Research Fellows and Research Projects (2003/2004)

IMST programme

Dr Chen Xing
Expertise: Computer aided design and engineering in plastic injection molding, numerical simulation in powder injection molding, and flow analysis in microfluidic device

Simulation of Particle Migration of Powder-Resin in Injection Molding

Project Advisor (Singapore) : Prof Lam Yee Cheong
Duration : July 2000 to July 2003

Project Abstract :
Powder injection molding is an important processing method for producing precision metallic or ceramic parts. Experience, intuition and trial-and-error have been the practice for the design and process optimization of such molding operations. However, this practice is becoming increasingly inefficient and impractical for the molding of larger, more complicated and more costly parts. In this investigation, a numerical method for simulating the mould-filling phase of powder injection molding was developed. The flow was modeled using the Hele-Shaw approach coupled with particle diffusion transport equation for the calculation of powder concentration distribution. The variation of powder density distribution can be predicted, which is ignored by the existing simulation packages. Simulation results indicated that powder concentration variation could be significant in practical PIM. Using a capillary rheometer with a specially design split die, experimental validations were obtained.

Analytical Modeling for Dispersion of Passive Analyte in Microfluidic Device

Project Advisor (Singapore) : Prof Lam Yee Cheong
Duration : July 2003 to October 2004

Project Abstract :
The research focuses on the understanding and the development of theoretical and numerical model to describe dispersion of passive solute in microfluidic device for Newtonian fluid under pressure driven flow. The results will have a direct application to analytical and bioanalytical chemistry. Analytical modeling will be employed to consider the axial dispersion of a solute along the flow direction, to simulate convection and diffusion transport in a pressure driven creeping flow for a rectangular shape slit. This represents the first effort in applying the lubrication approximation and averaging methods to the analysis of analyte concentration in microfluidic slit device, taking consideration of Taylor's dispersion. It now opens the door for optimization for such devices. Future plan is to extend the model for non-Newtonian flow, electrokinetic driven flow, and combination of pressure driven and electrokinetic driven flow.

Dr Deng Yimin
Expertise: Functional design theory and methodology, geometric modeling and CAD/CAE/CAM, injection molding design and optimization

Integrated Materials and Engineering Systems Design

Project Advisor (Singapore) : Dr Lu Wen Feng
Duration : February 2003 to February 2005

Project Abstract :
With the rapid development of high-tech in various engineering fields, there appears to be more critical requirements for specific and multi-functional materials. Traditionally, materials design follows a deductive cause-and-effect approach, which requires much experiment and trial-and-error effort. This project attempts to integrate materials design with engineering systems design by adopting an inductive goal means approach in materials design and development. The project aims at developing a comprehensive design framework, whereby materials design and engineering systems design can be conducted in a co-evolutionary manner. Specifically, it seeks to develop the strategies and methodologies for materials and engineering systems design integration and optimization, and topological design of cellular materials.

Dr Fu Yongqi
Expertise: Micro-optics, photonics, MOEMS, optical design, microfabrication and nanofabrication

One Step Transfer of Diffractive Structure from Designed Pattern to Replica with Hybrid Sol-Gel Film

Project Advisor (Singapore) : Assoc Prof Ngoi Kok Ann, Bryan
Duration : January 2002 to June 2003

Project Abstract :
A novel one-step method of microfabrication of diffractive lens mold with continuous relief and six annulus, combining sol-gel process for corresponding replication is investigated. The mold is fabricated by use of focused ion beam milling (FIBM) on substrate material of bulk Silicon, and then being used directly for replication of the diffractive structure by aid of hybrid sol-gel glass stamping process. The hybrid sol-gel material is different from conventional sol-gel material with pure SiO_2. It consists of SiO_2 and TiO_2. With this hybrid sol-gel material, shrinkage during the replication process of gel and densification can be reduced greatly compared with the normal sol-gel material. Surface roughness of the replica, *Ra*, is 3nm in the area of 1um $\times$ 1um. Measured diffraction efficiency is 86% under the influence of accumulated mold geometry error and sol-gel process error. The demonstrated process of direct stamping using the

masterpiece fabricated by FIBM is potential for mass production use at very low cost. Further study will be performed in aims of improving uniformity of relief depth and lateral width of replica.

Nanofabrication of DNA Micro-Array by use of Focused Ion Beam Technology

Project Advisor (Singapore) : Assoc Prof Ngoi Kok Ann, Bryan
Duration : January 2003 to June 2004

Project Abstract :
Nanostructures, e.g. nano-pillars, tips array, micro-cantilever arrays, and micro-channel arrays, are very useful for biomedical use, such as cell adhesion, molecule separation and purification, and molecular detection. Particularly for arrays of nanometric sized pillars, inhibit cell attachment, and this will lead to important medical applications. The nano-pillars can be fabricated by several methods till now, such as conventional photolithography pattering and reactive ion etching transferring, and laser achromatic interferometric lithography, and then replicated by means of micro-contact imprinting, embossing, etc. However, theses methods are all need two or more steps for formation of the nanostructure. Compared with them, focused ion beam direct milling (FIBM) is only one step to transfer the designed pattern into substrate. Moreover, the pillars are perpendicular with the substrate (the angle of pillar axis to substrate surface is 90¡ã). The angle is determined by the crystal orientation of the substrate material during the process of dry or wet etching, and cannot be changed randomly according to practical requirements. If the angle can be changed randomly, design freedom of the nanostructure will be enlarged. It will be more helpful to cellular engineering. The FIBM is isotropic process, and limitation free of the crystal orientation. Different angles of the pillars can be obtained by use of the FIBM. Fabrication process of the FIBM investigated in detail in this project.

One-step Nanofabrication of Diffractive Structure via Focused Ion Beam Scanning

Project Advisor (Singapore) : Assoc Prof Ngoi Kok Ann, Bryan
Duration : September 2003 to December 2004

Project Abstract :
A new fabrication method for diffractive structures, we call it quasi-direct writing, was illustrated in this letter. The diffractive structures can be generated by changing pixel space of cross scan direction (overlap is zero) and keeping the other space along scan direction constant with normal overlap of 50-60% during scanning substrate surface by use of focused ion beam (FIB). It is a method of computer program free. The diffractive structures with different period and depth can be derived by controlling the parameters of pixel spaces, beam current, ion incident angle, and scan time/ion dose. It has no material selectivity, and can be used for materials of metal, insulator, and semiconductor.

Dr Kotireddy Rama Bhupal Reddy
Expertise: Modeling and evaluation of manufacturing systems

Analysis and Scheduling of Flexible Manufacturing Systems

Project Advisor (Singapore) : Asst Prof Velusamy Subramaniam
Duration : September 2002 to September 2004

Project Abstract :
The present evolution of enterprises is characterized by (i) competition based on increasing variety that requires shorter lead-times, (ii) better conformance to delivery schedules, (iii) competitive costs, and (iv) an ever increasing thrust on quality. Enterprises are required to respond to these challenges through appropriate manufacturing system configurations with relevant planning and control mechanisms. Accordingly, different manufacturing system configurations have emerged; flow lines (for high-volume/low-variety), batch production (for medium-volume/medium-variety), and job shops (for low-volume/high-variety). To overcome the problems faced by traditional process focused configuration (e.g. batch manufacturing and/or job shops) two distinct configurations have emerged, viz. Flexible Manufacturing Systems (FMSs) and Cellular Manufacturing Systems (CMSs). The changeover from one manufacturing system configuration to another or to a more automated system is a strategic decision that affects many other activities of the enterprise, as it requires a huge capital investment. It is expedient to develop a better understanding of the various factors and their impacts on the performance of the manufacturing enterprise, which may be synthesized into tools that would lead to the analysis and scheduling of FMSs.

Dr Loke Wan Khai
Expertise: Growth of compound semiconductor (III-V and III-N-As) using solid source molecular beam epitaxy (MBE). Optical, electrical and structural characterization of semiconductor materials which involves measurements using techniques such as low-temperature photoluminescence, x-ray diffraction, atomic force microscopy, scanning electron microscopy and Hall effects

Nitride-Arsenide Compound Semiconductor (GaInNAs and GaNAs)

Project Advisor (Singapore) : Prof Yoon Soon Fatt
Duration : January 2004 to August 2004

Project Abstract :
Radio-frequency (rf) plasma assisted molecular beam epitaxial growth of GaNAs and GaInNAs has been investigated in previous work, with suitable growth parameters being developed. In particular, the post-growth rapid thermal annealing (RTA) effect on the GaNAs films grown on GaAs (100)-oriented substrate was investigated.

The GaNAs films exhibit an overall blueshift in energy and an intermediate redshift of in the low-temperature (4K) photoluminescence (PL) spectra when subjected to different annealing temperature. This result suggests a possible mechanism where the GaNAs layer may have undergone an intermediate substitutional-interstitial diffusion. Samples annealed at 700-750^{o}C showed 1.7-2.1 times improvement in integrated PL intensity and 1.6-1.8 times reduction in PL full width half maximum (FWHM) as compared to the as-grown sample. The change in diffused scattering intensity and crystal truncation rod in x-ray reciprocal space mapping (RSM) of the GaNAs samples subjected to different annealing temperature was also investigated. The effect of nitrogen and indium incorporation on the structural and optical properties of GaInNAs with low lattice mismatch to GaAs grown by the rf nitrogen plasma assisted method has also been investigated. The results show that excessive introduction of nitrogen during the growth of GaInNAs may lead to greater incorporation of interstitial nitrogen and degradation in crystal quality. This effect is more significant in GaInNAs compared to GaNAs. By changing the In composition and fixing the N incorporation rate, a sample of $Ga_{0.924}In_{0.076}N_{0.026}As_{0.974}$/GaAs with relatively low lattice mismatch of -896ppm (or ~$8.96x10^{-4}$) was successfully grown. Low-temperature (4K) PL emission at 1518nm (long wavelength) for this sample was observed.

Optoelectronic Integration/Optical Interconnects

Project Advisor (Singapore) : Prof Yoon Soon Fatt
Project Advisor (MIT) : Prof Clifton G. Fonstad Jr.
Duration : January 2004 to August 2004

Project Abstract :
An optoelectronic integration project in collaboration with MIT is to develop and apply RM^3 (recess mounting with monolithic metallization) technologies, a technique pioneered by Professor Clifton G. Fonstad Jr. and his research team, for heterogeneous integration. One important part of this project undertaken by NTU is to epitaxially grow the InP-based heterostructures. This is followed by integration process using APB (aligned pillar bonding) or MASA (magnetically assisted statistical assembly) technologies in MIT. Such technologies will be of great use in producing optoelectronic integrated circuits (OEICs) for optical clock distribution, diffuse optical tomography, and smart pixel arrays. Other potential new applications of these technologies in intra- and interchip optical signal interconnects, in fluorescent dye detection and imaging for biomedical applications, and in III-V mini-IC integration on Si-CMOS for enhancing off-chip drive capabilities are outlined.

Dr Mu Li
Expertise: Drug delivery device, controlled release, fabrication and characterization of nanoparticles

Biodegradable Polymeric Micro- and Nano-Particles for Drug Delivery System

Project Advisors (Singapore) : Prof Yue Chee Yoon & Assoc Prof Chan Bee Eng, Mary
Duration : September 2003 to March 2004

Project Abstract :
Considerable effort has been devoted to develop nanotechnology for drug delivery since it offers a suitable means of delivering small molecular drugs, as well as macromolecules such as proteins, peptides or genes by either localized or targeted delivery to the tissue of interest. The nanotechnology focuses on formulating therapeutic agents in biocompatible nanocomposites such as nanoparticles, nanocapsules, and conjugates, while in recent years the micellar systems and gel systems (e.g. nanogels) have also been included under the term ‘‘nanoparticles’’. In such devices, the nanoparticles are formulated from biodegradable polymer or other biomaterial in which the active agent is dissolved, entrapped, encapsulated, adsorbed, attached or chemically coupled in the matrices depending upon the fabrication method. It has been a major goal to achieve desired therapeutic level while minimize side effects, the controlled release of pharmacologically active agents to the specific site of action at the optimal rate and dose regimen in designing the drug delivery devices. Therefore, there is a need to understand well the pharmaceutical characteristics of the NPs which could be determined and influenced by many factors in the manufacturing process. The project has related to a few key problems in nanoparticles manufacture and characterization, including 1) to choose appropriate biocompatible and biodegradable materials that must be adhesive to the cell membrane and protective to the drug activity; 2) to control the size of nanoparticles; 3) to achieve high drug encapsulation efficiency; and 4) to achieve the desired drug release kinetics.

Dr Narayananswamy R. Sivakumar
Expertise: Interferometric nanometrology (surface profile measurement, instantaneous phase shifting, laser doppler vibrometry, laser shearography); laser micromachining

On-Line Nano-Profile Measurement of Large and Flat Surfaces utilizing the Concept of Instantaneous Phase Shifting in combination with Michelson Interferometry

Project Advisor (Singapore) : Assoc Prof Ngoi Kok Ann, Bryan
Duration : August 2003 to March 2005

Project Abstract :
The rapid development in electronic and manufacturing industry has driven the development in the field of nanometrology. Over the past decades, phase shifting interferometry has been used with

great success in surface profiling of smooth surfaces. Many works have been done on this to improve the accuracy and repeatability of the measurement. However, comprehensive literature review suggested that these systems are often restricted to point measurement and are unable to perform online measurement. In the proposed research, an optical layout that uses the concept of array of points with a modified Michelson interferometer is being developed to measure relatively large surface area without scanning. In combination with instantaneous phase shifting arrangement, the system will be therefore immune to vibration and environmental effects during data acquisition. The system will be calibrated with results obtained from commercial surface profilers. In order to ascertain the suitability of the system to on-line measurement (read vibrating environments), the optical layout will be subjected to vibrations of varied frequencies. The capability of the system to measure accurately at high vibration frequencies should prove the concept of on-line surface profiling. This research work has proved that the developed system has the advantage on reducing the measurement time for large surface profile inspection where the time consuming scanning can be eliminated. In addition, online measurement is made possible by incorporating instantaneous phase shifting arrangement in the setup.

Dr Tang Yaxin
Expertise: Advanced manufacturing technology, rapid prototyping (RP) technology, laser materials process, 3D micro-fabrication

Rapid Prototyping and its Application in 3D Micro-Fabrication

Project Advisor (Singapore)	:	Assoc Prof Loh Han Tong
Duration	:	September 2002 to September 2004

Project Abstract :
The project will look into the improvements of a formerly developed rapid prototyping process-high temperature laser sintering (HTLS) system, especially in the optimization of materials and process parameters. Cooperating with a local company, a novel HTLS machine will be built to realize the process involving three kinds of material: metal, sand and plastic. Another related research will focus on the application of rapid prototyping in 3D micro-fabrication. A novel process based on UV laser micro-sterolithography, high-aspect electroforming and micro-molding has been proposed for exploration. A special device consisting of an excimer laser, a programmable pattern generator, and a reaction chamber will be constructed to realize the process. Research works include in-depth investigation into the interaction between the UV laser and the material, the accuracy control of the process, the measurement and evaluation of the process and its application in MEMS and nano-technology.

Dr Viswanath Kumar Ganesan
Expertise: Production planning and scheduling

Job Release Control and Synchronized Scheduling in Production Systems

Project Advisor (Singapore)	:	Assoc Prof Appa Iyer Sivakumar
Duration	:	September 2003 to March 2005

Project Abstract :
Scheduling of jobs in production environment for synchronized completions is more relevant with the advent of Just-In-Time manufacturing. Both early and late completions of jobs are not desirable in many delivery situations like dispatching of jobs either independently or together for a customized delivery or assembly, and particularly when the finished jobs incur costs for preserving/holding them (or penalties for late deliveries) till other matching jobs complete. Synchronization of job release and scheduling of the resources, with delivery requirements of jobs has many benefits in addition to providing economic advantage in the form of cost savings. Our research addresses the problems on synchronization of scheduling and deliveries of jobs in a dynamic production environment.

Dr Wang Shanzhong
Expertise: MBE and CVD growth of semiconductor materials and its microstructures; characterization of semiconductor materials with different kinds of tools such as microscope, SEM, XRD, TEM, SEM, AFM, Raman, PL PLE, PR, MPR, transmittance, I-V, C-V, Hall and so on; and standard semiconductor processing for electronic and optical devices

Development of Compound Semiconductor Device Fabrication and Epitaxial Growth Technology

Project Advisor (Singapore)	:	Prof Yoon Soon Fatt
Project Advisor (MIT)	:	Prof Clifton G. Fonstad Jr.
Duration	:	March 2001 to March 2003

Project Abstract :
The proposed project focuses on the development of novel compound semiconductor growth technology using the molecular beam epitaxy technique. Particular emphasis will be placed on investigations, which involve the introduction of gas sources such as hydrogen and nitrogen into a solid source molecular beam epitaxy system for the development of low temperature epitaxy involving dilute nitrides. The target applications for such dilute nitride compounds are in the areas of high frequency microelectronic devices such as high electron mobility transistors and heterojunction bipolar transistors with a view for these devices to be integrated into microwave monolithic integrated circuits. The project also involves a concurrent effort to develop novel mixed nitride materials for optoelectronic devices such as lasers

and detectors with a view for optoelectronic-VLSI integration. Extensive material and device/circuit characterization will be carried out as part of this work.

Dr Xiong Mohua
Expertise: Complicated information systems analysis and modeling, web-based supply chain management, advanced production planning and demand management, decision support systems

Customer Demand Fulfillment Approaches under Limited Capacity

Project Advisors (Singapore)	:	Assoc Prof Tor Shu Beng & Assoc Prof Rohit Bhatnagar
Duration	:	October 2001 to October 2004

Project Abstract :
Customer demand fulfillment is the business process within a company that determines how the customer demand is fulfilled. It strongly influences the order lead-time and the on time delivery, and hence plays a very important role in retaining and increasing the market shares. In the project, a new methodology for customer demand fulfillment is investigated and the corresponding approach is developed based on the fulfillment constraints of the material availability and the production capacity. In this research, based on an Integrated BOM Model, an Extended Dynamic BOM Approach is developed for effectively handling multilevel BOM of the product. For assessing the approach, a prototype will be developed on the Internet technologies. This new approach and its application would be very helpful to support companies to make reliable and informed decisions when facing customer requirements, especially in today's globalization progress.

Dr Yan Yehai
Expertise: Polymeric composites, thermosetting resins chemistry, nano- and micro-fabrication

Carbon Nanotubes Alignment in Parallel

Project Advisors (Singapore)	:	Prof Yue Chee Yoon & Assoc Prof Chan Bee Eng, Mary
Duration	:	March 2004 to July 2005

Project Abstract :
With the achievement of carbon nanotubes (CNTs) synthesized in macroscopic quantities, it has become possible to explore its physical and chemical characteristics and further find applications. Due to the high aspect ratio and nano-scale tips, CNTs own the ability to emit a cold electron at relatively low voltages. Depending on the method of production, CNTs may exhibit metallic, semiconducting or insulating behavior. These interesting properties allow CNTs having great potential for applications to electron-field-emitting flat-panel displays, single-molecular transistor, and molecular computing elements. To realize the above applications of practical significance, however, it is highly crucial to synthesize or pattern aligned (both horizontally and perpendicularly) CNTs. In spite of receiving ever-increasing attention in the field of aligned and/or micropatterned CNTs, there has been limited research done thus far to create regular CNTS arrays, especially horizontally aligned CNTs, efficiently and inexpensively in a mild environment. Contact printing is an efficient method for pattern transfer and has been successfully developed in micro-patterning. The procedure is remarkably simple and convenient: once the stamp is available, multiple copies of the patterns can be produced using straightforward techniques. In this project, the conception of microcontact printing was adopted and modified to use for CNTs alignment.

Dr Yuan Miaolong
Expertise: Computer vision, computer-aided design, augmented reality

Augmented Reality and its Applications in Assembly, Inspection and Maintenance

Project Advisor (Singapore)	:	Prof Andrew Nee Yeh Ching
Duration	:	October 2002 to October 2004

Project Abstract :
Augmented reality (AR) is a novel approach that augments computer-generated information, such as computer graphics, annotation and other modalities with the real world. Unlike Virtual Reality, AR enhances the real environment rather than replacing it. AR has potential applications in many fields, such as industrial training, computer-aided surgery, information visualization, entertainment, etc. One of the most promising applications of AR is in the area of manufacturing assembly, equipment maintenance, inspection, procedural learning, etc. This is an investigative work in the manufacturing field. The purpose of this project is to explore effective methods of AR and its applications in the area of assembly, inspection, and maintenance in order to increase productivity of these activities. The main issues of AR and its applications to be explored and developed are as follows:
(1) Registration technique;
(2) Sensing technique;
(3) Information visualization in the domain of assembly, inspection and maintenance;
(4) Case studies;
Development of a prototype AR-assisted assembly, inspection and maintenance system.

Dr Zhang Wenyu
Expertise: Progressive die design, sheet metal design, functional design, CAD/CAM, conceptual design, intelligent CAD, feature-based design, knowledge-based expert systems, artificial intelligence

Progrssive Die Design Automation

Project Advisor (Singapore)	:	Assoc Prof Tor Shu Beng

Duration : March 2002 to
March 2005

Project Abstract :
Though AI technologies have achieved a lot of success in the design of progressive dies, because of complexity of the die design process, most of the “intelligent” die design automation prototypes are rather restrictive in their applications. There is still a substantial distance to cover before these works can be put into practical use. It is found from the literature that feature-based scheme has been widely used to speed up progressive die design, but the computer representation and processing of feature relations needs more attention. The main purpose of this project is to develop a more scientific and efficient feature model embedded in a blackboard based knowledge driven design environment to automate the progressive die design process.

Dr Zhao Zhiwen
Expertise: Communication, control

Complexity of Decentralized Communication Network for Mechatronics Systems
Project Advisor (Singapore) : Assoc Prof Chen I-Ming
Duration : March 2003 to
March 2005

Project Abstract :
Generically there is a core access point in distributed communication network systems. Such arrangement has several obvious disadvantages: unsatisfied reliability, scalability and dynamics because of the bottleneck introduced by the core access point. However, a decentralized network system with high-performances is difficult to design, in particular the implementation mechanisms including the protocols, modulation/demodulation etc. The research here concentrates on how to describe the complexity, design the architecture and the protocols of a decentralized communication networks in order to obtain excellent characteristics of the decentralized systems. We mainly focus on the architecture description, protocols design and its verification, encoding/decoding modes and modulation/demodulation approaches etc. Simulation and experiments of the decentralized communication network will be carried out. Potentially the research will be applied to advanced mechatronic systems, such as small foot-print servo control systems with advanced network capability and distributed miniaturized autonomous systems.