"We report pronounced magnetoconductance oscillations observed on suspended bilayer and trilayer graphene devices with mobilities up to 270,000 cm$^2$/Vs. For bilayer devices, we observe conductance minima at all integer filling factors between 0 and 8, as well as a small plateau at $1/4 \approx 3$. For trilayer devices, we observe features at $1/4, 1, 2, 3,$ and $4$, and at $0:5$ that persist to 4.5 K at B $1/4 \approx 8$ T. All of these features persist for all accessible values of Vg and B, and could suggest the onset of symmetry breaking of the first few Landau levels and fractional quantum Hall states.”

Wenzhong Bao, et. al., UC Riverside. Work partially performed at UCSB

Wenzhong Bao, et. al, PRL 105, 246601 (2010)
Description:
Suspended carbon nanotube field effect transistors show a sudden drop in current “kink” in the $I$-$V$ characteristics when measured in gaseous environments. This kink does not appear in vacuum and changes in character and severity with the applied gate voltage.

Result:
The kink is found to be the threshold of the optical phonon emission which can only be observed in defect free suspended carbon nanotubes with non-equilibrium phonon population.

M. Amer, A. Bushmaker, S. Cronin, Physics Dept. USC. Work partially performed at UCSB

Funding Agencies:
ONR Award No. N000141010511
NSF award No. CBET-0854118
DOE Award No. DE-FG02-07ER46376
In this work, we demonstrated straight and curved filters based on waveguide Bragg gratings. Both filters had a total length of 920 μm, a stop band of 1.7 nm, and an extinction ratio larger than 23 dB. The curved structure occupied an area of 190 μm × 114 μm, attaining packing efficiency of $L/A^{1/2} \approx 6:2$. Nevertheless, it exhibited the same performance as its straight counterpart. The proposed approach opens a route to avoid the stitching errors present in the typical lithographic process of long structures. The developed analytical model aims to assist in the design of such structures in the future.

S. Zamek, et. al.  
ECE Dept., UC San Diego  
Work partially performed at UCSB

Highest Electricity Conversion Efficiency
Achieved by GaN FET & Diode

Most electricity is regulated before use. Efficiency is key in energy saving. GaN FET & diode by Transphorm Inc. achieve >99% efficiency in a 1:2 boost converter.

GaN power devices reduce energy loss in Si devices by 45%.

GaN solution drastically simplifies converter circuits: No gate resistor, no snuber, no insulating shim.

A Total GaN Converter to boost voltage from 220V to 400V

$R_G=0\,W$, $V_{IN}=220\,V$, $V_{OUT}=400\,V$, $f=100\,kHz$

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Work by Transphorm Inc., Goleta, California
Part of earlier power device development performed at UCSB NNIN Facility
QmagiQ develops infrared sensors based on quantum wells and superlattices made from compound semiconductors. Part of the process development is carried out at the UCSB node of the NNIN. Shown below is a 1Kx1K (million) pixel chip that produces longwave infrared imagery using InAs/GaSb superlattice photodiodes. With their high quantum efficiency and relative low cost, these sensors hold the promise of revolutionizing infrared imaging. Funded by the Missile Defense Agency, the chip was partly developed at UCSB. Cameras containing such chips find uses in security and surveillance, missile defense, pollution detection and monitoring, and infrared astronomy.

Infrared Imaging Sensors

Chip on puck
Sensor Engine
Camera
QmagiQ
Work performed at UCSB and Harvard in 2011
“We present an overview of our recent results on the growth, fabrication, and characterization of high-power long-wave infrared quantum cascade lasers with multimode and single-mode waveguides. Powers of up to 1.2W at wavelengths of $\lambda = 6.1 \, \mu m$ are obtained with InGaAs/InAlAs buried heterostructure lasers grown lattice matched on InP substrates. For longer wavelengths, up to $\lambda = 9 \, \mu m$, powers of $P = 800 \, mW$ are delivered from room-temperature-operated devices. Distributed-feedback waveguides have been fabricated with buried grating geometry, leading to single-mode emission of more than $P = 150 \, mW$ output at $\lambda = 7.74 \, \mu m$ when the device is operated at room temperature in continuous mode”

M. Troccoli, et. al.
AdTech Optics, Inc.
Work partially performed at UCSB Facility

M. Troccoli, X. Wang, and J. Fan, “Quantum cascade lasers: high-power emission and single-mode operation in the long-wave infrared ($\lambda>$6 $\mu m$)”, Opt. Eng. 49, 111106
Metal-Oxide Thin Film Transistor with High Performance and Good Operation Stability

Non-InGaZnO based metal-oxide TFT is developed with high performance and good stability. Manufacturability was demonstrated with a high capacity, Gen-2.5 size, color-filter production line. Superb TFT performance was achieved with $\mu>80 \text{ cm}^2/\text{Vsec}$, $I_{on}/I_{off}>10^{10}$ and $S<0.2 \text{ V/dec}$. This TFT shows high stability under OLED and LCD operation conditions. A 4.8” bottom emission AMOLED is demonstrated with aperture ratio larger than 50%. Power efficiency $>6 \text{ lm/Watt}$ at $>500 \text{ nits}$ was achieved with high display uniformity. The average power efficiency under video operation is beyond 20 lm/Watt.

G. Yu, et. al.
CBrite, Inc., Goleta CA
Work partially performed at UCSB Facility

High-Speed SiGe Microcoolers for Study of Ultrafast Peltier Effects

In this work, we have developed integrated microcoolers with SiGe superlattice as the active medium for study of ultrafast Peltier effects at the thermoelectric interface. The metallization was laid out as transmission lines (coplanar waveguides: GND-SIG-GND) to enable high-speed operation. We performed dynamic thermal characterizations with a variety of thermoreflectance imaging techniques.

We see from the measurements that Peltier cooling is quicker than Joule heating (as expected from associated thermal mass). A net cooling of 1 to 2 degrees observed with response times down to 100ns.

Exemplary thermoreflectance images of 10x10μm² sample. Active cooling is clearly visible; hot spots at electrode neck suggest insufficient metalisation of superlattice side wall.

Bjorn Vermeersch, Je-Hyeong Bahk, Ali Shakouri
UC Santa Cruz
Work partially performed at UCSB Facility
“A hallmark of mechanical resonators made from a single nanotube is that the resonance frequency can be widely tuned. Here, we take advantage of this property to realize parametric amplification and self-oscillation. The gain of the parametric amplification can be as high as 18.2 dB and tends to saturate at high parametric pumping due to nonlinear damping. These measurements allow us to determine the coefficient of the linear damping force. The corresponding damping rate is lower than the one obtained from the line shape of the resonance (without pumping), supporting the recently reported scenario that describes damping in nanotube resonators by a nonlinear force. The possibility to combine nanotube resonant mechanics and parametric amplification holds promise for future ultralow force sensing experiments.”

A. Eichler, J. Chaste, J. Moser, and A. Bachtold
Catalan Institute of Nanotechnology (ICN) and CIN2, Campus UAB, Barcelona, Spain
Work partially performed at UCSB Facility

Schematic diagram and false-color scanning electron microscopy (SEM) image of the device. The nanotube (arrows, dashed line in the SEM image) is suspended over a gate electrode (red) between two metal electrodes (gray). The distance between the electrodes is 1 μm. All measurements are performed in an ultrahigh vacuum chamber (about 10⁻¹⁰ mbar) at 100 K

(a) Amplification (Λ) as a function of the phase difference, Δφ, between the driving force and the pump for \( V_P = 11.5 \text{ mV} \) (solid dots) and \( V_P = 0 \) (hollow squares). \( V_{gAC} = 3 \text{ mV} \) and \( V_{sdAC} = 1.4 \text{ mV} \). Red lines are best fits. (b) Gain as a function of the amplitude of \( V_P \) for \( \Delta \phi \) at which the amplification is largest. We estimate the motion amplitude to be \( \sim 10 \text{ nm} \) at the largest gain.

A. Eichler, et. al., Nano Letters 11, 2699 (2011)
Heterogeneous Photonic Integrated Circuits

Aurrion is commercializing a semiconductor integration platform that enables all the elements of photonics systems to be fabricated on a single chip using control and cost-structure of silicon foundries. This technology is disruptive to the current photonics industry, therefore, in both its ability to change the economics of photonics manufacturing and its ability to push photonic integration on a growth curve similar to Moore’s law. Aurrion believes that such integration will be critical to the next generations of military systems and communication systems.

Aurrion Inc. - Work performed at UCSB Facility

Optical pulse compression is important for applications such as ultrafast optical time division multiplexing, optical coherence tomography and time resolved spectroscopy. In this work, pulse compression is achieved at low input peak powers in silicon waveguides through Re-phasing with an anomalously dispersive grating formed by precision electron beam lithography and etching. Dispersion is measured to be 1.3ps/nm resulting in a compression factor of 7 at a low input peak power of 10W.

D. Tan, et. al. Fainman Group, UC San Diego
E-Beam Lithography performed at UCSB Facility

D. Tan, et. al. Nature Communications, 1, 116
CMOS Biosensor system

The portable and sensitive molecular diagnosis platform with large dynamic range is the ultimate goal of a lot of research. This kind of system can enable point-of-care diagnosis and self diagnosis.

We designed a magnetic particle labeled immunoassay system for portable molecule diagnosis. This system uses magnetic particles to label the target molecule and detecting the magnetic particle magnetic field with magnetic sensors.

We used CMOS technology to design the magnetic sensor. Because CMOS technology can integrate large amount of sensors array and read our circuits on the same chip. So the whole system can be made portable and low cost. We also integrate CMOS technology and Microfluidic technology.

Prof. Mona Zaghloul and Bowei Zhang, Institute of VLSI&MEMS Technology, The George Washington University. Part of work done at UCSB facility.
InP DHBTs in a Refractory Emitter Process for THz Electronics

This work focuses on high frequency InP Double Heterojunction Bipolar Transistor (DHBT) development for use in 0.3-1.0THz imaging, sensing, radio astronomy, and spectroscopy and 100-500 GHz digital logic. We have made advances in epitaxial design and processing of emitter and base contacts to allow proper device scaling for multi-THz operation. The recent generation of devices using sub-200nm wide emitters and self-aligned base contacts has yielded 480 GHz $f_t$ and 1.0 THz $f_{max}$ HBT transistors.

V. Jain, et. al., Rodwell Group, UCSB
Work partially performed at UCSB Facility

Vibhor Jain et al., “1.0 THz $f_{max}$ InP DHBTs in a refractory emitter and self-aligned base process for reduced base access resistance”, DRC, 2011

Funding: DARPA THETA
A major challenge in the field of quantum computing is the construction of scalable qubit coupling architectures. Here, we demonstrate a novel tunable coupling circuit that allows superconducting qubits to be coupled over long distances. We show that the interqubit coupling strength can be arbitrarily tuned over nanosecond time scales within a sequence that mimics actual use in an algorithm. The coupler has a measured on/off ratio of 1000. The design is self-contained and physically separate from the qubits, allowing the coupler to be used as a module to connect a variety of elements such as qubits, resonators, amplifiers, and readout circuitry over distances much larger than nearest-neighbor. Such design flexibility is likely to be useful for a scalable quantum computer.

R. C. Bialczak, et al., Martinis and Cleland Groups, Physics Dept., UCSB
Work partially performed at UCSB Facility

A mesa merging oxidation method has been developed to create large low-loss SiO2 dielectrics on low-resistivity silicon. In the mesa merging method, thermal oxidation converts an array of silicon mesas into a solid block of SiO2. The SiO2 dielectrics are combined with further micromachining steps to create high aspect ratio coplanar waveguide (hicoplanar) transmission lines. The large SiO2 dielectrics enable high-impedance and low-loss hicoplanar transmission lines to be created with this method. Hicoplanar transmission lines with high impedance of 80 Ohms and loss less than 1 dBcm\(^{-1}\) up to 67 GHz have been successfully fabricated.

SEM micrographs of a hicoplanar thru line showing critical steps in the fabrication process.

Attenuation constant versus frequency of a 1600 μm long mesa merged hicoplanar line before and after silicon removal.

Microfluidics technology offers compelling tools for integrating multiple biochemical processes in a single device, but despite significant progress, only limited examples have shown specific, genetic analysis of clinical samples within the context of a fully integrated, portable platform. Herein we present the Magnetic Integrated Microfluidic Electrochemical Detector (MIMED) that integrates sample preparation and electrochemical sensors in a monolithic disposable device to detect RNA-based virus directly from throat swab samples. By combining immunomagnetic target capture, concentration, and purification, reverse-transcriptase polymerase chain reaction (RT-PCR) and single-stranded DNA (ssDNA) generation in the sample preparation chamber, as well as sequence-specific electrochemical DNA detection in the electrochemical cell, we demonstrate the detection of influenza H1N1 in throat swab samples at loads as low as 10 TCID50, 4 orders of magnitude below the clinical titer for this virus.

S. Fergusen, et. al. Soh Group, UCSB
Work partially performed at UCSB Facility

B. Fergusen, et. al Journal of the American Chemical Society 133, 9129-9135 (2011)
In this study we demonstrate how a single semiconducting nanowire whose surface has been decorated with metal nanoparticles and configured as the channel in a field-effect transistor can function as a miniature laboratory. The above device is used to investigate chemical processes occurring at the surfaces both of the metal nanoparticles and of the semiconductor and their effect on the electronic and transport properties of the device, and reciprocally how the transfer characteristics of the FET influence the chemistry occurring at the device’s surface. These effects, negligibly small at the surfaces of ordinary materials systems, are enormously amplified when the FET’s channel is a nanowire whose radius is comparable to, or smaller than the material’s Debye screening length.

Syed Mubeen and Prof. Martin Moskovits, University of California, Santa Barbara
Work performed at UCSB Facility

Effect of hydrogen partial pressure on the measured transfer characteristics of Pd-nanoparticle decorated SnO$_2$ nanowire

Spin Control of Drifting Electrons Using Local Nuclear Polarization in Ferromagnet-Semiconductor Heterostructures

We demonstrate methods to locally control the spin rotation of moving electrons in a GaAs channel. The Larmor frequency of optically injected spins is modulated when the spins are dragged through a region of spin-polarized nuclei created at a MnAs-GaAs interface. The effective field created by the nuclei is controlled either optically or electrically using the ferromagnetic proximity polarization effect. Spin rotation is also tuned by controlling the carrier traverse time through the polarized region. We demonstrate coherent spin rotations of 5π rad during transport.

M. Nowakowski, et. al., Awschalom Group
Physics Dept., UCSB
Work partially performed at UCSB Facility

Versatile Chip Specific Integration Technology (VCSIT)

VCSIT is a novel technique for the integration of small CMOS dies in a large area substrate. A key component of the technique is the CMOS die based self-aligned masking. This allows the fabrication of sockets in wafers that are at most 5μm larger than the die. The die and large area substrate are bonded onto a carrier using BCB such that the top surfaces of the two components are flush. SOG is then applied to fill any small gaps between the chip and the substrate, and to planarize the top surface. The VCSIT platform has been designed with CMOS-, MEMS- and bio-compatible materials and processes. It allows for the integration of macroscale components, such as leads and microfluidics, and post-CMOS micromachining of the packaged chip. Because of its versatility, the VCSIT promises to be a formidable approach to implement next-generation biochips, integrated CMOS RF IC’s and photonic CMOS chips.

Ashfaque Uddin, Kaveh Milaninia, Chin-Hsuan Chen, Luke Theogarajan, UCSB
Work performed at UCSB Facility


Sponsored by Intel Corporation and NIH
The extremely rapid performance advances of N-polar GaN HEMTs are a significant indication of their relevance and viability in modern electronic device applications. The advantages of HEMTs on N-polar GaN include low contact resistance, built-in back-barrier for improved electron confinement and modulation efficiency, and ability to scale the barrier thickness independently of 2DEG channel charge. The current study highlights a novel high-aspect-ratio T-gate design and its resulting state-of-the-art RF device performance on the N-face GaN material system. We report measured $f_{\text{max}}$ data of over 300 GHz on an MOCVD-grown N-polar GaN HEMT using a high-aspect-ratio T-gate. To our knowledge, this > 300-GHz $f_{\text{max}}$ value is the highest reported to date for N-polar GaN HEMTs.
InGaN-based alloys have also begun to receive considerable attention for photovoltaic applications. This interest has been driven by the favorable physical properties of InGaN-based alloys for photovoltaic applications, including a direct band gap ranging from 0.64 eV for InN to 3.4 eV for GaN, high absorption coefficients of $10^5 \text{ cm}^{-1}$ near the band edge, superior radiation resistance compared to other photovoltaic materials, and the potential for integration with existing silicon technology. We demonstrate high quantum efficiency InGaN/GaN multiple quantum well (QW) solar cells with spectral response extending out to 520 nm. Increasing the number of QWs in the active region did not reduce the carrier collection efficiency for devices with 10, 20, and 30 QWs. Solar cells with 30 QWs and an intentionally roughened p-GaN surface exhibited a peak external quantum efficiency (EQE) of 70.9% at 390 nm, an EQE of 39.0% at 450 nm, an open circuit voltage of 1.93 V, and a short circuit current density of 2.53 mA/cm$^2$ under 1.2 suns AM1.5G equivalent illumination.

**Dependence of EQE (solid lines) and absorption (dashed lines) on wavelength for samples A(10QW, smooth), B(20QW, smooth), C(30QW, smooth), and D(30QW, rough)**

R. M. Farrell, et. al. *APPLIED PHYSICS LETTERS* 98(20), 201107
Next generation display technologies, including full color displays and mobile projectors, require light emitters that are spectrally pure, thermally stable, energy efficient, and small in size. For these applications, wurtzite (Al,In)GaN-based laser diodes (LDs) have emerged as the leading candidate for blue and green direct-emission light sources. We present the first reported continuous-wave (CW) operation of pure blue AlGaN-cladding-free (ACF) nonpolar m-plane InGaN/GaN laser diodes (LDs). CW lasing was achieved at a wavelength of 461 nm and a threshold current density of 4.1 kA/cm² for LDs with an InGaN-based separate confinement heterostructure (SCH) waveguide design. The devices showed a 9 nm/decade blue-shift of spontaneous emission wavelength with increasing current density, a characteristic temperature of 156 K, a red-shift with increasing stage temperature of 0.05 nm/K, and an estimated thermal impedance of 60 K/W.

K. Kelchner, et. al. Speck, Nakamura, DenBaars Groups, Materials and ECE Depts, UCSB
Work performed at UCSB Facility

We demonstrate an integrated programmable photonic filter structure capable of producing bandpass filters with both tunable passband bandwidth and center frequency. Such filters could provide dynamic pre-filtering of very wide bandwidth analog microwave signals, essential to the next generation RF-front ends. The photonic filter is constructed from an array of uncoupled identical filter stages, each reconfigurable as a zero or a pole using an asymmetrical Mach-Zehnder Interferometer (MZI) structure with feedback. Integrated on a standard InP–InGaAsP material platform, semiconductor optical amplifiers (SOAs) and current injected phase modulators (PMs) are used to rapidly adjust the individual pole and zero locations, thereby reconfiguring the overall filter function. In this paper, we demonstrate cascaded filter structures with up to four filter stages, capable of producing a variety of higher order filters. Demonstrated filters have a free spectral range (FSR) of 23.5 or 47 GHz.

Examples of higher order filters synthesized with our programmable filter device. (b) Bandpass filter utilizing both zeros and poles. (c) 2nd order bandpass filter with zeros placed to eliminate the next filter order and thus double the FSR.
Recent efforts in silicon photonics have focused on developing a wide range of optical components that can be integrated on a single platform. A lot of work has focused on modulators as they are crucial for the generation and transmission of high-speed signals such that increasing demands on data capacity can be satisfied. To be able to efficiently send information at high frequencies, modulators with large optical bandwidth, high-speed operation and good modulation efficiency are required. Modulators based on a Mach-Zehnder interferometer (MZI) architecture are of particular interest because they satisfy several of the aforementioned criteria. In this work, we demonstrate a hybrid silicon modulator operating up to 40 Gb/s with 11.4 dB extinction ratio. The modulator has voltage-length product of 2.4 V-mm and chirp of -0.75 over the entire bias range. As a switch, it has a switching time less than 20 ps.
Bulk acoustic wave resonators are used to filter unwanted frequencies in wireless microwave applications such as cell phones. Currently used materials, such as AlN, only allow for fixed frequency and constantly ON filters. At UCSB, novel thin film materials are being explored for these applications, such as SrTiO$_3$ and (Ba,Sr)TiO$_3$. Surface roughness is a scattering loss mechanism that degrades the Quality factor of the resonator. Comparison of the surface roughness between two SiO$_2$ surfaces deposited by two different methods figure 1 PECVD and figure 2 ICP PECVD in Panel A. The Quality factor improves significantly for the resonator with the smoother electrode surface Panel B.

G. Saddik, S. Stemmer, R. York
ECE and Materials Depts, UCSB
Work at UCSB Facility


U.S. Army Research Office (Grant No. W911NF-0601-0431), NSF (Grant No. CCF-0507227)