Technology & Capabilities

Overview

Spring 2006

Wealth from innovation

Herschel building University of Newcastle Newcastle upon Tyne NE1 7RU
T +44 (0)191 222 3500 F +44 (0)191 222 3528 E enquiries@inex.org.uk W www.inex.org.uk

Introduction

INEX is a research & commercialisation centre for MEMS and nanotechnology and is a part of the University of Newcastle-upon-Tyne. Operational since 2002 and in receipt of funding of €40million from the UK and European governments, INEX works with technology innovators and systems integration firms worldwide to develop new technologies and products enabled through MNT.

INEX is currently the largest public-sector MNT facility in the UK with a total of 1,250m^2 facilities incorporating MEMS fabrication cleanrooms, packaging & test facilities, analytical and bio-hybrid integration laboratories. INEX employs 40 full-time staff of whom >70% are directly from the semiconductor/optoelectronics/electronics sectors and with relevant industrial R&D and manufacturing expertise.

INEX has recently put forward its management procedures and systems for certification to the ISO:9001/2000 standard and has commissioned Lloyds Register Quality Assurance to undertake the certification process.

Our Technology and Competencies

INEX has invested capital and resources into developing an industry-class 100mm/150mm MEMS fabrication capability. Using advanced microsystems techniques such as High Aspect Ratio Processing, dry metal etch, advanced oxide etching, and flip-chip bonding of ASIC and functional materials (e.g. II-VI). INEX has sufficient breadth of capability to enable our partners to explore and exploit the full potential of microsystems technologies. Our growing portfolio and track record has grown around sensor and detection technologies including 3-axis accelerometers and gyroscopes, chemical detectors, biosensors, magnetic sensors, and more.

Uniquely, INEX has a strong complementary bio-science capability with experienced and talented biologists and bio-MEMS staff and facilities. Examples of technology being developed are: biosensors, integrated microfluidic systems, detection systems, and tissue engineering.

Our People

On the technology side INEX employs 18 full-time staff to perform technology development and application engineering in MEMS and microfluidics. The majority of technical staff have been recruited directly from industry and represent a cumulative 150 years relevant experience in the commercialisation of miniaturised components across a wide range of industry sectors.

INEX also employs commercial and managerial staff with experience and expertise in managing large contracts and projects within the defence contractor markets. Projects at INEX are run under the Prince-2® methodology with in-house practitioners.

The Opportunity

We are looking for new industry partners with whom we can develop new technologies and products based on microsystems. Furthermore, we are also interested in exploring R&D and manufacturing outsourcing opportunities.

Competencies and capabilities have been developed within INEX to address industry needs in MEMS fabrication, integration and device production. The processes outlined below are an introduction to our services, for more details on how we can facilitate your business please contact our business development team directly.

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I: Design, modelling & simulation

INEX designs various MEMS devices, from the initial concepts to 2D/3D drawings, performance modelling and simulation, design optimization, and mask layout for prototype development manufacture.

Design/Modelling	Specification
Device design using CAD tools (AutoCAD, ProEngineer)	2D or 3D design for components and system, including: layout for manufacture system assembly diagram geometry files for auto-manufacture tools, e.g. CNC, e-beam geometry files for simulation and optimization.
MEMS device performance modelling using FEA (ANSYS® Multiphysics, and CFX)	Modelling capability includes: Structural analysis Non-structural analysis, including thermal, electrostatics, magnetostatics, electromagnetics, ion optics, piezoelectric, piezoresistive and acoustics analysis Fluidics (CFD) analysis Coupled physics analysis e.g. thermal-structural; piezoelectric or piezoresistive –structural; electrostatic or magneto –structural; acoustics-structural; electromechanical circuit simulation; fluid-thermal or structural; thermal-electric or electromagnetic; fluid/electromagnetic.
Photomask design (L-Edit, AutoCAD, CleWin)	Photomask design derived from: Outline concepts of device or process Device geometry drawings Direct layout and consultation

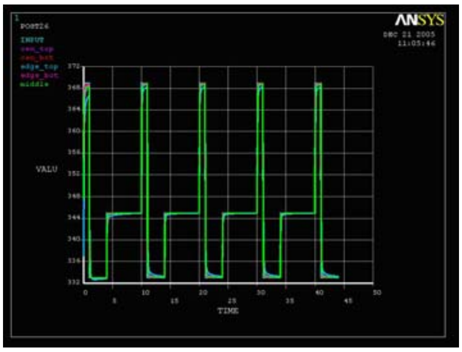

Figure 5.1 Simulation of temperature response of micro PCR (genetic analysis) device during thermal cycles

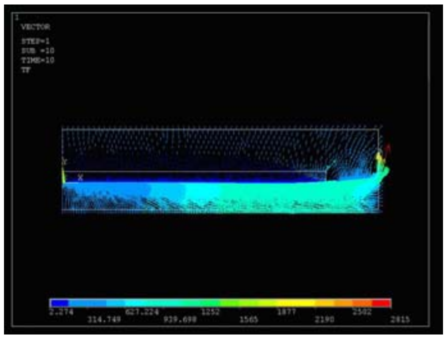

Figure 5.2 Modelling of heat-flux vector of micro PCR device during cooling sequence

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2: High aspect ratio processing of MEMS

High aspect ratio processing allows highly directional and selective etching of silicon (or ceramics, oxides, nitrides). This leads to the creation of deep structures (see Figure 2.1) that find application in a range of sensors and actuators from mass detection, inertial sensing to valve actuation, and microfluidic pumps. There is also an emerging trend for the development of solid-state biosensors and chemical sensors requiring such highly vertical structures.

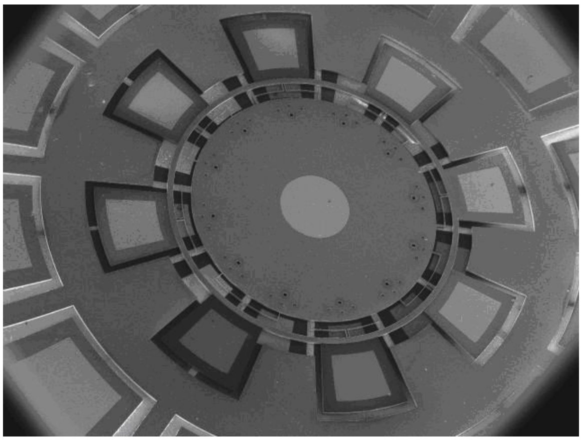

Figure 2.1 An example of a 3-axis gyroscope fabricated using high-aspect ratio processing techniques. HARP can be used across a broad range of feature sizes from several cm's to 10's of microns. Average aspect ratios are 1:15.

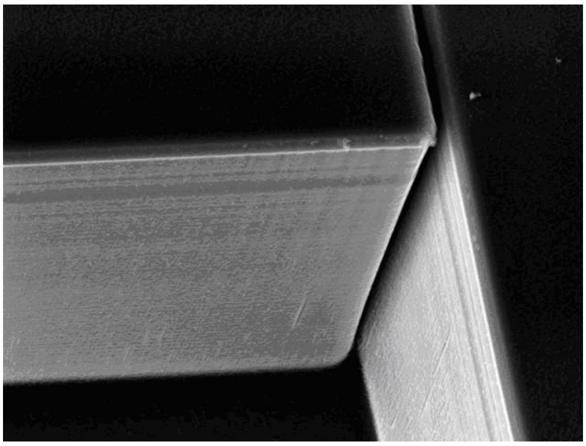

Figure 2.2 A magnified section of the gyroscope where the electrode interfaces and drives the ring into resonance. Changes in rotation and movement change the frequency at which the ring vibrates thus allowing detection of motion.

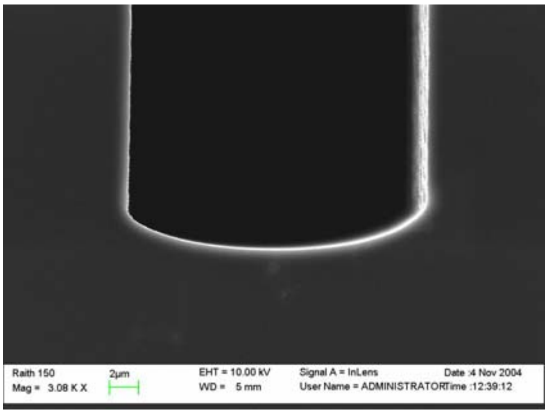

Figure 2.3 An example of a vertical trench being etched into Silicon. Note that near 90 degree profile and smooth sidewalls. The quality of the etch, as illustrated here, is an important factor in the repeatability and reliability of device performance and in the yield of devices during manufacturing.

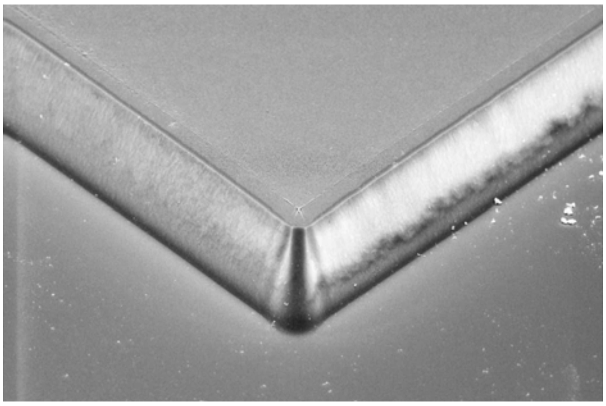

Figure 2.4 Example of an advanced oxide etch of a 10µm layer of silicon oxide. Note the smooth and controlled angular side wall. Such etch processes are ideal for a range of optoelectronic and optical applications, for example, a waveguide (as shown here).

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3: Packaging and Integration

INEX has the capability to bond a wide variety of materials and substrates using a range of techniques, as shown in Table 3.1 below

Materials	Type of Bond
Silicon to Silicon	Fusion bonding
Silicon to Glass	Anodic bonding
Metal to metal	Eutectic bonding
Multi-materials at low-temperature	Adhesion bonding
Off chip interconnection	Wire bonding
IC integration	Die bonding
MEMS to ASICs/CMOS	Flip-chip bonding

Table 3.1 Types of bonding process available at INEX

Figure 3.1 is an example of an epoxy-bond used to attach a port to a glass microstructure for use within a microfluidic device. Figure 3.2 illustrates the ball grid array of a chip prior to flip-chip bonding. Figure 3.3 demonstrates a fully packaged microfluidic device (actually 5 parallel microfluidic ports) of which all components from the microfluidic structures and microelectrodes through to the housing itself were designed and manufactured by INEX.

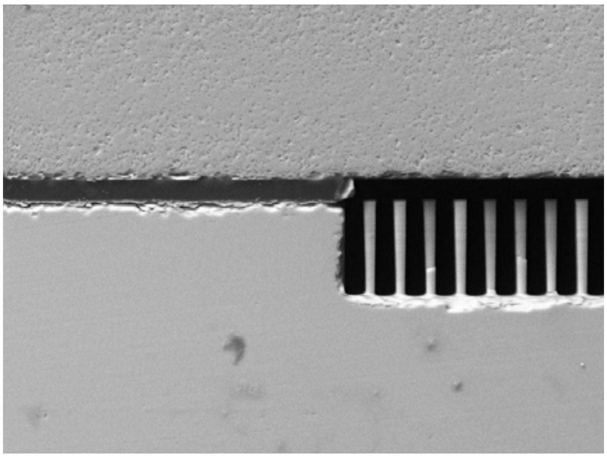

Figure 3.1 An example of an adhesive bond using a UV-curable epoxy. Capillary flow enables uniform epoxy distribution. These flow forces are no longer active within the microchannel and device occlusion is avoided.

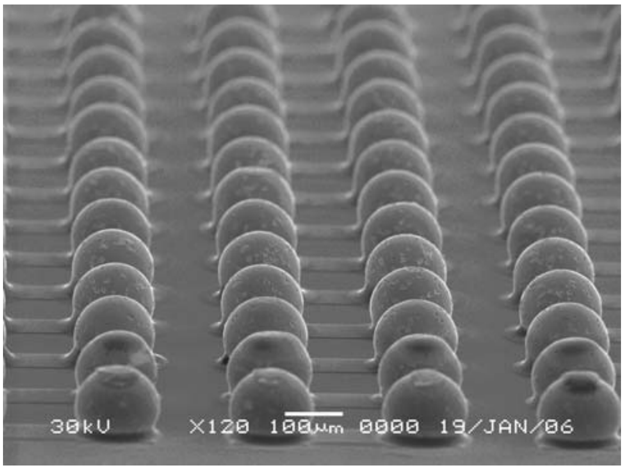

Figure 3.2 An example of a ball-grid array of Sn–Pb solder bumps (as supplied to INEX) prior to flip-chip bonding. Flip-chip bonding is a hybrid packaging technique used by INEX for integrating MEMS devices with CMOS.

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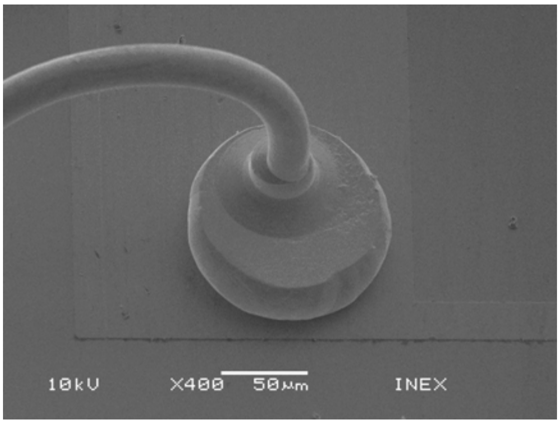

Figure 3.3 A magnified section of a wire bond to a FR4 ceramic board with pre-printed circuits. This image shows a gold wedge bond connection.

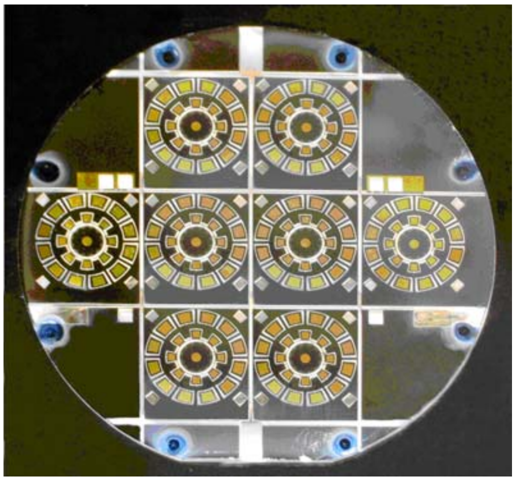

Figure 3.4 A wafer of 3-axis micromachined gyroscopes triple stack bonded to glass by anodic bonding. Note the scribe lanes for the next step, wafer dicing.

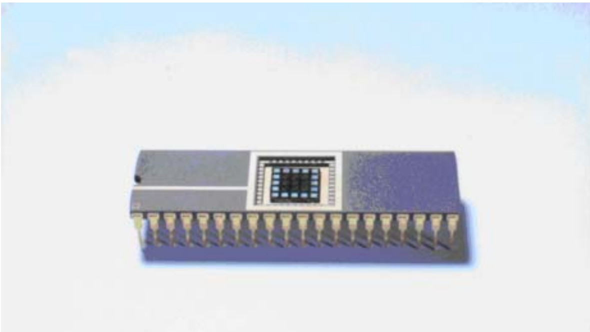

Figure 3.5 A biosensor chip (centre) die bonded to a ceramic IC package. The outer electrodes are wirebonded to the lead pins on the package.

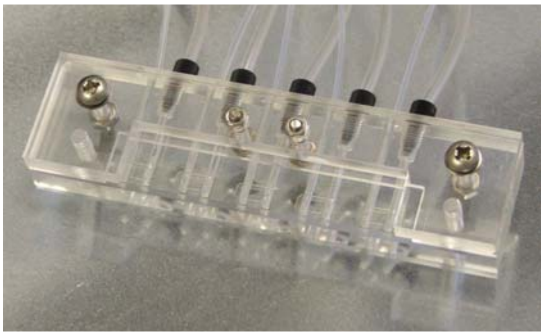

Figure 3.6 A 5-parallel flow-cell cytometry device incorporating micro- and milli-fluidics. Housings such as this are fabricated by INEX using its in-house CNC micro-milling capability.

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4: Microfluidic devices for biomolecular processing

In many bio-hybrid devices a critical step in the process flow is biological sample preparation. Microfluidic devices are being investigated for their ability to separate different components of a fluid system. In the example below a DNA extraction device was designed by Molecular ID Systems (a spin-out from INEX) with the aid of Fluent® CFD software, see Figure 1.1, to enable high flow rate actuation with a low pressure drop.

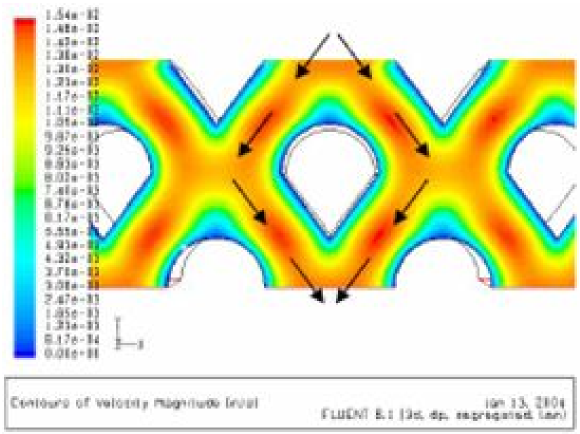

Figure 1.1 Velocity flow simulation using FLUENT® software

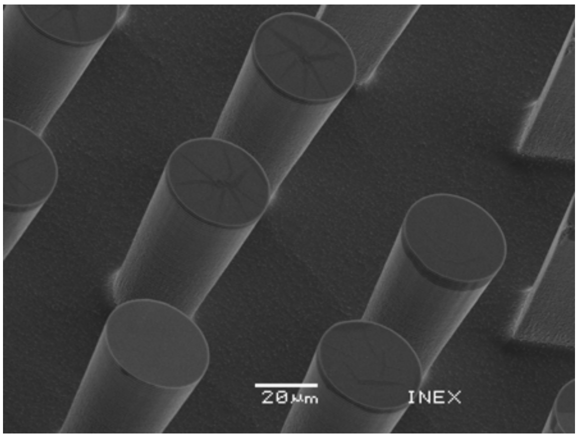

Figure 1.2 Prototype of the design fabricated in silicon using Advanced Silicon Etch® process.

This device incorporates microstructures to provide a high surface area for the efficient capture and purification of DNA molecules during continuous flow operation, as shown in Figure 1.2. The device was fabricated by INEX using the ASE (Advanced Silicon Etch®) deep reactive ion etching process. A packaged device is pictured in Figure 1.3 with fluidic interfacing to the real-world.

In addition to healthcare applications, there are nearer term prospects to apply the underlying technology to further applications in the defence and homeland security sector, such as the detection and identification of biothreat agents in air and liquid.

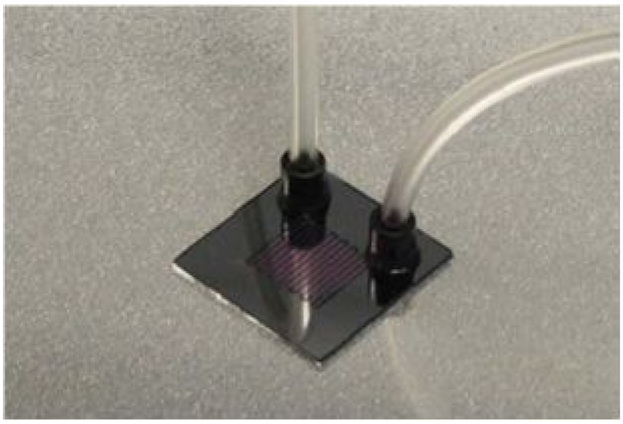

Figure 1.3 Completed prototype device with fluidic interfacing to the real-world

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5: Bio-hybrid integration and engineering

With the increasing application of micro and nano technology solutions to biological problems INEX has developed an expertise in understanding and manipulating the relationship between implantable devices and the cellular environment.

Ensuring an appropriate interface between living cells and inorganic surfaces, such as implants or microelectrodes is an important factor in the performance of medical implants and devices. INEX has the capability to modify biomaterial surfaces to introduce a desired functionality using topographic, chemical and biomolecular approaches.

The EVG520 Hot Embosser can be used to produce topographic features from tens of microns in size to the 50nm scale in substrates such as polycarbonate.

While photolithographic techniques can be used to produce PDMS "stamps" to enable the printing of biomolecules.

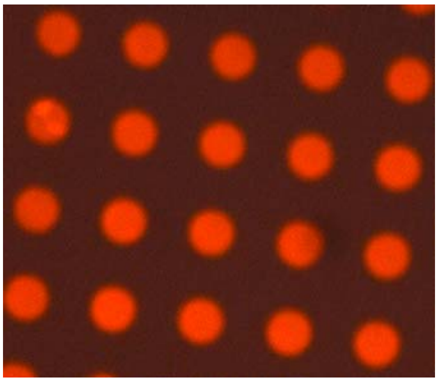

Figure 4.1 Printing of biomolecules such as collagen, here labelled with a florescent marker, can be used to influence cell adhesion.

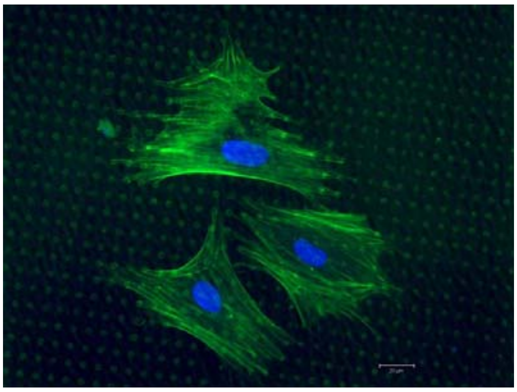

Figure 4.2 Osteoblasts (bone cells) grown on a microstructured surface of pillars (represented by the dots).

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6: Nanotoxicology

The potential risk of nanoscale particles to health and the environment is becoming an important area of research as their use in consumer products and medical applications increases.

Particle properties such as size, size distribution, shape, structure, microstructure, composition, and homogeneity are critically important to determining the potential impact of such materials.

At INEX we have access to a range of analytical and biological applications that can begin to probe the likely effects of nanoscale particles. Our class II microbiological facility allows the in vitro culture of a range of model cell types. Their response to the presence of nanoscale particles can be investigated using such methods as fluorescent microscopy, fluorescent and UV spectroscopy and quantitative PCR.

Characteristics	Description
Size, shape & morphology	Atomic Force Microscopy (AFM) and Scanning Electron Microscopy (SEM) can be used to characterise nanoparticles in terms of their size, shape and morphology. MultiMode SPM & Jeol 6060
Magnetic properties	Magnetic Force Microsocopy (MFM) can be used to study the magnetic properties of nanoparticles. MultiMode SPM.
Composition	Raman and infrared spectroscopies are commonly used to identify materials by comparison to known references, obtain information about how chemical species are bound to one another in a sample, and quantify the concentration of specific chemical species in a sample. HR800 LabRam and FTIR

Name	Description
Cell viability / cytotoxicity study	Two colour fluorescence assays can be used to determine cell viability. Molecular Probes Live/Dead Assay
Proliferation study	Colorimetric methods can be used to determine the proliferation rates of cell populations. Promega CellTiter 96 Proliferation Assay
Oxidative stress	Reactive oxygen species generated during oxidative stress can be detected by an increase in fluorescence following oxidation of the compound dichlorofluorescein. Molecular Probes ROS Detection Reagents
Molecular characterisation	Characterisation of the expression changes of specific genes can be carried out using quantitative PCR.

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Appendix A: Capability Summary

Allowed Substrates

100 mm silicon, SOI, glass and quartz wafers
150 mm silicon, SOI, glass and quartz wafers
Single wafers or bonded pairs
Limited capability to process 3” wafers and irregular substrates
Polyimide film and other flexible substrates

Design and Modelling

Mask layout (L-Edit, AutoCAD)
FEA modelling (Ansys)

Lithography

Single and double-sided contact aligners (1:1)
Minimum feature size: 2.5 µm
Alignment accuracy ± 1 µm (front side align), ±2 µm (front to back align)
Stepper (1:1)
Minimum feature size: ~1 µm
Overlay accuracy: 0.16 µm
E-beam writer:
Minimum feature size ~20 nm
Overlay & stitching accuracy ~40 nm
HMDS vapour priming
Spin coating of photoresists and polyimides
Puddle, spray or tank development
Hotplate and oven baking
Deep UV resist treatment
Lift-off process (image reversal and bi-layer)

Wafer Bonding

Ultrasonic wafer cleaning station
Silicon fusion bonding
Anodic bonding
Adhesive wafer bonding
Eutectic bonding
Bonding at atmospheric pressure or vacuum (to 10^{-5} mbar)
Aligned wafer bonding with < 10 µm accuracy

Plasma Etching

DRIE of silicon (Bosch process)
DRIE of silicon dioxide and glass (ICP source)
RIE of silicon dioxide, nitride, poly-silicon, polyimide and PZT
Metal etching (ICP source)
Emission and optical end-point detectors
Resist stripping and descum

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Wet Processing
Dedicated wet process stations for solvent, acid and alkali processing
Anisotropic silicon etching (TMAH and KOH)
HF etching of silicon dioxide and glass
Wet etching of metals (e.g. Ti, Cr, Au, Cu, NiCr and Al)
Wafer cleaning (RCA, Piranha and solvent)
Solvent tools for lift-off and resist stripping
Photo-mask cleaning
HF release etch with supercritical CO_2 drying

Metallisation
DC & RF sputtering of metals (e.g. Al, Ti, Cr, Pt, Au, Cu and NiCr)
E-beam evaporation of metals (e.g. Cr, Au, Ti, Al)
DC and pulse plating of metals (Au, Ni, Pt and Cu)
Thermal Processing
Wet oxidation of silicon
Dry oxidation of silicon
High temperature anneal (N_2 or O_2 atmosphere)

CVD Processing
LPCVD deposition of poly and amorphous silicon (un-doped)
High and low frequency PECVD deposition of silicon oxide, nitride oxy-nitride and amorphous silicon
Mixed frequency PECVD deposition of silicon nitride (low stress)
Polymer Processing
Hot embossing and nano-imprinting
PDMS casting
Polymer micro-milling

Inspection and Metrology
Optical microscopy
Scanning electron microscopy

Metrology
Spectroscopic ellipsometry (film thickness and RI)
Reflectance spectrometry (film thickness)
Prism coupling (RI measurement)
Linewidth and CD measurement
Wafer thickness, bow and stress measurement
Bulk and sheet resistivity
Stylus profilometry (step height and surface roughness)

Characterisation
FTIR spectrometry
Raman spectrometry
EDAX analysis
Scanning probe microscopy (AFM & STM)
Contact angle measurement

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Back-End and Packaging
Wafer dicing (glass, silicon and ceramic substrates)
Wire bonding (Al and Au)
Bond pull/shear testing
Flip chip bonding (Pb–Sn and Pb-free)
Die bonding

Testing
Semi-automated and manual probe stations
Electrical testing
Testing of resonant devices

DNA Manipulation
PCR and Q-PCR

Surface functionalisation
Hot embossing
Surface chemistry
Biomolecular surface functionalisation
Micro-contact printing
Farfield Analight Bio200 Dual beam interferometry

In vitro studies
Cell culture of primary and secondary cell lines
Cell viability studies
Cell proliferation studies

Imaging
Phase microscopy
Fluorescent microscopy
Immunocytochemistry

Imaging System
Fura-2 ratiometric imaging of intracellular calcium
Ratiometric imaging of cell membrane potential using voltage sensitive dyes
BCECF monitoring of intracellular pH

Analytical tools
Spectroscopy
Autolab potentiostat and galvanostat
Autolab surface Plasmon resonance
Micro particle image velicometry (μPIV)

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Appendix B: Equipment Summary

Lithography

Ultratech 1500 stepper
EVG 620 contact/bond aligner
Karl Suss MA-6 aligner
Raith 150 e-beam writer
EV101 spin coat station
EMS 5000 spin coater
Headway spin coater
EV102 develop station
Solitech S110 D spray develop tool
YES 310 HMDS and image reversal oven
EMS hotplates
Lab-line oven
Dispatch LLD1 polyimide oven
Fusion M150PC DUV flood exposure tool
Fortex dry film laminator

Wafer Bonding and Embossing

EVG 301 wafer cleaner
EVG 501 wafer bonder
EVG 520 hot embosser
Logitech single station wafer bonder

Wet Processing

Larmaflo wet stations
Felcon solvent station
MAG acid wet station
MAG alkali wet station
Expert Development electroplating system
Semitool 470S and 870S SRDs
SSEC 203 solvent processor

Plasma Processing

STS ASE^{HRM} (advanced silicon etcher)
STS AOE (advanced oxide etcher)
STS ICP cluster (metal etcher)
Tegal 902e reactive ion etcher
STS dual frequency PECVD
Oxford Plasmalab 80+ PECVD
Tepla 300 microwave asher

PVD

Balzers BAK550 e-beam evaporator
BOC-Edwards Auto 500 e-beam evaporator
BOC-Edwards Auto 500 sputterer
Nordiko sputterer
Varian 3290 sputterer

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Furnaces
Tempress TSC603 furnace stack
Wellman anneal furnace

Metrology, Inspection & Characterisation
J.A. Woollam M2000 spectroscopic ellipsometer
Filmetrics F-20 reflectance spectrometer
Metricon 2100 prism coupler
Veeco Dektak 6M stylus profiler
Jandel four-point resistivity probe
Tencor M-Gauge
Tencor 4500 Surfscan
JEOL JSM-6060 SEM
Olympus MX-50 inspection microscopes
MueTec 50 line-width measurement system
BRSL David CD measurement system
MTI Proforma 200S wafer measurement tool
Digilab FTS7000 FTIR spectrometer
Jobin Yvon LabRam Raman microscope
Veeco Nanoscope IV (AFM & STM)

Back-End & Packaging
Loadpoint Micro-Ace 3 dicing saw
Datron M9 machining centre
K&S 4123 ball bonder
K&S 4523 wedge bonder
Karl Suss FC150 flip chip bonder
Dage 4000 bond tester
Cammax Precima die bonder
Ultron UH114 film frame applicator
Emitech critical point dryer

Testing
Wentworth AWP 200 semi-automatic probe station
Agilent/HP: 35670A signal analyser, 4140B I–V / C–V test, 4275A LCR meter
Keithley: 237 source meter, 617 picoammeter, 195, 2000 series multimeters

DNA Manipulation
Eppendorf PCR Mastercycler
Stratgene MX-4000 Q-PCR
UVitec BTS-20.M UV imaging station

Imaging
Olympus BX41M fluorescent microscope
JVC video capture suite
Image proplus software

Imaging System
Olympus BX51WI fluorescent microscope
Andor iXon EMCCD camera
Andor IQ software

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Cell Culture
Sanyo CO_2 incubators
Class 2 safety cabinets

Spectroscopy
Fluorescence plate reader, Varian Carey Eclipse
UV-visual Spectrophotometer, Varian Carey 50

Analytical tools
Autolab potentiostat and galvanostat
Autolab surface Plasmon resonance
DANTEC micro particle image velicometry
Farfield Analight Bio200 Dual beam interferometry

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