with higher annealing temperature. Using X-ray diffraction the layers cristallinity has been studied. Using AFM and SEM the surface condition and grain boundaries have been characterized. Layers as deposited show generally amorphous state with only small amounts of cristallytes below 20nm in size. The crystallographic appearance can be controlled by the annealing processing. Stress measurements by laser deflection of the wafer bow revealed, that annealing convertes the original pressure layer stress into tensile stress. In order to investigate the impact on electrical properties in electronic devices dot structures and field effect transistors from this layers have been prepared and CV-characteristics and transistor functions recorded. So transfer and drain characteristics, hysteresis and dielectric properties under various environments has been obtained.

10:30 AM *D3.5
An Electronic Nose from Arrays of Polymer Composite Vapor Sensors. Nathan S. Lewis, Division of Chemistry and Chemical Engineering, California Institute of Technology, Pasadena, California.

A method is described for generating a variety of chemically diverse, broadly responsive, low power vapor sensors. A key to our ability to fabricate chemically diverse sensing elements is the preparation of processable, air stable films of electrically conducting organic composites. An array of such sensing elements produces a chemically reversible, diagnostic pattern of electrical resistance changes upon exposure to different odorants. Such conducting composite elements are simply prepared and are readily modified chemically to respond to a broad range of analytes. In addition, these sensors yield a fairly rapid, low power, dc electrical signal in response to the vapor of interest, and their signals are readily integrated with software or hardware-based neural networks for purposes of analyte identification. Principle component analysis has demonstrated that such sensors can identify and quantify different airborne organic solvents, and can yield information on the components of gas mixtures.

11:00 AM D3.6
External Coupling of Molecular Dye Emission to High-Q Microdisk Resonators. David R. Rink[1], Michael H. Bartl[4,2], Lidong Zhang[4], Galen D. Stucky[2] and Evelyn L. Hu[1,3,4]; [1]Electrical and Computer Engineering, UC Santa Barbara, Santa Barbara, California; [2]Chemistry and Biochemistry, UC Santa Barbara, Santa Barbara, California; [3]Materials, UC Santa Barbara, Santa Barbara, California; [4]California NanoSystems Institute, UC Santa Barbara, Santa Barbara, California.

Semiconductor microdisk resonators have proven to be excellent high-Q microcavities with the ability to efficiently modify emission from embedded self-assembled semiconductor quantum dots. For emerging applications in, for example ultralow threshold lasing, quantum computing, and bio-sensing, however, it would be desirable to separate emitter/resonator fabrication and incorporation. This would not only greatly expand the choice of the emitting species including colloidal nanocrystal quantum dots, organo-metallic complexes and organic dyes, but would also allow individual fine-tuning and optimization of both emitter and microresonator. It would be desirable to independently fabricate the emitter and resonator such that the emitter is not incorporated within the microdisk but rests on the surface. In order to couple to a mode of the microdisk, an emitter must coincide in frequency and spatially overlap the mode. Theoretical simulations show that the mode leaks out tens of nanometers in the vertical direction of the disk. We demonstrate here the proof-of-principle coupling of external emission from dye molecules to the cavity modes provided by a microdisk resonator. Coupling is achieved by bringing the dye molecules - embedded in a low refractive index SBA-15 type nanostructured hybrid silica matrix - in close proximity to the microdisk utilizing a fast and simple fabrication method that combines semiconductor microprocessing with sol-gel supramolecular self-assembly chemistry. We found that emission from dye molecules located at the rim of the microdisk is strongly modified, exhibiting several well-defined high-Q modes. In contrast, much poorer coupling was observed to emission of dye molecules in the center of the microdisk, and no mode structure was observed in the emission of dye molecules distant from the microdisk. We will discuss the external coupling behavior and efficiency in terms of spatial position of the emitter, properties of the silica host matrix, and microdisk dimensions.

11:15 AM *D3.7
Some Recent Applications Colorimetric Sensor Arrays.
Ken Suslick, Michael Janzen, Jennifer B. Wilson and Chen Zhang; Chemistry, University of Illinois, Urbana, Illinois.

Array based vapor sensing has emerged as a powerful approach toward the detection of chemically diverse analytes. We have developed a unique chemical detection technology [1-4] in which colorimetric changes in an array of dyes constitute a signal much like that generated by the mammalian olfaction system; each dye is a cross-responsive sensor. This technology uses a disposable two-dimensional array of chemoresponsive dyes as the primary sensor elements, making it particularly suitable for detecting many of the most odiferous compounds. Striking visual identification of a wide range of VOC's are easily made at parts per billion (ppb) levels, for example to amines, carboxylic acids, and thiols (i.e., sensitivities comparable to GC-MS detection). Nearly all prior sensors rely exclusively on van der Waals interactions (e.g., physical adsorption on to surfaces, absorption into polymers) between the analytes and the sensors. Unfortunately, vdW interactions are the weakest and least selective of all intermolecular interactions and are a poor choice for any process involving molecular recognition. In contrast, our design of colorimetric sensor arrays is based chemo-responsive dyes that must contain a center to interact strongly with analytes, through reversible bond formation, strong acid-base interactions, or strong dipolar interactions. The consequent dye classes from these requirements are (1) Lewis acid dyes (i.e., metal ion containing dyes), (2) Brønsted acidic or basic dyes, and (3) dyes with large permanent dipoles (solvatochromic dyes). By using hydrophobic dyes on a hydrophobic substrate, we have avoided essentially any response to changes in humidity, which is a very serious problem for other electronic nose technology. A variety of recent applications will be discussed. [1] Rakow, N. A.; Suslick, K. S. "A Colorimetric Sensor Array for Odor Visualization" *Nature*, **2000**, 406, 710-714. [2] Suslick, K. S.; Rakow, N. A. "Colorimetric Artificial Nose Having an Array of Dyes & Method for Artificial Olfaction" *U.S.Patent6, 368, 558*; April 9, 2002.; Suslick, K. S.; Rakow, N. A.; Sen, A. "Colorimetric Artificial Nose Having an Array of Dyes and Method for Artificial Olfaction: Shape Selective Sensors" *U.S.Patent6, 495, 102*; Dec. 17, 2002. [3] Suslick, K.S.; Rakow, N.A.; Kosal, M.E.; McNamara III, W.B.; Sen, A. "Chemsensing: A Colorimetric Array Detector" *Proc.ISOEN02* (ed. A. D'Amico and C. DiNatale; IEEE: Baltimore, 2003), pp. 46-52. [4] Suslick, K. S. "An Optoelectronic Nose: Colorimetric Sensor Arrays" *MRSBulletin*, **2004**, 29, 720-725. Suslick, K. S.; Rakow, N. A.; Sen, A. "Colorimetric Sensor Arrays For Molecular Recognition" *Tetrahedron* **2004**, in press;

11:45 AM D3.8
A Novel Technology to Create Monolithic Instruments for Micro Total Analysis Systems. Konstantin Seibel, Lars Schoeler, Marcus Walder, Heiko Schaefer, Dietmar Ehrhardt and Markus Boehm; Institute for Microsystem Technology, University of Siegen, Siegen, Germany.

For micro total analysis systems methods for micropatterning, sealing, and manufacturability, as well as techniques for connecting the microstructures to the macroworld are of particular significance. Monolithic instruments consist of an assembly of three-dimensional integrated modules (e.g. fluidic networks, electrical and optical sensors, microelectronic circuits) to support the advantage of efficient interconnections. To demonstrate the feasibility of an application specific lab-on-microchip, results on a fabricated micro flow cytometer with monolithically integrated optical detectors based on amorphous silicon, an electroosmotic micropump without moving parts and a mass flow sensor using the thermal anemometric principle are reported. Further developments and potential applications for microanalysis are outlined. The fluidic channel network is built into a polymer layer (SU-8) which is sandwiched between two plates (e.g. glass-glass, ASIC wafer-glass). In case of the cytometer the excitation light, λ_{ex}=380nm, enters through the glass plate and irradiates the chromophore in the channel. Lab-on-microchip test results with anthracenyl-oxazoline (Ox) demonstrate a significant difference in the normalized intensity spectrum of Ox and Ox-H^+ according to 260fmol amount of substance. Experimental test parameters are bias voltage V_{bias}=-2.5V, detection volume $\Delta V \sim$26nl, fluid concentration c=10^{-5}M, diode area A_{Det}=0.1225mm^2 and a constant flow of 1μl/min. The micropump consist of several stages of narrow channel structures (channel cross section 4μm x 15μm) to enhance electroosmotic flow. The pump operates at voltages around 4-6V. It is capable of pumping against the hydrostatic pressure that arises from differences in the liquid level of the reservoirs. Typical pumping speeds are on the order of 100μm/sec corresponding to the flow rate of 5nl/min. The present pump design uses a PDMS cover to allow electrolysis gases to escape the pumping channels. The mass flow sensor consists of a heater sandwiched between two temperature sensors, all made of platinum and placed on the substrate on the channel's bottom. The flow rate measurements for DI water were performed using a syringe pump. The sensitivity is about 1μV/(nl/min) at the amplifier input for flow rates ranging from 10nl/min to 2μl/min. It can be improved by thermal isolation of the sensor elements from the substrate.

SESSION D4: Photonic Systems
Chair: Don Gardner
Wednesday Afternoon, March 30, 2005
Room 2008 (Moscone West)

1:30 PM D4.1
Integration of Polymer Pillar Optical Interconnects with Group IV MSM Photodetectors.
Ali K. Okyay[1], Chi On Chui[1], Muhannad S. Bakir[2], James D. Meindl[2] and Krishna C. Saraswat[1]; [1]Electrical Engineering, Stanford University, Stanford, California; [2]Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, Georgia.

As the degree of integration in ICs continue to increase, electrical interconnects are facing severe limitations such as speed, power dissipation, and cross-talk. On-chip optical interconnects are promising to eliminate many problems associated with large multi-GHz Si ICs particularly in global signaling and clocking. In such applications, monolithic integration of photodetectors (PD) with the advanced Si CMOS is essential to accommodate a high density of detectors on the chip in a cost-effective way. MSM-PDs are attractive for their integration simplicity for low-cost realization of Si-based optoelectronics. Efficient distribution of optical signal to PDs is of utmost interest. Amongst optical transmission media, polymer waveguides play a key role in optical systems due to their ease of integration. Moreover, being mechanically compliant, polymer waveguides can tolerate thermal expansion mismatches and maintain optical alignment. In this work, Si MSM-PDs are integrated with Sea of Polymer Pillars, interconnection technology that enables high density and mechanically compliant electrical and optical I/O interconnects at the wafer level. Interdigitated Si-MSMs were fabricated by liftoff of 15nm Ti and 35nm Au. A thin ($<1\mu m$) SiO_2 layer for adhesion was then deposited at 150^oC on the prefabricated MSM-PDs. Avatrel 2000P polymer was spin-coated followed by UV irradiation, hard bake, and spray development. Finally, wafers were cured for 1 hour at 200^oC. Pillars with different geometry, size and aspect ratio were fabricated on identical MSM-PDs. Some pillars were intentionally removed to asses the effects of polymer processing on detector performance. Current-voltage (I-V) characteristics for PDs with different pillars were measured under dark conditions. A reduction in leakage, primarily attributed to the SiO_2 passivation, was observed. I-V of PDs with no polymer processing was also measured as reference. Similar responsivity values around 0.45A/W over different species were obtained using a $\lambda \sim$790nm and 1mW laser. Photo-to-dark current ratio normalized to input optical power (NPDR) metric was used to evaluate overall device performance. NPDR was higher for PDs with better surface passivation coverage because of lower I_{dark}. Finally, we also studied the effect of processing with different thermal budgets. I_{dark} of MSM-PDs increased only slightly after an additional hour of cure; possibly attributed to an enhanced metal-silicon interaction or intermixing. Efficient light coupling into photodetectors is achieved without significantly degrading device performance with polymer processing. Such an integrated optoelectronic device would envision many applications in future on-chip optical interconnects and telecommunications.

1:45 PM *D4.2
Liquid Crystal on Silicon Devices.
Mark A. Handschy[1] and Timothy J. Drabik[2]; [1]Displaytech, Inc., Longmont, Colorado; [2]Page Mill Technology Corp., Palo Alto, California.

The concept of using liquid-crystal light modulators to read out the state of underlying electrodes on an integrated circuit had its origins in the 1970's and 80's when experimental active-matrix displays were constructed on 2-3 inch-diameter silicon wafers. The same concept was also used a tool to diagnose defective integrated circuits by allowing signal propagation to be visualized. The intersection in the late 1980's of interest in optical computing with the ready availability of custom wafers from silicon foundries spurred research into liquid-crystal-on-silicon (LCOS) spatial light modulators (SLMs). Ferroelectric liquid crystals (FLCs), with their fast switching speeds, provided SLMs with 10 kHz frame rates. In addition to light modulators, LCOS SLMs can integrate micro-optical elements (such as lenslet arrays), photodetector arrays, intra- and inter-pixel analog and digital signal processing circuitry, and interface and control logic into a single silicon die. The few-fJ/μm^2 switching energies of FLC materials match the favorable power-delay product of silicon CMOS technology, which does not degrade at the comparatively low rates corresponding to liquid crystal switching times. Consequently, silicon/FLC technology suits applications having massive parallelism and requiring low power operation at moderate speeds, such as front-end image processing systems. The adoption by silicon foundries of chemical-mechanical planarization (CMP) enabled LCOS devices with high-quality pixel mirrors, leading to improved liquid crystal alignment and higher optical reflectivity and setting the stage for utilization of LCOS devices as *microdisplays*. LCOS microdisplays are currently finding commercial application as electronic viewfinders for camcorders and digital still cameras, and are being developed as image generators for projection televisions. Future applications for LCOS devices might include write-heads for holographic optical data storage drives and optical beam steering and adaptive conditioning elements. This talk reviews the history of LCOS devices and their applications, provides an overview of current LCOS device fabrication practice, and speculates on future directions.

2:15 PM D4.3
Surface Acoustic Wave-Induced Electroluminescence Intensity Oscillation in Planar Light-Emitting Devices.
Marco Cecchini[1], Vincenzo Piazza[1], Fabio Beltram[1], Martin Ward[2], Andrew Shields[2], Harvey Beere[3] and David Ritchie[3]; [1]Scuola Normale Superiore and NEST-INFM, Pisa, Italy; [2]Toshiba Research Europe Limited, Cambridge, United Kingdom; [3]Cavendish Laboratory, Cambridge, United Kingdom.

Surface acoustic waves (SAWs) are attracting much interest in semiconductor community in view of the exploitation of their interaction properties with two-dimensional-electron-gases (2DEGs) embedded in semiconductor heterostructures[Phys. Rev. Lett. 56, 2104 (1986); Phys. Rev. Lett. 71, 3846 (1993)]. SAWs propagating through mesas containing high-quality 2DEGs indeed drive modifications on the 2DEG equilibrium state. Acoustic waves propagating along piezo-electric substrates are accompanied by potential waves which can trap electrons in their minima and induce dc currents or voltages (the so-called acoustoelectric effect)[Surf. Sci.305, 83 (1994); Solid State Commun. 84, 939 (1992); Solid State Commun. 84, 735 (1992)]. Moreover, this same interaction induces changes in SAW velocity and amplitude that can be used to probe the transport properties of two-dimensional systems[Phys. Rev. Lett. 56, 2104 (1986); Phys. Rev. Lett. 71, 3846 (1993); Phys. Rev. B 45, 11342 (1992); Phys. Rev. B 54, 13878 (1996)]. Many devices were proposed and realized exploiting the acoustoelectric effect but very few SAW based optoelectronic devices were reported. We recently introduced an original technique for fabricating high-performance planar light-emitting devices (pLEDs) with a geometry which is fully compatible with SAW propagation. pn lateral junctions were obtained by standard semiconductor processing techniques within a single GaAs quantum well embedded in a p-type modulation doped AlGaAs/GaAs heterostructure[Appl. Phys. Lett. 82, 636 (2003)]. We have integrated these junctions with interdigital transducers and studied the effect of SAWs on device optical and transport properties. From a fundamental physics point of view such devices extend the acoustoelectric effects to planar systems where both electrons and holes are present and allow detailed studies of the effects of the acoustic modulation in light-emitting devices. We demonstrated the possibility of controlling the electroluminescence emission by means of SAWs[Appl. Phys. Lett. in press]. Devices were systematically characterized by current-voltage, light-voltage, photoluminescence and lifetime measurements at cryogenic temperature. The traveling electric field associated with SAWs was found to drive electrons into the p-side of the junction when the junction was biased below the conduction threshold. It was thus possible to turn on transport and light emission by acoustic perturbations. We also studied SAW-induced electroluminescence signal by time-resolved measurements. We found that the intensity of the SAW-induced electroluminescence is modulated at the SAW frequency ($\sim$1 GHz), demonstrating electron injection into the p-type region synchronous with the SAW wavefronts.

2:30 PM D4.4
Efficient Focusing with an Ultra-Low Effective-Index Lens Based on Photonic Crystals.
Eugen Foca[1], V. V. Sergentu[2], Helmut Foell[1], Juergen Carstensen[1], Frank Daschner[1], Reinhard Knoechel[1] and I. M. Tiginyanu[2]; [1]Chair for General Materials Science, Faculty of Engineering, Christian-Albrechts-University of Kiel, Kaiserstr. 2, 24143 Kiel, Germany; [2]Institute of Applied Physics, Technical University of Moldova, 2004 Chisinau, Moldova.

Photonic Crystals (PC) are meta materials that allow to manipulate the propagation of electromagnetic radiation in hitherto unknown ways. Treating a PC as quasi-homogeneous meta material for suitable wavelength regions, it can be assigned an effective refractive index n_{eff} under certain circumstances that will be outlined, and this n_{eff} can be quite different from some average index obtained from the refractive indices of the material constituents of the PC; in particular it might be close to, or even smaller than zero. While these "negative index" or "left-handed" meta-materials have received considerable interest in recent years, quantitative experiments with these materials are still rather scarce. Based on a modified multiple scattering technique, the properties of a PC consisting of Al_2O_3 rods ($n \cong 3$ in the GHz regime) and having a sufficiently well-defined n_{eff} were calculated for wavelengths in the microwave regions; the corresponding frequencies are 6 GHz - 12 GHz. Based on these calculations, an optical element resembling a concave lens with an expected ultra-low n_{eff} was constructed from 112 Al_2O_3 rods and extensively characterized with microwave radiation in an anechoic chamber. The measurements mapped the intensity distribution behind the lens at high spatial resolution for a large range of frequencies in the TM and the TE mode. The results were analyzed with respect to the frequency dependence of n_{eff}, the focusing quality of the lens, and the transmission coefficient, and compared to predictions of