company Supervisor | : | Dr Isabel Rodriguez (Institute of Materials Research and Engineering) |

Project Abstract :

Microfluidic devices are finding increasing applications as biomedical devices, tools for chemistry and biochemistry, assembly tools for nanoparticles, and systems for fundamental research. In this project, microchannel devices in poly(dimethylsiloxane) (PDMS) elastomer were built using rapid prototyping and replica molding techniques with SU-8™ negative photoresist. Inlet and outlet connections to these microchannels were made through capillary tubes. These microchannels will then be connected to pressure-driven shear flows of pretreated carbon nanotubes (CNTs) suspension by micropump with the attempt to align CNTs along the flow direction. Before these processes, the CNTs were pretreated. The pretreatment included filtration to remove impurities and reduce the length of the CNTs; functionalization of the CNTs with the fluorophore $DiOC_{16}$ to enhance the visualization. Flow of CNTs suspension inside the microchannels was studied showing that microfluidic assembly of CNTs is feasible. Degree of alignment of CNTs was also analyzed. The aligned patterns of CNTs on Si substrates can then be used as building blocks for electronic and photonic devices.

**Evaluation of HR/AR Mirror Coatings for Visible (Red) Lasers**

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| Student | : | Lei Ming |
| SMA Supervisor | : | Prof Chua Soo Jin |
| Company Supervisor | : | Mr Sia Eng Kee (Eudyna Devices Asia Pte. Ltd) |

Project Abstract :

High reflectivity (HR) and Antireflection (AR) mirror coatings play pivotal roles in improving the performance of semiconductor laser diodes. In this work, Transmission Matrix Method was realized by MATLAB programming and successfully applied to the simulation of HR/AR coatings for GaAs-based red lasers and GaN-based blue lasers. It is found by that three pairs of quarterwave (HL) stack and one quarterwave layer of AlN are able to provide reflectivity of 93.9 % and 1.4 %, 91.0 % and 8.0 % for GaAs and GaN lasers respectively. The stopband width for GaAs and GaN lasers with current HR/AR settings are 64 nm and 109 nm respectively. By

increasing the ratio of $n_H/n_L$, higher HR reflectivity and wider stopband width can be achieved also increases. It is also found that, although one single AlN layer is able to provide an AR reflectivity ≤ 10%, the margin left is not much. Therefore an AR design with an ultra-thin Si layer followed by quarterwave $Al_2O_3$ layer is proposed for lower AR reflectivity and higher COD proof.

**Bandgap Engineering of QD Structures by Laser Annealing**

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| Student | : | Li Shaozhou |
| SMA Supervisor | : | Assoc Prof Pey Kin Leong |
| Company Supervisor | : | Mr Chia Ching Kean (Institute of Materials Research and Engineering) |

Project Abstract :
The ability to control local optical and electrical characteristics of quantum dots system is fundamental important for photonic integrated circuits (PICs). In investigations to this aim, Quantum Dot intermixing (QDI) is one of the promising ways to solve this problem. The advantages of offering direct writing capability and potential high spatial resolution attract more and more researchers.

In this thesis, the significant modification of the band gap energy of the InAs/InP quantum dot (QD) structure using rapid thermal processor (RTP) and laser annealing techniques has been reported. The relation between PL intensity and the shift of wavelength is built when defect density is low enough. An analytical model for qualitative understanding the relation between wavelength change and intensity was developed.

**Vddmin Margin Improvement on 0.15 Micron CMOS Logic Device**

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| Student | : | Lin Geng |
| SMA Supervisor | : | Assoc Prof Pey Kin Leong |
| Company Supervisor | : | Dr Chan Yee Ming (Systems on Silicon Manufacturing Co. Pte. Ltd.) |

Project Abstract :
As CMOS IC device dimension became smaller, it was found that Vddmin margin of the device degraded, which caused significant yield loss. This project is to seek effective methods to improve Vddmin margin. The effect of Shallow Trench Isolation (STI) structure on Vddmin margin was investigated and studied in depth. Process-tuning experiments showed that shallower trench depth, leading to higher step height, could significantly improve Vddmin margin. Electrical characterizations were also done to find out the root cause of low Vdd failures. It was found that subthreshold S/D leakage could be possible failure mechanism.

**Materials and Processes for the Fabrication of Organic Thin Film Transistors**

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| Student | : | Liu Liang |
| SMA Supervisor | : | Assoc Prof Li Yi |
| Company Supervisor | : | Dr Mark Dai Joong Auch (Institute of Materials Research and Engineering) |

Project Abstract : Confidential

**Investigation of Magnetic Materials for Data Storage**

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| Student | : | Nripan Mathews |
| SMA Supervisor | : | Assoc Prof Choi Wee Kiong |
| Company Supervisor | : | Dr S.N. Piramanayagam (Data Storage Institute) |

Project Abstract :
Perpendicular recording media is looked upon as the alternative to longitudinal magnetic recording technology which is prevalent today. Perpendicular recording has various advantages like higher data stability as well allows the postponement of the superparamagnetic limit of recording. Co based alloys are one of the most common alloys that are used in magnetic recording nowadays and is being actively researched as a material for perpendicular recording as well. Chromium and Platinum are normally alloyed with Cobalt to improve its properties.

This project investigated the effect of adding zirconium to Co70Cr8Pt22. The samples for this project were prepared by co-sputtering zirconium with the alloy. Two types of structures were investigated. One of the structures involved the use of a titanium underlayer below the cobalt alloy while the second structure used titanium as well as a ruthenium underlayer. The magnetic properties as well as the crystallinity of the films were investigated using X-ray diffraction, Vibrating Sample Magnetometer and Alternating Gradient Magnetometer. It was found that the addition of zirconium to the cobalt alloy resulted in the production of a soft magnetic material as well as resulted in poor c-axis alignment.

**Development and Characterization of Si Pillars/Trench Etch for Si Based Photonic Crystal Application**

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| Student | : | Ong Kng Yih |
| SMA Supervisor | : | Prof Chua Soo Jin |
| Company Supervisor | : | Dr Feng Hanhua (Institute of Microelectronics) |

Project Abstract :
Photonic crystal (PC) will greatly increase the operating speed of integrated circuit and enhance performance of modern IC. However, the propagation loss of silicon waveguide is mainly due to the non-uniformities arising from the film deposition and etching process.

In this work, sidewall profile and roughness of silicon waveguides (made up of via/trench) fabricated by Reactive Ion Etching (RIE) process using the P5000 etcher of the Applied Materials was investigated.

The critical roles of the $SF_6$ and $HeO_2$ gas flow rate (the chemical etching component), as well as the RF power and total chamber gas pressure in determining geometric parameters of the PC via/trench such as the depth, sidewall profile are examined. The etching parameters such as the etch rate and selectivity was also looked into. It is shown that good quality PCs can be etched only when the chemical and physical components in the etch process are balanced.

An optimal recipe was created at the end of the project and a vertical and smooth sidewall was fabricated.

**Hall and AFM Measurements on OMVPE Grown Thin Films for VCSEL Application**

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| Student | : | Rohit Narula |
| SMA Supervisor | : | Prof Chua Soo Jin |
| Company Supervisor | : | Mr Chu Chen (Agilent Technologies Singapore Pte Ltd) |

Project Abstract : Confidential

**Tunnel Diode and Resonant Tunneling Diode Characterization and Modeling**

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| Student | : | Ta Minh Chien |
| SMA Supervisor | : | Dr Wu Ping |
| Company Supervisor | : | Dr Lin Fujiang (Institute of Microelectronics) |

Project Abstract :
Besides negative differential resistance (NDR) feature, the most valuable property of resonant tunneling diode (RTD) is its high-speed operation. The RTD has become a promising applicant for use in high-speed circuits since it has been shown to operate at frequencies up to 2.5THz [1]. In addition to that, the use of RTDs in electronic circuits can help reduce the complexity of the system [2]. These virtues make resonant tunnel diode a good choice for the building block in complex and high-speed communication systems, such as Ultra-Wide Band (UWB) radio IC.

For circuit design purposes, an accurate model is needed to carry out circuit simulation and performance optimization. Throughout this project, a model for the tunnel diode and another model for the one-peak resonant tunneling diode were derived and implemented in circuit simulation tools. The new models, which were developed from a carefully mathematical analysis of measured data, exhibit a great flexibility that allows circuit designers to adjust the model's parameters to obtain the characteristics that accurately describes the behaviors of the devices.

**Integrated Silicon Micro Pipette for Patch Clamp Applications**

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| Student | : | Wong Yeow Sheong |
| SMA Supervisor | : | Assoc Prof Lu Li |
| Company Supervisors | : | Dr Levent Yobas & Dr Rajnish Sharma Kumar (Institute of Microelectronics) |

Project Abstract : Confidential

**Characterization and Reliability Performance of the Immersion Gold Plated Module Fingers**

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| Student | : | Xie Fang |
| SMA Supervisor | : | Assoc Prof Wong Chee Cheong |
| Company Supervisor | : | Dr Tan Ah Chin (Micron Semiconductor Asia Pte Ltd) |

Project Abstract :
Memory modules are inserted into a socket in a typical PC set up. In order to maintain the conductivity and rigidity, the edge connect fingers are made of copper plated with thin gold layer, which is chosen for its tarnish resistance and good electrical conductivity. Traditionally, about 1 micron hard gold is used together with nickel under plate. The hard gold contributes a significant cost to the module. Immersion gold layer as a surface finish is targeted as a means to improve cost effectiveness. However, there is increasing evidence indicating that immersion gold may be detrimental in applications calling for long-term reliability.

A brief introduction into the gold plating technology, PCB surface finish and contact resistance theory is given in this thesis. Subsequently a study of the reliability of immersion gold connectors is carried out using hard gold connectors as a reference. This is done by examining the effects of aging on their contact resistance. Surface analysis, insertion, hardness and thickness tests are also performed on selected samples to further characterize the gold connectors.

Preliminary findings indicate that there are not much significant differences between the reliability of immersion gold connectors and electrolytic gold connectors. However there is still a possibility that its reliability performance will degrade after longer usage. Further work needs to be done before conclusive results can be established.

**Studies of Electroosmotic Flow for Microfluidic Applications**

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| Student | : | Yu Liangchun |
| SMA Supervisor | : | Assoc Prof Li Yi |
| Company Supervisor | : | Dr Isabel Rodriguez (Institute of Materials Research and Engineering) |

Project Abstract :
The concept of miniaturized total analytical systems (μTAS) was proposed to achieve automatic chemical analysis with small volume. Crucial to μTAS is the control of liquid flow through the network. Electroosmotic flow (EOF) is a favored pumping method in μTAS because of its absence of moving parts, accurate controlled flow rate, wide range of working fluids conductivity, less dispersion etc. However, there are several potential problems derived from accompanying electrolytic reactions when voltage is applied through integrated electrodes. In this work, we focus on the reduction or elimination of bubble generation due to electrolysis. The microfluidic devices used were fabricated using hybrid glass/polydimethyl-siloxane (PDMS) assemblies. Electrodes were patterned on glass plates using photolithographic techniques. Channels were cast in PDMS using SU-8 molds and were then bonded to the glass plates.

Several buffer electrolytes were studied and the relationship flow rate - electrical current generation was investigated. Tris[(hydroxymethyl)aminomethane hydrochloride] (TRIS) was found to produce less current , thus less bubbles as well as a high EOF flow rate. We also investigated copper electroplating as a new system to suppress bubble generation. The underlying principles were stated. Experimental results showed the feasibility of this method.

**Fabrication and Sensitivity Analysis of Quartz Sensor Chips with Modified Electrodes**

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| Student | : | Yuan Zhaoxin |
| SMA Supervisor | : | Assoc Prof Du Hejun |
| Company Supervisor | : | Dr Su Xiaodi (Institute of Materials Research and Engineering) |

Project Abstract :
The quartz crystal microbalance (QCM) is an ultra-sensitive mass-detecting device, consists of an AT-cut quartz disk sandwiched between two metal electrodes. The application of a driving voltage through the electrodes initiates a shear mode vibration of the quartz disk at a resonant frequency determined by the thickness of the quartz disk and mass loading on the surface. Under certain conditions, the shift in the frequency is linearly related to the mass loading.

In this work, QCM sensor disks with modified electrode geometries are successfully designed and fabricated. Unlike the conventional QCM disks, which utilize identical circular, concentric electrodes (‘plate-plate’ type), the fabricated QCMs have either a plate electrode on one side, a ring electrode on the other side (‘ring-plate’ type) or both sides ring electrode (‘ring-ring’ type). The differential sensitivity distribution of the two types of QCM is analyzed by a numerical analysis program. For both the ‘ring-plate’ and ’ring-ring’ type QCM, the mass sensitivity is concentrated on the fully electroded regions. With the increase of the internal diameter of ring electrode, the sensitivity profile becomes sharper in the fully electroded regions, and the values of the peak sensitivity become higher.

By measuring the frequency changes caused by polymer coatings and protein adsorption, we prove that the modified QCMs can be used properly as mass-detecting sensors in both solid phase and liquid phase measurements, with retained overall mass sensitivity and sufficient stability.

Ultimately, this study is motivated by the possibilities of establish dual-probed sensing systems, involving QCM measurements and optical measurements, as the ring electrodes allow a light transmission from one side to the other side of the quartz disks.