25th IEEE International Conference on Micro Electro Mechanical Systems

FINAL PROGRAM

29 JANUARY - 2 FEBRUARY 2012
PARIS, FRANCE

Paris Marriott Rive Gauche Hotel & Conference Center

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ROBOTICS AND AUTOMATION SOCIETY
IEEE
RÉGION Nord-Pas de Calais

CONFERENCE AT A GLANCE

	SUNDAY 29 January	MONDAY 30 January	TUESDAY 31 January	WEDNESDAY 1 February	THURSDAY 2 February
08:00		REGISTRATION (07:30 - 17:50)	REGISTRATION (08:00 - 18:00)	REGISTRATION (08:00 - 17:30)	REGISTRATION (08:00 - 13:30)
08:30		Welcome Address (08:30 - 09:00)	PLENARY SPEAKER II (08:30 - 09:10)	PLENARY SPEAKER III (08:30 - 09:10)	POSTER/ORAL SESSION IV (08:30 - 10:30)
09:00		PLENARY SPEAKER I (09:00 - 09:40)	SESSION IV Fabrication (09:10 - 10:30)	SESSION VII Medical Microsystems (09:10 - 10:30)	
09:30		SESSION I Optical MEMS (09:40 - 10:40)			
10:00					
10:30		Break & Exhibit Inspection (10:40 - 11:10)	Break & Exhibit Inspection (10:30 - 11:00)	Break & Exhibit Inspection (10:30 - 11:00)	Break & Exhibit Inspection (10:30 - 11:00)
11:00		SESSION II RF MEMS (11:10 - 12:30)	SESSION V Actuators (11:00 - 12:20)	SESSION VIII Sensors (11:00 - 12:20)	SESSION X Gyroscopes (11:00 - 12:00)
11:30					
12:00					SESSION XI Nano & Materials (12:00 - 13:20)
12:30		Lunch & Exhibit Inspection (12:30 - 13:30)	Lunch & Exhibit Inspection (12:20 - 13:20)	MEMS 2013 Announcement	
13:00				Lunch & Exhibit Inspection (12:30 - 13:30)	
13:30		POSTER/ORAL SESSION I (13:30 - 15:30)	POSTER/ORAL SESSION II (13:20 - 15:20)	POSTER/ORAL SESSION III (13:30 - 15:30)	CONFERENCE ADJOURNS (13:20)
14:00					
14:30					
15:00					
15:30		Break & Exhibit Inspection (15:30 - 16:00)	Break & Exhibit Inspection (15:20 - 15:50)	Break & Exhibit Inspection (15:30 - 16:00)	
16:00		SESSION III Power MEMS (16:00 - 17:40)	SESSION VI Bio & Chemical Microsystems (15:50 - 17:50)	SESSION IX Microfluidic Components & Systems (16:00 - 17:20)	
16:30					
17:00					
17:30				Adjourn for the day (17:20)	
18:00		Adjourn for the day (17:40)	Adjourn for the day (17:50)		
18:30	REGISTRATION AND WINE & CHEESE WELCOME RECEPTION (18:30 - 20:30)				
19:00					
19:30					
20:00				CONFERENCE BANQUET (20:00 - 23:00)	
20:30					
21:00					
21:30					
22:00					

TECHNICAL PROGRAM INFORMATION

The Technical Program consists of three plenary speaker presentations, a general session of contributed papers and 4 poster/oral sessions.

Oral Sessions

All oral sessions will be held in the La Seine Ballroom, Level 0.

Poster/Oral Sessions

The poster/oral format will consist of three (3) scheduled 10 minute, oral presentations which will be presented during each poster session on their assigned day in front of each poster starting at the designated times below. The remainder of the time should be used for questions & answers. The chimes will ring five minutes before the start of each presentation. Posters will be on display from Monday at 07:30 through Thursday at 11:00 in the Les Clubs de Jazz, Level -1. All poster papers are listed in this program by topic category with their assigned number starting on page 13. Authors will be available for questions throughout the entire assigned session.

SESSION I	SESSION III
Monday, 30 January 13:30 – 15:30	**Wednesday, 1 February** 13:30 – 15:30
Poster/Oral Presentation 1 – 14:00 Poster/Oral Presentation 2 – 14:30 Poster/Oral Presentation 3 – 15:00	Poster/Oral Presentation 1 – 14:00 Poster/Oral Presentation 2 – 14:30 Poster/Oral Presentation 3 – 15:00
SESSION II	**SESSION IV**
Tuesday, 31 January 13:20 – 15:20	**Thursday, 2 February** 08:30 – 10:30
Poster/Oral Presentation 1 – 13:50 Poster/Oral Presentation 2 – 14:20 Poster/Oral Presentation 3 – 14:40	Poster/Oral Presentation 1 – 09:00 Poster/Oral Presentation 2 – 09:30 Poster/Oral Presentation 3 – 10:00

Guide to Understanding Poster Numbering

Each poster is assigned a unique number which clearly indicates when and where the poster is presented. The number of each poster is shown on the left-hand side before the title. The number (i.e. 132) is the assigned poster board position on the floorplan. See floorplan on page 58.

A typical poster number is shown here is **132-TH**

The next character (i.e. **Th**) indicates the day of the Conference: **M** = Monday, **T** = Tuesday, **W** = Wednesday, **TH** = Thursday

Page Numbering

To assist you with finding the paper in the Technical Digest, we have provided the page number following each paper title.

Grand Palais © Paris Tourist Office - Photographer : David Lefranc

TECHNICAL PROGRAM

SUNDAY - 29 JANUARY 2012

18:30 - 20:30 **Registration, Wine & Cheese Welcome Reception and Exhibit Inspection**

MONDAY - 30 JANUARY 2012

08:30 - 09:00 **Welcome Address**
Lionel Buchaillot, *IEMN, FRANCE*
Hans Zappe, *University of Freiburg, GERMANY*

PLENARY SPEAKER I

Session Chairs:
L. Buchaillot, *IEMN, FRANCE*
H. Zappe, *University of Freiburg, GERMANY*

09:00 **CHALLENGES AND EMERGING DIRECTIONS IN SPINTRONICS** 1
Albert Fert
Unité Mixte de Physique CNRS and Université Paris-Sud, FRANCE

SESSION I - OPTICAL MEMS

Session Chairs:
T. Bourouina, *ESIEE, FRANCE*
H. Urey, *Koç University, TURKEY*

09:40 **A MICRO TRANSLATING LENS UNIT FOR STEREO IMAGING THROUGH SINGLE-IMAGE ENDOSCOPE** 3
W. Choi[1], G. Sigal[2], V. Rubtsov[2], and C.-J. Kim[1]
[1]University of California, Los Angeles, USA and [2]Intelligent Optical Systems, Inc. (IOS), USA

A translating lens device is developed to generate stereo images especially for endoscopic applications through a single-objective lens setup. A silicon comb-drive translates a miniature lens across the optical axis in front of an optical circuit to create different viewing angles through a single optical channel. With the added 3D viewing capability, this technology aims to enhance the operator's visual perception and work performance without sacrificing the endoscope's size.

10:00 **A FULLY INTEGRATED OPTOFLUIDIC MICRO-IRIS** 7
P. Müller, R. Feuerstein, and H. Zappe
University of Freiburg - IMTEK, GERMANY

We report on a novel type of tunable optofluidic micro-iris composed of a microfluidic chamber filled with two immiscible liquid phases, a highly absorbing aqueous pigment dispersion and a mixture of transparent silicone oils. The pigment dispersion, which is forced to assume a ring shape using a combination of changes in surface wettability and topography, defines a circular optical aperture of high contrast. Using integrated electrowetting actuation for tuning the aperture diameter in four discrete steps, a remarkable compactness of design is achieved.

10:20 **POLARIZATION SELECTIVE TUNABLE FILTER VIA TUNING OF FANO RESONANCES IN MEMS SWITCHABLE METAMATERIALS** 11
W.M. Zhu[1], J.H. Teng[2], X.H. Zhang[2], J.M. Tsai[2], Q.Y. Wu[2], H. Tanoto[2], H.C. Guo[2], T. Bourouina[3], G.Q. Lo[2], D.L. Kwong[2], and A.Q. Liu[1]
*[1]Nanyang Technological University, SINGAPORE, [2]Agency for Science, Technology and Research (A*STAR), SINGAPORE, and [3]Université Paris-Est, FRANCE*

We experimentally demonstrated polarization selective tuning of Fano resonance in tunable metamaterial using Microelectromechanical systems (MEMS). The transmission spectra of TE polarized incidence can be tuned while maintain those of the TM polarized incidence by continuously shifting one trapezoid of the cross-shaped unit cell. We fabricated an array of 400 _ 400 cross-shaped cells array using silicon deep reactive-ion etching (DRIE) technology. It measures a Fano resonance frequency shift of 37.9% (low frequency region) and 25.7% (high frequency region) for TE polarized incidence and only 0.8% for TM polarized incidence. Compared with the previous efforts on tunable metamaterials, the tunable metamaterial promises unprecedented tunability, such as single to dual band tuning, polarization selective tuning etc.

10:40 - 11:10 **Break & Exhibit Inspection**

MONDAY - 30 JANUARY 2012

SESSION II - RF MEMS

Session Chairs:
T. Kenny, *Stanford University, USA*
G. Piazza, *University of Pennsylvania, USA*

11:10 **AN INTEGRATED RF MEMS TUNABLE FILTER** **15**
Y. Shim, J. Ruan, Z. Wu, and M. Rais-Zadeh
University of Michigan, USA

This paper reports on a high-performance lumped bandpass filter continuously tuned from 1 GHz to 0.6 GHz using 12 electrostatically actuated MEMS capacitors. To demonstrate the benefits of MEMS technology, a reconfigurable filter array is implemented on a PCB using SMT components and its performance is compared to that of the MEMS filter. Besides the advantage in size, the MEMS filter also exhibits lower loss and greater rejection. To become a viable solution for RF applications, other performance specifications of MEMS filters such as tuning speed and reliability need to be improved.

11:30 **A SILICON NITRIDE OPTOMECHANICAL OSCILLATOR WITH ZERO FLICKER NOISE** **19**
S. Tallur, S. Sridaran, and S.A. Bhave
Cornell University, USA

We present an integrated chip-scale Radiation-Pressure driven Opto-Mechanical Oscillator (RP-OMO) in silicon nitride with excellent close-to-carrier phase noise. We illustrate a process to micro-fabricate opto-mechanical resonators, waveguides and grating couplers in silicon nitride and demonstrate an RP-OMO operating at 41.947MHz, with phase noise of -85dBc/Hz at 1kHz offset. The phase noise does not show 1/f^3 or other higher order slopes all the way down to 10Hz offset from carrier.

11:50 **A 27 MHZ TEMPERATURE COMPENSATED MEMS OSCILLATOR WITH SUB-PPM INSTABILITY** **23**
R. Tabrizian, M. Pardo, and F. Ayazi
Georgia Institute of Technology, USA

This paper reports on the implementation and characterization of a low phase-noise 27 MHz MEMS oscillator with sub-ppm temperature instability based on a high-Q composite bulk acoustic wave resonator. An array of silicon dioxide pillars has been uniformly embedded in the silicon body of a piezoelectrically-transduced resonator to compensate its temperature coefficient of frequency. Using this technique, overall frequency drift < 90 ppm is achieved over the temperature range of -20°C to 100°C while resonator Q remains greater than 7,500 in atmospheric pressure. An electronically compensated oscillator based on these resonators exhibits sub-ppm temperature instability using active shunt-capacitance cancellation and varactors. Long-term stability measurement has been carried out for both temperature-compensated resonator and oscillator in environmental chambers to study their long-term frequency and Q stability.

12:10 **MICROMACHINED SAPPHIRE GHz LATERAL OVERTONE BULK ACOUSTIC RESONATORS TRANSDUCED BY ALUMINUM NITRIDE** **27**
N.-K. Kuo[1], S. Gong[1], J. Hartman[2], J. Kelliher[2], W. Miller[2], J. Parke[2], S.V. Krishaswamy[2], J.D. Adam[2], and G. Piazza[1]
[1]*Univesity of Pennsylvania, USA and* [2]*Norhrop Grumman Corporation, USA*

This work introduces a new class of piezoelectric-transduced bulk acoustic wave resonators formed by a micro-machined c-plane sapphire membrane (~ 750 nm) in the lateral overtone bulk acoustic resonator (LOBAR) configurations. For the first time, thin film sapphire is achieved via a layer transfer process from a single crystal c-plane sapphire wafer. A novel annular geometry exhibits high f_Q of 4.1•E12 Hz and 4.6•E12 Hz at 1 and 2 GHz, respectively with a 9% of transducer to sapphire coverage ratio. The conventional rectangular LOBAR with coverage ratio of 0.57% exhibits the highest f_Q (1.53·E13 Hz) ever reported for AlN-based suspended resonators.

12:30 - 13:30 **Lunch & Exhibit Inspection**

13:30 - 15:30

POSTER/ORAL - SESSION I

Session Chairs:
J. Ducrée, *Dublin City University, IRELAND*
D. Young, *University of Utah, USA*

15:30 - 16:00 **Break & Exhibit Inspection**

Notre-Dame, rose window © Paris Tourist Office - Photographer: Amélie Dupont

MONDAY - 30 JANUARY 2012

SESSION III - POWER MEMS

Session Chairs:
R. Ghodssi, *University of Maryland, USA*
A. Holmes, *Imperial College, UK*

16:00 **A NOVEL ELECTROMECHANICAL INTERROGATION SCHEME FOR IMPLANTABLE PASSIVE TRANSPONDERS** **31**
A. Kim, T. Maleki, and B. Ziaie
Purdue University, USA

We report on a novel electromechanical energy scavenging and wireless interrogation scheme using low frequency components of musical vibrations. The device incorporates a piezoelectric cantilever beam that converts the acoustic vibrations into electric power in parallel with a PDMS based inductive pressure sensor. Musical sound wave from a loudspeaker induces vibrations in the piezoelectric cantilever at harmonics, which match its resonant frequency. This, in turn generates a voltage that is rectified and stored in the capacitor. At non-resonant harmonics, the supply is interrupted, causing the stored charge to be dumped into the sensing LC tank inducing oscillations at its natural frequency, which is picked up externally with a receiver coil.

16:20 **A MICROSTRUCTURED CATHODE FOR FUEL CELL WITH SELF-REGULATED O_2 BUBBLE CREATION AND CONSUMPTION** **35**
J.I. Hur and C.-J. Kim
University of California, Los Angeles, USA

We introduce a monolithic cathode that self-regulates oxygen supply to a fuel cell, complementing the monolithic self-pumping anode previously developed in our lab. Our cathode generates oxygen, consumes generated oxygen bubbles, and stops the generation when not consumed, all in a self-regulating fashion. Half-cell tests show reasonable current output, suggesting a complete (full) fuel cell of no moving part in the near future.

16:40 **SILICON CARBIDE NANOWIRES AS AN ELECTRODE MATERIAL FOR HIGH TEMPERATURE SUPERCAPACITORS** **39**
M. Vincent, M.S. Kim, C. Carraro, and R. Maboudian
University of California, Berkeley, USA

We report on the growth of silicon carbide (SiC) nanowires and the evaluation of their performance as electrode material for micro-supercapacitors. Their specific capacitance has been studied as a function of their morphology (size, diameter) and the optimal growth conditions to a capacitance at the level of the state of the art. They exhibit an exceptional stability, with a lifetime exceeding lead 106 charge/discharge cycles. An excellent thermal stability is expected, opening the way to the fabrication of high temperature micro-supercapacitors.

17:00 **µL-SCALE MICROBIAL FUEL CELL WITH OPTIMAL POWER GENERATION AND BIOFILM FORMATION** **43**
S. Choi and J. Chae
Arizona State University, USA

We report a µL-scale microfluidic Microbial Fuel Cell (MFC) having optimal biofilm formation and minimal oxygen invasion into its anode chamber to generate high power density. We obtained a maximum power density of 95 µW/cm2, the highest value among previously reported µL-scale MFCs and even comparable to that of macro-scale counterparts.

17:20 **HIGH EFFICIENT µ-PEMFCS BY INTEGRATING MICRO/NANO SCALED PERFORMANCE IMPROVING COMPONENTS** **47**
H.-C. Peng[1], C.-N. Wang[1], Y.-C. Su[1], T.-K. Yeh[1], and F.-G. Tseng[1,2]
[1]National Tsing Hua University, TAIWAN and [2]Academia Sinica, TAIWAN

A silicon-based and fully integrated micro proton exchange membrane fuel cell(µ-PEMFC) is introduced in this paper which can carry out high-efficient catalyst utilization and outstanding cell performance. The design integrates micro/nano-machining technique to enhance reaction surface areas, micro-patterned reaction chamber to create more three-phase zones and reduce fuel diffusion impedance, and micro-interlocks to solidify interfacial strength and reduce ohmic impedance of a single chip.

17:40 Adjourn for the Day

Jardin des Tuileries (public garden) © Paris Tourist Office - Photographer : Amélie Dupont

TECHNICAL PROGRAM

TUESDAY - 31 JANUARY 2012

PLENARY SPEAKER II

Session Chairs:
L. Buchaillot, *IEMN, FRANCE*
H. Zappe, *University of Freiburg, GERMANY*

08:30 **SEMICONDUCTOR DEVICES INSPIRED BY AND INTEGRATED WITH BIOLOGY** **51**
John A. Rogers
University of Illinois, Urbana-Champaign, USA

Biology is curved and elastic; silicon wafers are not. Semiconductor technologies that can bridge this gap in form and mechanics will create new opportunities in devices that adopt biologically inspired designs or require intimate integration with the human body. This talk describes ideas for electronics that offer the mechanical properties of a rubber band and illustrates their use in (1) bio-integrated, 'skin-like' systems for mapping cardiac and neural electrophysiology, and (2) bio-inspired, 'eyeball' cameras for wide field-of-view imaging.

SESSION IV - FABRICATION

Session Chairs:
S. Lacour, *École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND*
L. Lin, *University of California, Berkeley, USA*

09:10 **AN ULTRA-COMPLIANT, SCALABLE NEURAL PROBE WITH MOLDED BIODISSOLVABLE DELIVERY VEHICLE** **56**
P.J. Gilgunn[1], R. Khilwani[1], T.D.Y. Kozai[2], D.J. Weber[2], X.T. Cui[2], G. Erdos[1], O.B. Ozdoganlar[1], and G.K. Fedder[1]
[1]Carnegie Mellon University, USA and [2]University of Pittsburgh, USA

We have developed a fabrication method for the formation of biodissolvable needles that serve as delivery vehicles for ultracompliant neural implants with wire dimensions on the order of 10 microns width and 3 microns thickness.

09:30 **3-D WIRING ACROSS VERTICAL SIDEWALLS OF SI PHOTO CELLS FOR SERIES CONNECTION AND HIGH VOLTAGE GENERATION** **60**
S. Kumagai, T. Yamamoto, H. Kubo, and M. Sasaki
Toyota Technological Institute, JAPAN

This paper first reports 3-D wiring across vertical sidewalls for summing the voltage of Si photo cells based on photolithography. Si photo cells on the buried oxide are isolated by etching the SOI device layer. Wiring using the vertical sidewalls minimizes the shadow region caused by the metal electrode. The techniques of the spray coating of the photoresist and the angled exposure through the absorbent liquid are applied. 100 cells with 100-micrometer spans are connected generating 10.1V.

09:50 **FOIL-LEVEL FABRICATION OF INKJET-PRINTED PYROMEMS BALLOON ACTUATORS** **64**
D.A. de Koninck, F. Molina Lopez, D. Briand, and N.F. de Rooij
École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

We present the fabrication, modeling and validation of polymeric pyroMEMS balloon actuators compatible with low-cost printing and lamination techniques at the foil level. The device consists of a solid propellant charge deposited within a micro-fabricated cavity covered by a thin PDMS membrane. Fuel combustion generates high-pressure gas, which inflates the membrane to do work. The resulting devices were not only simpler to fabricate, but consumed less power than similar silicon-based devices.

10:10 **A METHOD AND ELECTRICAL MODEL FOR THE ANODIC BONDING OF SOI AND GLASS WAFERS** **68**
E. Tatar, M.M. Torunbalci, S.E. Alper, and T. Akin
Middle East Technical University, TURKEY

This paper provides a method for the anodic bonding of SOI and glass wafers and explains the bonding mechanism with an electrical model, for the first time. SOI-glass anodic bonding can be achieved at voltages as low as 250V similar to Si-glass anodic bonding, and the underlying principles can be understood by modeling the overall system with a series connected capacitor-resistor network. The proposed model is also successfully adapted to glass-Si-glass anodic bonding.

10:30 - 11:00 Break & Exhibit Inspection

TECHNICAL PROGRAM

TUESDAY - 31 JANUARY 2012

SESSION V - ACTUATORS

Session Chairs:
C.J. Kim, *University of Los Angeles, USA*
S. Takeuchi, *University of Tokyo, JAPAN*

11:00 **SELF-FOLDING CELL ORIGAMI: BATCH PROCESS OF SELF-FOLDING 3D CELL-LADEN MICROSTRUCTURES ACTUATED BY CELL TRACTION FORCE** **72**
K. Kuribayashi-Shigetomi, H. Onoe, and S. Takeuchi
University of Tokyo, JAPAN

We harness the cell traction force to fabricate cell hinges that induce the rapid origami-like self-folding of flat culture plates into diverse three-dimensional (3D) cell-laden microstructures. In order to gain precise control over the folding angle between the folding plate and substrate, we engineered a flexible joint between the microplates. We achieved mass production of the cell-laden microstructures with precise folding angles.

11:20 **MULTIARTICULAR ACTUATOR COMPOSED OF SERIALLY CONNECTED MICROPISTONS FOR WEARABLE ACTUATOR** **76**
T. Obara and S. Konishi
Ritsumeikan University, JAPAN

11:40 **CONTINUOUSLY LATCHABLE SHUTTLE USING CARBON NANOTUBES ON SIDEWALL SURFACES** **80**
Y. Eun, J. Choi, H. Na, D.-H. Baek, M.-O. Kim, J.-I. Lee, and J. Kim
Yonsei University, SOUTH KOREA

We demonstrated a novel usage of self-adjusted, vertically aligned carbon nanotube (CNT) arrays integrated on the sidewalls as latching components. The CNT array-based latching mechanism showed stable latching at multiple latching positions, together with reversible and bidirectional latching capabilities.

12:00 **HIGH-PERFORMANCE MEMS RELAY USING A STACKED-ELECTRODE STRUCTURE AND A LEVERING AND TORSIONAL SPRING FOR POWER APPLICATIONS** **84**
Y.-H. Song, C.-H. Han, M.-W. Kim, J.O. Lee, and J.-B. Yoon
Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA

We suggest, fabricate, and demonstrate an electrostatically-actuated MEMS relay, featuring extremely low contact resistance, high stand-off voltage and relay resurrection. It is based on a unique stacked-electrode structure for very low contact resistance and a levering and torsional spring for enhancing a stand-off voltage (maximum drain voltage to withstand in the off-state) and contact endurance.

12:20 - 13:20 Lunch & Exhibit Inspection

13:20 - 15:20

POSTER/ORAL - SESSION II

Session Chairs:
S. Franssila, *Aalto University, FINLAND*
S. Sedky, *American University in Cairo, EGYPT*

15:20 - 15:50 Break & Exhibit Inspection

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SESSION VI - BIO & CHEMICAL MICROSYSTEMS

Session Chairs:
K. Böhringer, *University of Washington, USA*
S. Kwon, *Seoul National University, SOUTH KOREA*

17:50 **Adjourn for the Day**

TECHNICAL PROGRAM

WEDNESDAY - 1 FEBRUARY 2012

PLENARY SPEAKER III

Session Chairs:
L. Buchaillot, *IEMN, FRANCE*
H. Zappe, *University of Freiburg, GERMANY*

08:30 **MICROROBOTS IN SPOTLIGHT FOR EVOLUTION OF BIOMEDICINE** **112**
Fumihito Arai[1,2] and M. Hagiwara[2]
[1]Nagoya University, JAPAN and [2]Seoul National University, SOUTH KOREA

SESSION VII - MEDICAL MICROSYSTEMS

Session Chairs:
M. Mehregany, Case Western University, USA
H. Takao, Kagawa University, JAPAN

09:10 **LABEL-FREE ULTRARAPID SPHEROID FORMATION IN MICROFLUIDIC CHIP USING MAGNETO-ARCHIMEDES EFFECT** **116**
Y. Akiyama[1] and K. Morishima[1,2]
[1]Tokyo University of Agriculture and Technology, JAPAN and [2]Osaka University, JAPAN

This paper demonstrates to form spheroids on an array in a microfluidic chip without cell labeling nor specific pattern of a microchannel. Label-free ultrarapid magnetic cell manipulation became possible by adding a paramagnetic salt into culturing medium to enhance the diamagnetic property of the cells. Cells in the paramagnetic medium were aggregated rapidly on an array within a microchannel by applying a magnetic field and the cell aggregates became spheroids after one day of culture. Heterospheroids consisting of two different kinds of cells were also formed by this method.

09:30 **DEVELOPMENT OF A NOVEL CATHETER FOR EARLY DIAGNOSIS OF BACTERIAL MENINGITIS CAUSED BY THE VENTRICULAR DRAIN** **120**
C. Li[1] and R.K. Narayan[2]
[1]Feinstein Institute for Medical Research, USA and [2]Hofstra North Shore-LIJ School of Medicine, USA

A novel smart catheter for the early diagnosis of bacterial meningitis caused by the use of external ventricular drainage catheter was developed and characterized in this work. The specific targeted aim is the rapid differentiation between bacterial meningitis and aseptic meningitis by continuous measurement of the cerebrospinal fluid lactate levels. A long-term implantable lactate biosensor was developed to achieve this goal.

09:50 **PARYLENE-BASED ELECTROCHEMICAL-MEMS FORCE SENSOR ARRAY FOR ASSESSING NEURAL PROBE INSERTION MECHANICS** **124**
B.J. Kim[1], C.A. Gutierrez[1], G.A. Gerhardt[2], and E. Meng[1]
[1]University of Southern California, USA and [2]University of Kentucky Chandler School of Medicine, USA

We present the first Parylene-based electrochemical-MEMS sensor array for instrumentation of ceramic-based intracortical shanks. The array leverages the impedance-based force transduction capability of encapsulated liquids within a Parylene microchannel to measure in real time out-of-plane interfacial forces imposed on the shank surface during insertion. We demonstrate measurements of the relative force distribution of interfacial forces produced along the shank surface, which facilitates a deeper understanding of probe insertion mechanics and better probe design.

10:10 **TRIAXIAL FORCE SENSOR FOR LINGUAL MOTION SENSING** **128**
Y. Takei[1], K. Noda[1], T. Kawai[2], T. Tachimura[2,3], Y. Toyama[4], T. Ohmori[4], K. Matsumoto[1], and I. Shimoyama[1]
[1]University of Tokyo, JAPAN, [2]Aggregate Co. TOUCH, JAPAN, [3]Osaka University, JAPAN, and [4]MEIJI Co., Ltd., JAPAN

We fabricated the triaxial force sensor applicable to human lingual motion measurement. Water swallowing experiment was carried out and we measured the triaxial shear force acting on palate (roof of the mouth). This result leads to quantification of the ease of consumption.

10:30 - 11:00 Break & Exhibit Inspection

WEDNESDAY - 1 FEBRUARY 2012

SESSION VIII - SENSORS

Session Chairs:
G. Krijnen, *University of Twente, THE NETHERLANDS*
T. Tsuchiya, *Kyoto University, JAPAN*

11:00 **STOCHASTIC GRAVITY SENSOR WITH ROBUST OUTPUT USING WHITE-NOISE-APPLIED BI-STABLE STATE FOR LOW S/N ENVIRONMENTS** **132**
Y. Hatakeyama, M. Esashi, and S. Tanaka
Tohoku University, JAPAN

This paper describes the simulation and experiment of a stochastic gravity sensor, which just counts the number, m, of pull-in to either of counter electrodes in n-times trials to know pull-in probability, m/n, under white-noise-applied bistable state. This new sensing principle is robust against noise and parasitics, which severely limit sensor performance in such a low S/N situation that the sensor in a harsh environment is connected with a read-out circuit using a long wire.

11:20 **CMOS INTEGRATED SILICON/GLASS-BONDED 3D FORCE/TORQUE SENSOR** **136**
J. Handwerker, P. Gieschke, M. Baumann, and O. Paul
University of Freiburg - IMTEK, GERMANY

We report on the design, processing and characterization of a miniaturized 3D force/torque sensor with a load range of 10 N and 5 cNm. The sensor has a total size of only 4x3x1.6 mm3 and is available in two designs. It consists of a CMOS sensor chip and a patterned Pyrex cap which is firmly attached either by anodic or adhesive Cytop bonding and concentrates the mechanical stress the surface of the CMOS chip. Locations of the stress sensors for maximum sensitivity and selectivity with respect to all six possible loads were determined by 3D finite-element simulations. The successful measurement of arbitrary 3D force and torque combinations is demonstrated.

11:40 **TRIAXIAL FORCE SENSOR WITH STRAIN CONCENTRATION NOTCH BEAM FOR MEASUREMENT OF INSECT FLIGHT FORCE** **140**
K. Azuma, H. Takahashi, T. Kan, K. Matsumoto, and I. Shimoyama
University of Tokyo, JAPAN

We propose a triaxial force sensor for measurement of insect flight force. The sensor is composed of a cantilever and beams to support the cantilever. Among them, notch beams with sidewall doping were formed in order to achieve both high sensitivity and high resonance frequency. We demonstrated measurement flight force of a fruit fly (drosophila) using this sensor.

12:00 **MULTI-FUNCTIONAL INTEGRATED SENSORS FOR THE ENVIRONMENT** **144**
C.L. Roozeboom[1], J.Y. Sim[1], D. Wickeraad[2], B. Dura[1], W.S. Smith[2], M.A. Hopcroft[2], P.G. Hartwell[2], R.S. Williams[2], and B.L. Pruitt[1]
[1]Stanford University, USA and [2]Hewlett-Packard, USA

We present a multi-functional integrated sensor for the environment (M-FISE) that combines ten sensor functions on a single silicon die. The purpose of the M-FISE is to monitor important environmental parameters such as temperature, humidity and air speed, along with acceleration in three axes. To our knowledge, the M-FISE demonstrates the highest degree of sensor fusion yet demonstrated on a single chip.

12:20 - 12:30 **MEMS 2013 Announcement**

12:30 - 13:30 **Lunch & Exhibit Inspection**

13:30 - 15:30

POSTER/ORAL - SESSION III

Session Chairs:
K. Takahata, *University of British Columbia, CANADA*
X. Wang, *Tsinghua University, CHINA*

15:30 - 16:00 **Break & Exhibit Inspection**

WEDNESDAY - 1 FEBRUARY 2012

SESSION IX - MICROFLUIDIC COMPONENTS & SYSTEMS

Session Chairs:
G.-B. Lee, *National Tsing Hua University, TAIWAN*
M. Seki, *Chiba University, JAPAN*

16:00 **AIR-FLOW BASED MULTIFUNCTIONAL TACTILE DISPLAY DEVICE WITH MULTI-JET INTEGRATED MICRO VENTURI NOZZLE ARRAY 148**
M. Arai, K. Terao, T. Suzuki, F. Simokawa, F. Oohira, and H. Takao
Kagawa University, JAPAN

In this paper, the first air-flow based multifunctional tactile display with 1-D mixed array of integrated air nozzles and multi-jet integrated micro venturi atomizers are presented. This device realizes simultaneous tactile presentation of "object surface shape" by distributed air-flow pressures and "sense of cold (cryesthesia)" by arrayed liquid mist injection. Multifunctional and distributed tactile presentation has been successfully demonstrated for the first time.

16:20 **A MONOLITHIC 48-STAGE SI-MICROMACHINED KNUDSEN PUMP FOR HIGH COMPRESSION RATIOS 152**
N.K. Gupta, S. An, and Y.B. Gianchandani
University of Michigan, USA

This paper reports a Si-micromachined, 48-stage, monolithic Knudsen pump that can pump down from 760Torr to <50Torr or from 250Torr to ≈5Torr. These compression ratios of 15 and 50 offer 10x improvement over those reported in the past. This paper also describes the first single-wafer microfabrication process for a Knudsen pump; past approaches have utilized more than one wafer.

16:40 **NANO-OPTOFLUIDICS FOR SINGLE MOLECULE DETECTION AND SORTING 156**
Y. Yang[1], J.M. Tsai[2], D.L. Kwong[2], and A.Q. Liu[1]
*[1]Nanyang Technological University, SINGAPORE and [2]Agency for Science, Technology and Research (A*STAR), SINGAPORE*

This paper reports a nano-optofluidic device using evanescent wave sensing for single molecule detection and sorting based on hydrodynamic focusing and total internal reflection (TIR). Nano-sized samples in liquid can be measured and counted even their size is smaller than the diffraction limit. We have demonstrated successful imaging of 200-nm nanoparticle. As compared to the conventional TIR microscopy, all samples focused in the fluids can be measured and counted rather than only the solid-liquid interface. It has wide range applications in single molecule detection, imaging and counting in the near future.

17:00 **A SINGLE-MICROBEAD-BASED MICROFLUIDIC DIODE FOR ULTRA-LOW REYNOLDS NUMBER APPLICATIONS 160**
R.D. Sochol, K. Iwai, J. Lei, D. Lingam, L.P. Lee, and L. Lin
University of California, Berkeley, USA

A single-layer microfluidic diode that uses a single microbead as a resistive element is demonstrated for the first time. Fluid dynamics simulations and experimental approaches were employed to characterize the single-microbead-based microfluidic diode under ultra-low Reynolds Number conditions (Re < 0.25).

17:20 **Adjourn for the Day**

20:00 - 23:00 **Conference Banquet**
La Seine Ballroom

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TECHNICAL PROGRAM

THURSDAY - 2 FEBRUARY 2012

08:30 - 10:30

POSTER/ORAL - SESSION IV

Session Chairs:
J. Oberhammer, *Royal Institute of Technology (KTH), SWEDEN*
K. Turner, *University of California, Santa Barbara, USA*

10:30 - 11:00 Break & Exhibit Inspection

SESSION X - GYROSCOPES

Session Chairs:
F. Ayazi, *Georgia Institute of Technology, USA*
J. Miao, *Nanyang Technical University, SINGAPORE*

11:00 **NORTH-FINDING WITH 0.004 RADIAN PRECISION USING A SILICON MEMS QUADRUPLE MASS GYROSCOPE WITH Q-FACTOR OF 1 MILLION** **164**
I.P. Prikhodko, A.A. Trusov, and A.M. Shkel
University of California, Irvine, USA

We report a feasibility demonstration of precision north-finding with measured 4 milliradian (mrad) 1-σ uncertainty using an in-house developed silicon MEMS rate sensor. The sensor utilizes recently introduced dynamically balanced, high performance Quadruple Mass Gyroscope (QMG) architecture. A stand-alone, vacuum packaged QMG with measured isotropic Q-factor of 1.2 million and in-run bias stability of 0.1 deg/hr was instrumented for true North (azimuth) detection by measuring components of the Earth's rotation. Continuous carouseling of the gyroscope's sensitive axis in a horizontal plane using a rate table was investigated. Each 360 deg turn of the carouseling yields an azimuth datapoint with a Gaussian random error. Filtration of multiple-turn azimuth datapoints produces a true azimuth estimation whose uncertainty distributed scales down as the square root of the number of the carouseling cycles. This method yields a progressively more precise azimuth, beyond the noise limits of the gyroscope. Self-calibration algorithms including temperature compensation and 2-point azimuth measurement have been also implemented as potentially more practical alternatives to the carouseling.

11:20 **3-D MICROMACHINED HEMISPHERICAL SHELL RESONATORS WITH INTEGRATED CAPACITIVE TRANSDUCERS** **168**
L.D. Sorenson, X. Gao, and F. Ayazi
Georgia Institute of Technology, USA

We present a self-aligned fabrication method developed for 3-D micro-scale hemispherical shell resonators with integrated capacitive transducers and a center post for electrical access to the shell. The self-aligned process preserves the axisymmetry for robust, balanced resonators that can potentially reach very high-Q due to suppressed anchor loss. High-Q operation of a polysilicon shell resonator is verified by exciting devices capacitively into a breathing resonance mode, with measured Q of 8,000 at 412kHz.

11:40 **HIGH-Q, 3KHZ SINGLE-CRYSTAL-SILICON CYLINDRICAL RATE-INTEGRATING GYRO (CING)** **172**
J. Cho, J.A. Gregory, and K. Najafi
University of Michigan, USA

We present the design, fabrication, and test results of a low-frequency single-crystal-Si cylindrical rate-integrating gyroscope (CING). The gyro is fabricated using the silicon-on-glass (SOG) process, operates at 3kHz, and provides a damping time of ~10 seconds when the frequencies are matched. The gyro is controlled by a digital circuit, implemented in the FPGA in a USRP DSP, for both rate and rate-integrating modes.

SESSION XI - NANO & MATERIALS

Session Chairs:
J. Kim, *Yonsei University, KOREA*
C.-H. Lin, *National Sun Tau-sen University, TAIWAN*

12:00 **THERMAL CONDUCTIVITY MANIPULATION IN SINGLE CRYSTAL SILICON VIA LITHOGRAPHYCALLY DEFINED PHONONIC CRYSTALS** **176**
B. Kim[1], J. Nguyen[1], P.J. Clews[1], C.M. Reinke[1], D. Goettler[2], Z.C. Leseman[2], I. El-Kady[1,2], and R.H. Olsson, III[1]
[1]*Sandia National Laboratories, USA and* [2]*University of New Mexico, USA*

Thermal conductivity of single crystal silicon was engineered as low as 32.6W/mK using lithographically formed phononic crystals, which is ~75% reduction compared to bulk silicon thermal conductivity. Specifically sub-micron through-holes were periodically patterned in 500nm-thick silicon layers effectively enhancing both coherent and incoherent phonon scattering, resulting in as large as 37% reduction in thermal conductivity beyond the contributions of the thin-film and volume reduction effects. The demonstrated method uses conventional lithography-based technologies that are directly applicable to diverse micro/nano-scale devices, leading toward huge performance improvements where heat management is important.

THURSDAY - 2 FEBRUARY 2012

12:20 **MEMS SWITCHES EMPLOYING ACTIVE METAL-POLYMER NANOCOMPOSITES** **180**
S. Paydavosi, F.M. Yaul, A.I. Wang, F. Niroui, T.L. Andrew, V. Bulovic, and J.H. Lang
Massachusetts Institute of Technology, USA

It has been known for several decades that polymers doped with conducting particles, for example silicone with nickel nano-particles, exhibit a dramatically decreasing resistivity as the polymer is compressed. Such composites conduct via tunneling from particle to particle, and the tunneling currents grow exponentially as the particles become closer together. In this study, we employ this property of conductive composites to develop an electrostatically actuated squishable switch, or "squitch" which functions as a gated transistor.

12:40 **LAYER-BY-LAYER NANOASSEMBLY OF IRIDIUM OXIDE/PLATINUM-BLACK FOR LOW IMPEDANCE, HIGH CHARGE INJECTING MICROELECTRODE APPLICATIONS** **184**
S. Yamagiwa, A. Fujishiro, A. Ikedo, M. Ishida, and T. Kawano
Toyohashi University of Technology, JAPAN

We report an electrode device with a low impedance and high charge injecting characteristics for a powerful application to micro/nano-scale electrophysiological measurements of neuron/cells. Due to the small effective electrode area, conventional microelectrodes exhibit high impedance (~10MΩ at 1kHz) and low charge injection characteristics, making the targeted cells impossible to record/stimulate. To overcome these limitations, we propose enhanced surface-area of an electrode with a low impedance material, based on layer-by-layer assembled iridium oxide (IrOx)/platinum-black (Pt-black) with nano-scale roughness. The assembled nanorough-IrOx/Pt-black electrode exhibits 2 times lower impedance and 2.4 times larger injection delivery capacity (QCDC) compared to a conventional planer-IrOx electrode with the same size. Additionally, we fabricated nanorough-Ir/Pt-black tipped microprobes and demonstrated in saline, while improved stimulating currents were observed.

13:00 **SELF-ASSEMBLED NANO-ELECTRO-MECHANICAL TRI-STATE CARBON NANOTUBE SWITCHES FOR RECONFIGURABLE INTEGRATED CIRCUITS** **188**
J. Cao, W.A. Vitale, and A.M. Ionescu
École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

Carbon nanotubes (CNTs) have been proved to be ideal for building nano-electro-mechanical systems (NEMS), such as nano-switches. We report, for the first time, self-assembled cantilevered and clamped-clamped tri-state CNT (T-CNT) NEM switches with 100 nm air-gap dual lateral gates. Sub-50 nm precision and high yield have been achieved. Unlike conventional bi-state CNT switches, the T-CNT NEM switches operate in three states: CNT in the center (OFF), CNT attracted to the left gate (ON-1) or to the right gate (ON-2). They exhibit excellent sensing current windows (Ion/Ioff~1E7), ultra-low Ioff (~1E-14A), good isolation and high endurance (cycle>100). The proposed hysteretic switches offer a CMOS-compatible bottom-up approach for various potential applications: logic devices, memories, etc., with higher circuit density and novel ultra-scaled configurability functions.

13:20 **Conference Adjourns**

POSTER/ORAL PRESENTATIONS

M	- Monday 13:30 – 15:30	W	- Wednesday 13:30 – 15:30
T	- Tuesday 13:20 – 15:20	TH	- Thursday 08:30 – 10:30

FABRICATION TECHNOLOGIES

28-TH **NEW WAFER-SCALE MEMS FABRICATION OF 3D SILICON/METAL CANTILEVER ARRAY SENSOR** 297

Y. Zhang[1], A. Toda[2], H. Okada[1], T. Kobayashi[1], T. Itoh[1], and R. Maeda[1]
[1]National Institute of Advanced Industrial Science and Technology (AIST), JAPAN and [2]Meltex Inc., JAPAN

This paper presents a new wafer-scale micromachining technology of three-dimensional (3D) cantilever array for sensor application. The 3D cantilever consists of a vertically Si/metal laminated structure so that it works in the in-the-plane mode, which is totally different from those traditional cantilevers of planar laminated configuration. The 3D cantilever has the advantage of easy-to-package, non-stiction and compact but it is involved of surface micromachining technology on high topography surface. High resolution patterning technology of thick electroless-plated nickel alloy film was for the first time successfully established. The minimum feature size of 10 um was successfully formed in the 1.5 µm-thick nickel film with the undercut ratio of about 1. Prototype of 5-pair 3D cantilever array was successfully fabricated by the new micromachining technology.

29-M **ONE-STEP FABRICATION OF OPTICALLY TRANSPARENT POLYDIMETHYLSILOXANE ARTIFICIAL LOTUS LEAF FILM USING UNDER-EXPOSED UNDER-BAKED PHOTORESIST MOLD** 301

Y. Yoon[1], D.-W. Lee[1,2], J.-H. Ahn[2], J. Sohn[1], and J.-B. Lee[1]
[1]University of Texas, Dallas, USA and [2]Chonnam National University, SOUTH KOREA

We report a novel extremely simple one-step fabrication technique to create optically transparent combined micro/nano surface lotus leaf-like PDMS thin film using under-exposed under soft baked photoresist (PR) mold. Significant under soft baking makes photoresist retains good amount of solvent which greatly increase the dissolution rate of the unexposed photoresist during. Once this condition is combined with the under-exposure condition, we believed that it would create a mushroom developing -like structure. Such high optical transmittance is greatly beneficial to apply this optically transparent water-repellent artificial lots leaf PDMS film to various applications including emerging self-cleaning applications such as self-cleaning solar panel protective coating and permanent anti-fog mirror application, etc.

30-T **POLY-SIGE-BASED CMUT ARRAY WITH HIGH ACOUSTICAL PRESSURE** 305

Ph. Helin, P. Czarnecki, A. Verbist, G. Bryce, X. Rottenberg, and S. Severi
IMEC, BELGIUM

This paper reports a novel manufacturable build-up of a CMUT device, CMOS compatible using polycrystalline silicon-germanium (poly-SiGe) as structural material complemented with silicon carbide (SiC) as dielectric layer. Some acoustical tests are reported as demonstration. Center frequency and fractional bandwidth have been measured for different geometry based on the Fourier transform of the pulse-echo signal. Breakdown voltage of above 500V and 600kPa acoustical pressure are demonstrated and are among the highest values reported for transmit CMUT devices.

31-W **PRINTED MEMS MEMBRANES ON SILICON** 309

A. Murarka, S. Paydavosi, T. Andrew, A. Wang, J. Lang, V. Bulovic
Massachusetts Institute of Technology, USA

We report a new method for additive fabrication of thin gold membranes onto patterned silicon dioxide substrates for acoustic MEMS applications. The deflection of thin (140-nm-thick) gold membranes suspended over cavities in a silicon dioxide dielectric layer atop a conducting electrode can be used to produce sounds or monitor pressure. Our fabrication uses a novel technique of dissolving an underlying organic release layer using acetone, to transfer membranes onto patterned silicon dioxide substrates. This process avoids fabrication of MEMS diaphragms via wet or deep reactive-ion etching, which in turn removes the need for etch-stops, and wafer-bonding.

32-TH **RECOVERY OF PLASMA-INDUCED MECHANICAL DAMAGE IN RESONATORS USING NEUTRAL BEAM ETCHING: WAFER-SCALE VALIDATION BY ARRAYED CANTILEVERS** 313

Y. Nishimori[1,2], S. Ueki[1], K. Miwa[1,3], T. Kubota[2], S. Samukawa[1,3], G. Hashiguchi[1,2], and M. Sugiyama[1,4]
[1]BEANS Project, JAPAN, [2]Shizuoka University, JAPAN, [3]Tohoku University, JAPAN, and [4]University of Tokyo, JAPAN

Neutral Beam Etching (NBE) is a very attractive technique for MEMS fabrication. As an effective application of NBE to MEMS fabrication process, we here propose a combined approach between conventional plasma processes and NBE: removal of plasma-induced damage by NBE. If it is feasible, we can obtain a method to remove surface imperfection of a MEMS structure at low temperature, which is quite favorable for advanced integration such as MEMS and electrical circuits.

33-M **ROBUST SILICON DEEP ETCHING WITHOUT THERMAL ISOLATION IN LARGE MASS AND LONG SPRING STRUCTURES** 317

Y.-S. Lee[1], Y.-H. Jang[1], J.-M. Kim[2], and Y.-K. Kim[1]
[1]Seoul National University, SOUTH KOREA and [2]Chonbuk National University, SOUTH KOREA

This paper suggests a complete solution for thermal isolation which hinders the stable fabrication of silicon micro-structures with a large proof mass and long spring when utilizing DRIE process. Comprehensive analysis on the thermal equivalent circuit and the implementation of thin metal layers have successfully resolved the temperature rise to only 2.8% (217 °C to 6.16 °C in simulation), leading to improved spring width (20 um to 35 um, design: 40 um) as well as resonant frequency (439 Hz to 678 Hz, design: 754 Hz).

PACKAGING TECHNOLOGIES

Materials and Device Characterization

POSTER/ORAL PRESENTATIONS

MECHANICAL SENSORS AND SYSTEMS

80-M **A MULTIDIRECTIONAL-SENSITIVE INERTIAL MICROSWITCH WITH ELECTROPHORETIC POLYMER-METAL COMPOSITE FIXED ELECTRODE FOR FLEXIBLE CONTACT** 504

Z. Yang, B. Zhu, G. Ding, H. Wang, Y. Wang, and X. Zhao
Shanghai Jiao Tong University, CHINA

In this paper, we proposed and fabricated a multidirectional-sensitive inertial microswitch with polymer-metal composite fixed electrode based on surface micromachining. The composite electrode was completed by electroplating and electrophoretic deposition, which can realize a flexible contact between the electrodes and eliminate the bouncing phenomenon in the microswitch. As a result, the stability and reliability of the inertial switch will be greatly improved.

81-T **A NEW ELECTRONIC SCHEME TO COMPENSATE MEMS RESONATORS NONLINEARITIES** 508

R. Levy and G. Papin
Onera, FRANCE

The mechanical and electrostatic nonlinearities of MEMS resonators limit their power handling and thus the frequency stability and phase noise of MEMS resonators based oscillators. This paper reports a new circuit scheme to cancel the nonlinear behaviour of MEMS resonators. The VIA quartz resonator developed at ONERA has been used for simulations and experimental measurements to demonstrate the nonlinearities cancellation by the compensation circuit.

82-W **A NEW METHOD FOR RESONANT SENSING BASED ON NOISE IN NONLINEAR MEMS** 511

C.B. Burgner, L.A. Shaw, and K.L. Turner
University of California, Santa Barbara, USA

A new method of tracking frequency in MEMS resonators is revealed. This measurement technique is based on noise squeezing phenomena found in nonlinear MEMS. Experimental results show 50ppm frequency resolution on a device near 100kHz is achievable without a phase lock amplifier or sophisticated signal processing. High sensitivity is attained while maintaining the amplitude of vibration near the noise floor.

83-Th **A PASSIVE HYDROGEL-BASED INERTIAL SWITCH INTEGRATED WITH MICROMACHINED L-C RESONATOR** 515

J.-C. Kuo and Y.-J. Yang
National Taiwan University, TAIWAN

This work presents the development of an inertial switch employing stimuli-sensitive hydrogel integrated with a passive inductor/capacitor (LC) resonator. The device consists of a glass substrate with capacitor plates and an inductor coil, and a PDMS microfluidic chip with micro-channels and micro-cavity containing hydrogel and water droplet. When the acceleration exceeds the designed threshold-level, the water passes through the channel to the hydrogel cavity. The hydrogel swells and changes the capacitance of the integrated LC resonator, which in turn changes the resonant frequency that can be remotely detected. The functionalities of proposed device were demonstrated, and the detected signals were transmitted wirelessly.

84-M **A SINGLE PROCESS FOR BUILDING CAPACITIVE PRESSURE SENSORS AND TIMING REFERENCES WITH PRECISE CONTROL OF RELEASED AREA USING LATERAL ETCH STOP** 519

C.-F. Chiang[1], A.B. Graham[2], G.J. O'Brien[2], and T.W. Kenny[1]
[1]Stanford University, USA and [2]Robert Bosch RTC, USA

In this paper, we present a capacitive absolute pressure sensor co-fabricated with a MEMS resonator using a modified epitaxial polysilicon encapsulation process. The process features insensitivity to the timed etch in releasing structures from sacrificial silicon dioxide. Moreover, the demonstrated process is capable of fabricating additional structures (resonators, inertial sensors, etc.) for driving and sensing in both lateral (x,y) and vertical (z) directions, providing a powerful fabrication platform for sensor integration on either bulk silicon or SOI wafer substrates.

85-T **AN AUTOMATICALLY MODE-MATCHED MEMS GYROSCOPE WITH 50 HZ BANDWIDTH** 523

S. Sonmezoglu, S.E. Alper, and T. Akin
Middle East Technical University, TURKEY

This paper presents the architecture and experimental verification of an automatic mode matching system that uses the phase relationship between the residual quadrature and drive signals in a gyroscope to accomplish and maintain the frequency matching condition, where the system also allows controlling the system bandwidth by adjusting the closed loop controller parameters of the sense mode, which is achieved first time in literature. This study experimentally examines the angle random walk (ARW) and bias instability performances of fully decoupled MEMS gyroscopes under mismatched (~100Hz) and mode-matched conditions.

86-W **AN ELECTROSTATIC FIELD SENSOR DRIVEN BY SELF-EXCITED VIBRATION OF SENSOR/ACTUATOR INTEGRATED PIEZOELECTRIC MICRO CANTILEVER** 527

T. Kobayashi[1], S. Oyama[2], H. Okada[1], N. Makimoto[1], K. Tanaka[1], T. Itoh[1], and R. Maeda[1]
[1]National Institute of Advanced Industrial Science and Technology (AIST), JAPAN and [2]Hirose Electric Co., JAPAN

We have developed MEMS-based electrostatic field sensors (MEMS-EFS), which integrate probe to detect electrostatic field and Pb(Zr,Ti)O3 (PZT) thin films for sensor and actuator into microcantilever. The MEMS-EFS were fabricated through sol-gel deposition of PZT thin films and MEMS microfabrication process. Self-excited vibration of the microcantilevers has been achieved by amplifying and forwarding the output voltage from the PZT thin film for sensor with band-pass filter circuit. The developed MEMS-EFS can evaluate an electrostatic field of -3 to 3 kV with good linearity.

POSTER/ORAL PRESENTATIONS

POSTER/ORAL PRESENTATIONS

PHYSCIAL MEMS (OPTICAL, MAGNETO)

113-W **HIGH FREQUENCY TORSIONAL MEMS SCANNER FOR DISPLAYS** 636
U. Baran[1], D. Brown[2], S. Holmstrom[1], D. Balma[3,4], W.O. Davis[2], A. Mazzalai[4], P. Muralt[4], and H. Urey[1]
[1]Koç University, TURKEY, [2]Microvision Inc., USA, [3]Polytechnic of Turin, ITALY, and
[4]École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

A high frequency resonant torsional microscanner actuated with thin film PZT is modeled, fabricated, and characterized. Sinusoidal actuation of 24V at a mechanical resonance frequency of 40kHz provides a total optical scan angle of 38.5deg for the 1.4mm mirror width. This is the highest performing resonant MEMS scanner designed for dynamic displays reported in the literature and it provides significant power and size advantages compared to electromagnetic and electrostatic scanners.

114-Th **IMPLEMENTATION OF VERTICAL-INTEGRATED DUAL MODE INDUCTIVE-CAPACITIVE PROXIMITY SENSOR** 640
P.-H. Lo, C. Hong, S.-H. Tseng, J.-H. Yeh, and W. Fang
National Tsing Hua University, TAIWAN

This study extends the authors previous concept to employ nanoporous anodic aluminum oxide (np-AAO) as insulation and dielectric layer to form the vertical-integrated inductive-capacitive proximity sensor. Subject matter shows the proximity sensor consists of vertical stacked metal-spiral, np-AAO insulation layer, and Ti film on Si-substrate. The magnetic-field from metal-spiral enables the inductive-sensing, and the fringe-capacitance between the metal-spiral and Ti-film enable the capacitive-sensing. The advantages of this vertical-integrated inductive-capacitive proximity sensor are as follows, (1) Enlarge the range of sensing-distance: capacitive-sensing remains sensitive for short-distance object and long-distance object remains detectable by inductive-sensing, (2) Conductive and non-conductive objects can be detected, (3) chip size is reduced by the vertical-integrated design, (4) fringe-effect is enhanced by the spiral-coil, and (5) np-AAO has good electrical properties: dielectric constant 7.4 (oxide:3.9), electrical resistivity: over hundred Mohm-cm (similar to oxide). Measurements demonstrate the performances of proposed sensor.

115-M **SIMULTANEOUS SELF-SUSTAINED ACTUATION AND PARALLEL READOUT WITH MEMS CANTILEVER SENSOR ARRAY** 644
S.Z. Lulec[1], C. Sagiroglu[1], A. Mostafazadeh[1], E. Ermek[1], E. Timurdogan[1,2], Y. Leblebici[3], and H. Urey[1]
[1]Koç University, TURKEY, [2]Massachusetts Institute of Technology, USA, and [3]École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

Simultaneous self-sustained actuation of resonant MEMS cantilever array is demonstrated using one actuation coil and one photodetector. The method allows parallel readout of dense array of sensors on a small chip. A closed-loop controller is used for actuating the array and oscillations are self-starting. Cantilevers are fabricated with one mask process and made of ~1μm thick Nickel on a thin Gold layer. Cantilevers have 2-3um wide grating slits at its tip to facilitate interferometric readout.

116-T **MULTI-SPECTRAL TUNABLE EXCITATION FLUORESCENCE MICROSCOPY WITH A NANOIMPRINTED PDMS-ON-SILICON GRATING OPTICAL FILTER** 648
N.-T. Huang, S. Truxal, Y.-C. Tung, and K. Kurabayashi
University of Michigan, USA

We report a MEMS-based optical grating filter and its integration with a fluorescence microscope for excitation wavelength tuning. This integration allows voltage-controlled tuning of excitation wavelength from a multi-band light source. We demonstrate the system's capability to selectively excite fluorescence dye molecules with different excitation/emission spectral characteristics using optical filter arrays, each with a very small (2mm _ 2 mm) device foot print. The demonstrated technology has potential to enable massively parallel multispectral fluorescence microscopy in biochip array settings.

117-W **RAPID DETECTING Z-POSITION OF MOVING OBJECTS IN MICROCHANNEL UTILIZING A NOVEL CHROMATIC ABERRATION EFFECT UNDER A DARK-FIELD ILLUMINATION SCHEME** 652
S.-Y. Su and C.-H. Lin
National Sun Yat-sen University, TAIWAN

This research describes a technique for detecting the depth of samples in MEMS-based micro-flow cytometer. According to the principle of chromatic aberration which occurs because of different wavelength has its according refractive index of lens for light, that makes it to be capable to identify the various depths of samples in z-direction by analyzing the change in intensity for specific wavelength in micro-flow cytometer. Through the wavelength analysis and simple calculation, it shows that depth versus the ratio of 450 nm to 670 nm gives a high linearity. Because the simple mathematical calculation, this developed depth detector can discriminate and identify the different depths of dynamic samples in MEMS-based micro-flow cytometer swiftly, and also provides ±15 μm sensing range.

118-Th **SELF-ALIGNED VCSEL-MICROLENS SCANNER WITH LARGE SCAN RANGE** 656
N. Quack, J.B. Chou, and M.C. Wu
University of California, Berkeley, USA

Design, fabrication and optical characterization of a self-aligned integrated MEMS/VCSEL laser beam scanner. The system comprises an alignment platform, a VCSEL, alignment beads and a comb-drive actuated MEMS lens scanner including a precision half-ball lens. Precise self-alignment is achieved using microspheres as alignment beads and angular beam scanning by displacing the lens horizontally with respect to the VCSEL. ±70 μm displacements (scanning angles of ±7°) have been demonstrated

RF MEMS

BIO AND CHEMICAL MICRO SENSORS AND SYSTEMS

146-TH **A SOFT HYDROGEL CONTACT LENS WITH AN ENCAPSULATED SENSOR FOR TEAR GLUCOSE MONITORING** 769
H. Yao, C. Marcheselli, A. Afanasiev, I. Lähdesmäki, and B.A. Parviz
University of Washington, USA

We report a hydrogel-based contact lens with an encapsulated glucose sensor. The sensor is fabricated on a flexible transparent parylene film. The parylene-based sensor is then encased inside a soft contact lens made of poly (hydroxyethyl methacrylate) (poly(HEMA)) hydrogel. We test the contact lens with different concentrations of glucose and interfering chemicals found in tear film, such as ascorbic acid. The rapid response, good linearity and repeatability demonstrate the basic functionality of this soft contact lens with embedded glucose sensor.

147-M **A STUDY OF CANCER CELL METASTASIS USING MICROFLUIDIC TRANSMIGRATION DEVICE** 773
Y. Fu[1], A.M.J. Vandongen[2], T. Bourouina[3], W.T. Park[4], M.Y. Je[4], J.M. Tsai[4], D.L. Kwong[4], and A.Q. Liu[1]
[1]Nanyang Technological University, SINGAPORE, [2]DUKE-NUS Graduate Medical School, SINGAPORE,
*[3]Université Paris-Est, FRANCE, and [4]Agency for Science, Technology and Research (A*STAR), SINGAPORE*

We studied the effect of chromatin condensation in cancer cell metastasis using microfluidic transmigration device. The device mimic the capillaries on the blood vessel meanwhile provide precise and consistent control of environmental parameters. Experimental results showed that chromatin condensation by anti-cancer drug increases the nuclear stiffness and subsequently reduces the transmigration of cancer cells up to 69%. As transmigration is critical for cancer metastasis, the results will be useful in designing new anti-cancer therapy.

148-T **AN INTEGRATED HYBRID MICROFLUIDIC SYSTEM FOR ONLINE BIOPROCESSES MONITORING: COMBINING ELECTRICAL LYSIS AND EWOD SAMPLE PREPARATION** 777
C. Wu[1,2], F. Brunelle[1,2], M. Harnois[1,2], J. Follet[1,3], and V. Senez[1,2]
[1]University of Lille, FRANCE, [2]RENATECH Network, FRANCE, and [3]Institut Supérieur d'Agriculture, FRANCE

This work presents an original device allowing high throughput electrical lysis of yeast cells and its coupling to a sample preparation unit using a single plate EWOD platform. The advantage of electrical lysis is to avoid sample contamination with chemical reagents and protein denaturation due to high temperature. The advantage of digital preconditioning is to allow precise control of multiple reagents without the need of a complex network of microvalves.

149-W **CALCIUM IONS DETECTION USING MINIATURIZED INN-BASED SENSOR** 781
K.W. Kao, Y.W. Su, Y.S. Lu, D.-J. Yao, S. Gwo, and J.A. Yeh
National Tsing Hua University, TAIWAN

Ultrathin (~10 nm) InN ion sensitive field effect transistor (ISFET) with gate region functionalized with phosphotyrosine (p-Tyr) is proposed to detect calcium ion (Ca2+) in aqueous solution. This study provides to integrate with existing medical equipment, such as arterial catheter (A-line). The ISFET was miniaturized to have the chip size 100μm by 400μm and integrated at the tip of hypodermic injection needle (18G). The variation ratio of 1.11% with per decade change of Ca2+ and a detection limit of 10-6 M.

150-TH **CARBON DIOXIDE DETECTION BY SURFACE PLASMON RESOSNANCE WITH IONIC LIQUID** 784
K. Ishizu, T. Kan, Y. Takei, H. Takahashi, K. Matsumoto, and I. Shimoyama
University of Tokyo, JAPAN

We propose a CO2 gas sensor based on a permittivity change of ionic liquid. Our sensor consists of an ionic liquid (IL) droplet encapsulated on a surface plasmon resonance (SPR) coupling device. When the IL absorbs CO2 gas, its permittivity increases. The SPR sensor measures the reflection intensity and the shift of SPR coupling angle when the IL absorbed CO2.

151-M **CELL CULTURE BIOCHEMICAL IC CHIP WITH CELL-LEVEL BIOCOMPATIBILITY** 788
Y. Inoue and K. Ikuta
University of Tokyo, JAPAN

We develop a new Biochemical IC chip capable of cell culture with 3D capillaries fabricated by microstereolithography. This chip set realizes a real total system from biological synthesis to biochemical analysis. To realize this cell culture chip, we overcome a problem that photo curable polymer for conventional microstereolithography did not have biocompatibility. To overcome this issue, we developed an original approach, which was high temperature heat treatment, and accomplished to fabricate the cell culture chip based on biochemical IC.

152-T **CELL PAIRING RATIO CONTROLLED MICRO-ENVIRONMENT WITH VALVE-LESS ELECTROLYTIC ISOLATION** 792
Y.-C. Chen, X. Lou, P. Ingram, and E. Yoon
University of Michigan, USA

We present a microsystem that can perform cell assays with a specific ratio between two different cell types. Innovation in this work includes the use of electrolysis to seal the culture chamber. The manipulation of electrolysis is much simpler and more reliable than pneumatic actuation to isolate microenvironments. Electrolysis has been used in micro-pumps, but this work is the first attempt to use electrolysis for sealing the cell co-culture chambers. For proof of feasibility, we demonstrated the interaction between PC3 (prostate cancer cells) and C2C12 (muscle stem) cells by growth factor secretion.

153-W **CNT-FET GAS SENSOR USING A FUNCTIONALIZED IONIC LIQUID AS GATE** 796
N. Kiga, Y. Takei, A. Inaba, H. Takahashi, K. Matsumoto, and I. Shimoyama
University of Tokyo, JAPAN

We propose a gas sensor using combination of carbon nanotubes (CNTs) and an ionic liquid (IL). In our research, we use an IL, 1-ethyl-3-methyl imidazolium tetrafluoroborate([EMIM][BF4]) which specifically absorbs CO2/NH3. We utilize this IL as a surface modification to CNTs and CNT-FET IL-gate. When the IL absorbs specific gases, the ion types and concentrations change. We measure this change by applying a voltage to IL-gate to attract ions on the CNTs surface.

154-TH **COMBINATORY LOCALIZED CYTOLYSIS WITH MICRON PRECISION BY ACOUSTIC TRANSDUCER ARRAY FOR FAST SCREENING OF DRUG INDUCED CYTOSKELETON ALTERATION** 800
L. Wang, Y.-J. Li, A. Lin, Y. Choe, M. Gross, and E.S. Kim
University of Southern California, USA

This paper reports combinatory localized cytolysis by an array of MEMS ultrasonic transducers for fast screening of drug-induced cytoskeleton variation with fluorescence-stained cytolysis assay. An array of 6x6 Self Focused Acoustic Transducers (SFATs) and disposable cell culture microwells were fabricated for the cytolysis and the fluorescence stain analysis. Cells were cultured in the microwells, and different drugs were applied for changing the cell cytoskeletons. Multi-spot, localized cytolysis with micron precision was carried out with the SFAT array. Experimental results show that the SFAT array produced localized cytolysis with a focal spot area of about 100 microns in diameter in multiple microwells, and the changes of the acoustic intensity threshold (AIT) for cytolysis are in accord with the alterations of the cytoskeleton induced by drug treatments. Therefore, cytoskeleton-specific fast drug screening can be realized by observing the variation of the AIT. Since the SFAT array can lyse multiple cell samples within 3 minutes, and it is easy to discern the lysed cells under fluorescent microscope, the SFAT array system improves the efficiency and simplicity of the drug screening greatly.

155-M **DESIGN AND FABRICATION OF MICRO-VISCOMETER USING THE PROPAGATION OF ACOUSTIC WAVES IN MICRO-CHANNEL** 804
S. Choi[1], H. Jang[2], H. Lee[2], J. Park[2], Y. Cha[1], D. Shin[1], and K. Lee[1]
[1]Korea Institute of Industrial Technology (KITECH), SOUTH KOREA and [2]Changwon National University, SOUTH KOREA

A micro-viscometer for measuring viscosity changes in small amount of liquid in real time is designed and fabricated. The merits of the device are to use minimal quantity of liquids and to have high sensitivity of viscosity. It is composed of two chambers connected by four micro-channels. By many results obtained from repeated tests, the voltage gains at the resonant frequency of the unimorphic piezoelectric diaphragm were measured and averaged, and then the results with respect to the viscosity were plotted as mean values and standard deviations.

156-T **DOUBLE-LAYER HEPATOCYTE TUMOR CO-CULTURE USING HYDROGEL FOR DRUG EFFECTIVITY AND SPECIFICITY ANALYSIS** 808
L.K. Chin, K.Q. Luo, W. Park, M. Je, J. Tsai, D.L. Kwon, and A.Q. Liu
Nanyang Technological University, SINGAPORE

This paper presents the formation of double-layer cellular tumor spheroid for the co-culture of hepatocyte (HepG2 cancer liver cell and LO2 normal liver cell) using alginate hydrogel. Conventional technique only allow single cellular or mixed multicellular tumor spheroid. With the ease of controllability of microfluidic chip, double-layer cellular tumor spheroid can be formed by the hydrogel droplet to mimic the in vivo environment in which the cancer tumor is surrounded by normal cells. By encapsulating the cancer tumor by normal cells, anticancer drug can be tested for its effectivity and specificity. A microchip with concentration gradient generation and tumor spheroid trapping site is designed for the anticancer drug analysis.

157-W **DYNAMIC BIDIRECTIONAL CONDUCTANCE MODULATION DURING DNA TRANSLOCATION IN A NANOFLUIDIC CHANNEL** 812
Y.-H. Sen and R. Karnik
Massachusetts Institute of Technology, USA

We have observed and simulated ionic conductance modulation in a nanofluidic channel during DNA translocation. The origin of the phenomenon is similar to ionic current rectification, in that charge asymmetry results in ionic current depletion and enhancement. The observations and corresponding simulations suggest that under certain conditions, dynamic concentration enhancement and depletion effects can significantly affect the translocation signals of single DNA molecules in nanofluidic channels.

158-TH **EMULATED CIRCULATORY SYSTEM INTEGRATED WITH LOBULE-MIMETIC LIVER TO ENHANCE THE LIVER FUNCTION** 815
S. Shilpa[1], V.P. Srinivasu[1], T.-S. Dai[1], C.-W. Lin[1], S.-M. Yang[2], H.-Y. Chang[1], and C.H. Liu[1]
[1]National Tsing Hua University, TAIWAN and [2]National Chiao Tung University, TAIWAN

A DEP-based liver lab chip integrated with PEGDA based blood vessel within the microfluidic system for reconstructing the engineered liver tissue with the feature of liver function enhancement is demonstrated and reported in this paper. The electrodes are well designed to provide positive dielectrophoresis (pDEP) and negative dielectrophoresis (nDEP) force to pattern liver HepG2 and 3T3 fibroblast cells as a lobule structure uniformly. The hepatic veins and the hepatic venule are mimicked by the hydrogel based blood vessel for this reconstructed lobule-mimetic liver tissue. The blood vessel is mimicked by encapsulating smooth muscle cells and endothelial cells in PEGDA hydrogel. When assayed for urea concentration of cultured medium in 5 time points, the trend illustrated the enhanced metabolism of hepatocytes via blood vessel integrated lobule-mimetic pattern and co-culture with fibroblast cells.

159-M **FAST LOCALIZED SINGLE CELL MEMBRANE PORATION BY BUBBLE-INDUCED JETTING FLOW** 819
Z.G. Li[1], C.D. Ohl[1], J.B. Zhang[2], J. Tsai[2], and A.Q. Liu[1]
[1]Nanyang Technological University, SINGAPORE and
*[2]Agency for Science, Technology and Research (A*STAR), SINGAPORE*

we develop a method to realize the single cell membrane poration using cavitation bubble-induced jetting flow. The poration and trypan blue uptake process are observed and recorded using high speed camera. This developed method can realize fast localized membrane poration and be easily integrated with microfluidic system, which has great potential in bioengineering applications.

160-T **FIRST RECONFIGURABLE MEMS SEPARATION COLUMNS FOR MICRO GAS CHROMATOGRAPHY** 823
H. Shakeel[1], G. Rice[2], and M. Agah[1]
[1]Virginia Tech, USA and [2]College of William and Mary, USA

We present reconfigurable gas separation columns by merging MEMS and nanotechnology. The surface chemistry of these MEMS columns is reprogrammed using self-assembly of thiol on electrodeposited gold to 1) achieve both polar and non-polar stationary phases affording the separation of gas mixtures with a wide range of boiling points and polarities and 2) reconfigure the separation properties by removing the stationary phase and functionalizing it with another thiol. This method enables realization of highly reproducible, easy-to-coat, and reusable micro GC separation columns.

161-W **FROM BENCH-TO-BEDSIDE: REALIZING ON-CHIP ELECTROPHORETIC IMMUNOASSAYS FOR PROTEIN BIOMARKERS IN SERUM USING A STANDARD 9V BATTERY** 827
T.A. Duncombe, A.M. Tentori, C. Hou, and A.E. Herr
University of California, Berkeley, USA

To move electrophoretic immunoassays from the bench to the POC, we report the first, to our knowledge, confirmatory grade electrophoretic assay designed for use with a standard 9V battery. Key to our design strategy is an immunoassay that requires only a single, ultra-short (300 um) separation channel with 2 terminal fluid reservoirs to inject a moving boundary (front of material). Tuning of a nanoporous separation matrix allows us to clearly detect differentially migrating protein fronts.

162-TH **FUNCTIONALIZED MICRO BEAD WITH LIQUID-CORE PARYLENE-SHELL STRUCTURE** 831
H. Aoki, N. Binh-Khiem, T. Kan, K. Matsumoto, and I. Shimoyama
University of Tokyo, JAPAN

We report on the fabrication, properties and applications of functionalized micro beads with liquid-core Parylene-shell structure. We propose a method to fabricate the micro beads and show that this method provides efficient encapsulating shell to protect the core-liquid from surrounding solvents.

163-M **HIGH-THROUGHPUT WHITE BLOOD CELLS (LEUKOCYTES) SEPARATION AND ENRICHMENT FROM WHOLE BLOOD BY HYDRODYNAMIC AND INERTIAL FORCE** 835
H.-C. Tseng[1], R.-G. Wu[1], H.-Y. Chang[1], and F.-G. Tseng[2]
[1]National Tsing Hua University, TAIWAN and [2]Research Center for Applied Sciences, TAIWAN

In this work we introduce a like-biomimetic structure to separate red blood cells from whole blood and to enrich leukocytes (white blood cells) through the elastic properties of blood cells by the interaction of inertial force, shear lift, and wall crowding effect in a continuous flow system. As result of this work we are successfully solved clogging problem in microchannel and low separation rate in microfluidic devices that contained huge number of blood cells (4.3x10^6 cells/µl).

164-T **HIGHLY SENSITIVE PROTEIN DETECTION USING QUENCHING EFFECTS FROM APTAMER-FUNCTIONALIZED PHOTONIC CRYSTALS** 839
Y. Choi, E. Choi, and J. Park
Sogang University, SOUTH KOREA

Photonic crystal (PC) based biosensors have been attracted more attention due to their advantages, such as sensitivity, real time monitoring and low-cost realization. PC based sensors have been reported to measure various environmental changes, such as pH, temperature and glucose. In case of previous PC based biosensors, target biomolecules were detected by the shift of reflective wavelength in response to the change of refractive index or lattice constant in PC structures. These sensors can effectively identify the biomolecules, if the volume change of PC structures happens by stimulus of target molecules or the targets have high refractive index contrast. Here, we propose a new technique for protein detection using quenching effects from aptamer-functionalized photonic crystals. The surface of hydrogel based inverse opal structures are functionalized with aptamers and they are hybridized with quenchers. Then, target protein (thrombin) can be selectively, sensitively detected by monitoring the change of both intensity and color (change of reflective wavelength).

165-W **INTEGRATED FLUORESCENT ANALYSIS SYSTEM WITH MONOLITHIC GAN LIGHT EMITTING DIODE ON SI PLATFORM** 842
H. Nakazato[1], H. Kawaguchi[2], A. Iwabuchi[2], and K. Hane[1]
[1]Tohoku University, JAPAN and [2]Sanken Electric Co. Ltd., JAPAN

A GaN blue light emitting diode integrated monolithically on silicon substrate is used as a fluorescent light source of bio-fluidic micro total analysis system (µTAS) with polydimethylsiloxane channel. A silicon photodiode is also installed on silicon substrate for fluorescent detection. Therefore, all components necessary for fluorescent µTAS are integrated on a silicon platform.

166-TH **INTEGRATED VOC VAPOR SENSING ON FBAR-CMOS ARRAY** 846
M.L. Johnston, H. Edrees, I. Kymissis, and K.L. Shepard
Columbia University, USA

An array of monolithic FBAR devices on a CMOS integrated circuit substrate is employed for quantification of volatile organic compound (VOC) vapor concentration. Thin polymer layers are applied individually to FBAR devices to absorb organic vapors, and resulting FBAR-CMOS oscillator frequency shifts are measured on-chip in response to varying ambient VOC vapor concentration.

167-M **MICRO-FLUIDIC RESONATOR** 850
C. Pigot and A. Hibara
University of Tokyo, JAPAN

This paper presents fundamental investigations on a passive microfluidic resonator. It is aimed at monitoring microsized interface. We theoretically and experimentally show that surface capillary waves excited by random thermal fluctuations resonate when the surface of a fluid is constrained. It is label free, requires simple optics and, at the difference of other methods, it is downscalable to the diffraction limit.

168-T **UNIAXIAL CELL STRETCHER ENABLES HIGH RESOLUTION LIVE CELL IMAGING** 854
J.Y. Sim, N. Borghi, A. Ribeiro, M. Sorokina, O. Shcherbakova, D. Ramallo, A. Dunn, W.J. Nelson, and B.L. Pruitt
Stanford University, USA

We present a major advance for mechanobiology research as it enables direct mechanical actuation combined with imaging of FRET probes engineered to report strained proteins in live cells. To our knowledge, this device is the first to allow simultaneous FRET imaging and quantitative strain application to living cells to directly test the effects of externally applied stretch on adherent cells.

169-W **MICROMECHANICAL APTASENSOR-BASED PROTEIN DETECTION USING A COMPACT-DISC FORMAT MICROFLUIDICS SYSTEM** 858
F.G. Bosco[1], J. Yang[2], C.H. Chen[3], E.-T. Hwu[3], S.S. Keller[1], M. Bache[1], Q. Lin[2], and A. Boisen[1]
[1]Danmarks Tekníske Universítet (DTU), DENMARK, [2]Columbia University, USA, and [3]Academia Sinica, TAIWAN

In this paper we present the use of a plug-and-play CD-like platform for statistical detection of Platelet Derived Growth Factor (PDGF) proteins through aptamer-based surface functionalization of microcantilevers.

170-TH **MIMICKING INSECT SIGNALING: ARTIFICIAL GLAND FOR BIOSYNTHESIS AND RELEASE OF SEMIOCHEMICALS FOR COMMUNICATION** 862
W.P. Bula[1], N.G. Dimov[1], L. Muñoz[2], G. Carot-Sans[2], A. Guerrero[2], and J.G.E. Gardeniers[1]
[1]University of Twente, THE NETHERLANDS and [2]Institute of Advanced Chemistry of Catalonia (CSIC), SPAIN

We develop a chemoemitter platform mimicking the biosynthetic pathways and release of female sex pheromones of the Spodoptera littoralis moth. The system consists of a microreactor in which the pheromone biosynthesis takes place, and a micromachined evaporator that releases ratiometrically-encoded blend into environment. The chemoemitter was used to investigate the detection patterns of highly sensitive olfaction system of male moths by electroantennographic and behavioral assays. We present a new information emission scheme by utilizing semiochemicals as data carrier.

171-M **MUSCLE FIBERS ACTUATED BY NEURAL SIGNALS** 866
Y. Morimoto[1,2], M. Kato-Negishi[1], H. Onoe[1,2], and S. Takeuchi[1,2]
[1]University of Tokyo, JAPAN and [2]Japan Science and Technology Agency (JST), JAPAN

We propose a method for constructing "neuron-muscle fibers" driven by signals from activated neurons; the fibers consist of stretched muscle fibers covered with highly aligned neurons, and their axons extend into muscle fibers to form neuromuscular junctions. We believe that the neuron-muscle fibers will be not only used as soft-robotic actuators controlled by neural signals, but also used in therapeutic and pharmacokinetic applications for neuromuscular junction disease models.

172-T **ON-CHIP FORMATION AND PERFUSION CULTURE OF 3D TUMOR SPHEROIDS USING GRAVITY-DRIVEN CELL AGGREGATION AND PUMPLESS BALANCED DROPLET DISPENSING** 870
T. Kim and Y.-H. Cho
Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA

We present a three-dimensional (3D) tumor spheroid chip, achieving on-chip formation and perfusion culture of spheroids using gravity-driven cell aggregation and pumpless balanced droplet dispensing. Through the experiment using H358 human lung cancer cells, we have demonstrated the performance of the present chip for the on-chip formation and pumpless perfusion culture of 3D tumor spheroids with simple a structure.

MEDICAL MICROSYSTEMS

193-W **FLUIDIC PREPARATION OF PATTERNED HYDROGEL FIBERS USING MICRONOZZLE-ARRAY DEVICES FOR NEURAL CELL GUIDANCE 953**
Y. Naganuma, M. Yamada, S. Sugaya, and M. Seki
Chiba University, JAPAN

Micronozzle array-combined microfluidic devices have been newly developed to form anisotropically-patterned hydrogel fibers composed of soft and solid regions. The patterns of the vertical micronozzles determine the cross-sectional compositions of the Ca-alginate microfibers, with the widths of the fiber and the soft regions of 60~100 and 10~20 um, respectively. Neuron-like cells (PC-12 cells) were inoculated in the soft region of the fiber, which showed the unprecedented behaviors of linear colony formation and guided neurite outgrowth, and cellular networks were formed.

194-Th **INTEGRATED MICROFLUIDIC OXYGENATOR BUNDLES FOR BLOOD GAS EXCHANGE IN PREMATURE INFANTS 957**
N. Rochow, W.-I. Wu, E. Chan, D. Nagpal, G. Fusch, P.R. Selvaganapathy, S. Monkman, and C. Fusch
McMaster University, CANADA

We report the development of low volume lung assist device (LAD) acting as a pumpless artificial placenta to treat preterm infants with respiratory insufficiency. Microchannel oxygenators were tested with different membrane materials. Test included resistance characteristics using different perfusate media, including blood, as well as gas exchange range. Proof of principle was shown with application of the LAD in a hypoxic piglet model including cardiovascular parameters, respiratory parameters, and gas exchange across the device.

195-M **INTEGRATED MICROFLUIDIC SYSTEM FOR HIV DETECTION 961**
J.-H. Wang[1], C.-H. Wang[1], W.-S. Ling[2], L. Jheng[2], S.-W. Wang[2], and G.-B. Lee[1]
[1]National Tsing Hua University, TAIWAN and [2]National Cheng Kung University, TAIWAN

This study presented an innovative microfluidic system for molecular diagnosis of human immunodeficiency virus (HIV). In this study, magnetic beads conjugated with nucleotide probes specific to HIV were used to perform purification and enrichment of target DNA. Then an on-chip PCR module was used to perform amplification of four detection genes. Finally an optical module was used to detect the amplified PCR products. Experimental results demonstrated that multiple HIV detection fragments could be amplified successfully and real-time detected using the developed system in the HIV-infected cell line within 95 min.

196-T **LIQUID CAPPED ENCODED MICROSHELL AND PARTIPETTING FOR ULTRAPLEX LIQUID ASSAY 965**
Y. Song, T. Kwon, D. Lee, and S. Kwon
Seoul National University, SOUTH KOREA

In this paper, we demonstrated dispensing of thousands of heterogeneous liquid drops into microwells with only a single pipetting, which would normally requires thousands of individual pipetting. Key idea is first to fabricate liquid capped Teflon microshells and then to self-assemble those particles into microwells. Capped liquids then are released by breaking the Teflon microshell with pulsed laser. We believe this process would enable ultraplex microarray with liquid phase assay capability, whereas current multiplexed array technology is limited to multiplexing of surface bound molecules such as DNA or protein.

197-W **MEASUREMENT OF BREATHING CHARACTERISTIC IN MOUSE DURING INHALING DRUG 969**
T. Shikano, M. Shikida, M. Matsushima, T. Kawabe, and K. Sato
Nagoya University, JAPAN

We challenged the breathing measurement at the air passage in mice, in which the high humidity drug was given into air passage by a nebulizer for the evaluation of airway contraction. To fill the gap which shortened the lifetime of the catheter flow sensor, we newly introduced a silicone oil and parylene film coating in the packaging process. We applied the sensor to animal experiments, and confirmed that it was able to directly measure the breathing characteristics at the air passage in mice.

198-Th **NANO-PATTERNED HYDROGEL REDUCED INFLAMMATORY EFFECTS IN SUBCUTANEOUS TISSUE 973**
M. Takahashi[1,3], Y.J. Heo[1,2], H. Shibata[3], H. Satou[3], T. Kawanishi[1,2], T. Okitsu[1,2], and S. Takeuchi[1,2]
[1]BEANS Project, JAPAN, [2]University of Tokyo, JAPAN, and [3]TERUMO Co., JAPAN

We present a nano-patterned poly-acrylamide (PAAM) hydrogel that can reduce inflammatory effects after spontaneous implantation. Although hydrogel is considered as an excellent biomaterial for subcutaneous implants due to its biocompatibility, hydrogel still induces inflammation after implantation. To enhance biocompatibility for subcutaneous implantable sensors, we modified hydrogel surface with nano-patterns. To test the anti-inflammatory effect, we implanted the samples to rat's back. We counted macrophages after 3 and 7 days and measured thickness of encapsulation after 21 days from implantation because macrophages are vital cells that regulate the immune response and related to the thickness of encapsulation after inflammation reaction. We found the sample with the line of 600 nm in space successfully suppressed the inflammation reaction. Therefore, nano-patterned hydrogel is promising for long-term subcutaneous implantable sensors.

199-M **"NEURAL BYPASS" WITH HYDROGEL MICROFIBER ENCAPSULATING NEURONS 977**
M. Kato-Negishi[1], H. Onoe[1,2], and S. Takeuchi[1,2]
[1]University of Tokyo, JAPAN and [2]Japan Science and Technology Agency (JST), JAPAN

This paper describes a "neural bypass" formed by hydrogel microfiber encapsulating neurons and glial cells. The neural bypass has a high neuronal activity, and neuronal network is formed in the bypass. Using this neural bypass, we developed a technique to connect the selective neuronal region without cell damage. We also demonstrated that a completely-transected cortical network could be connected with neural bypass. We believe that our neural bypass would be an extremely effective tool for bypass of damaged neuronal networks in the neurodegenerative diseases.

MICRO-FLUIDIC COMPONENTS AND SYSTEMS

214-TH **ELECTROWETTING ON FLEXIBLE, TRANSPARENT AND CONDUCTING SINGLE-LAYER GRAPHENE** 1037
X.B. Tan, J. Yang, P. Zeng, E.G.R. Kim, C. Huard, and M.M.C. Cheng
Wayne State University, USA

We introduce electrowetting on dielectric (EWOD) on single-layer graphene, which is a novel, flexible, stretchable, transparent and conducting electrode. This paper describes the design, fabrication and contact angle measurement of electrowetting using chemical-vapor-deposition (CVD) graphene coated with a thin fluoropolymer layer. Compared to other electrode materials such as gold and ITO, we observed robust electrowetting on graphene, including reproducibility and high breakdown voltage.

215-M **HIGH THROUGHPUT AND PARALLEL FLOW CYTOMETER WITH SOLID IMMERSION MICROBALL LENS ARRAY** 1041
Y.J. Fan[1,2], H.J. Sheen[2], and P.Y. Chiou[1]
[1]University of California, Los Angeles, USA and [2]National Taiwan University, TAIWAN

We demonstrate a high-throughput fluorescence based microfluidic flow cytometer having 64 microfluidic channels with each channel capable of detecting 1600 droplets/sec. This cytometer is realized by utilizing solid immersed high N.A. microball lens array for high sensitivity, parallel, and low chromatic aberration fluorescence detection across a 6 mm distance.

216-T **INTEGRATION OF EWOD PUMPING DEVICE IN DEEP MICROFLUIDIC CHANNELS USING A THREE-DIMENSIONAL SHADOWMASK** 1045
S. Morishita, M. Kubota, and Y. Mita
University of Tokyo, JAPAN

A droplet propulsion system based on the electrowetting-on-dielectric (EWOD) is integrated in deep-trench microfluidic channels. Due to the unique three- dimensional multi-height silicon shadowmask, electrodes are simultaneously fabricated on the top, bottom and vertical walls of deep channels, thus enabling three-face EWOD driving by both the bottom and sidewalls. We have successfully moved a water droplet in a 230-micro-meter-deep, 750-micro-meter-wide trench by EWOD.

217-W **LIPID BILAYER ON A DROPLET: FORMATION OF LIPID BILAYERS ON A DROPLET ARRAY** 1049
T. Tonooka[1,2] and S. Takeuchi[1,2]
[1]University of Tokyo, JAPAN and [2]Kanagawa Academy of Science and Technology (KAST), JAPAN

This paper describes a method for the formation of a lipid bilayer chamber array. This method enables us to form small chambers sealed with lipid bilayers easily. We successfully observed a transmembrane phenomenon via the lipid membrane by fluorescent measurement. Due to its small volume, small changes of molecule amounts can be remarkably detected. By reconstituting membrane proteins (hemolysin), we inferred that those membranes were lipid bilayers.

218-TH **MICRO-PARTICLE TRANSPORT MANIPULATION BY GUIDED-WAVE OPTICAL INTERFERENCE** 1053
T.-C. Chen, Y.-T. Yang, S.-Y. Wang, W.-C. Chiu, L.-C. Hsu, C.-Y. Huang, D.-W. Shen, and M.-C.M. Lee
National Tsing Hua University, TAIWAN

We demonstrate that micro-particle transport is able to be manipulated by interference-type integrated photonic devices for the first time, to the best of our knowledge. By leveraging the state-of-the-art integrated optics technology, sophisticated particle movements can be accomplished. Here we present two frequently used integrated photonic elements; one is directional coupler and the other is multimode interferometer (MMI).

219-M **MICROFABRICATED ALL-AROUND-ELECTRODE AC ELECTROOSMOTIC PUMP WITH SIMPLE DESIGN AND INCREASED VELOCITY GENERATION** 1057
L. Ribetto, A. Homsy, and N.F. de Rooij
École Polytechnique Fédérale de Lausanne (EPFL), SWITZERLAND

We report a simple approach to the design and fabrication of AC electroosmotic (ACEO) micropumps with electrodes that completely surround the channel. A fabrication process with two lithographic steps is presented. The new prototypes allow for a dramatic increase of the velocity generation - up to 300% compared to devices where electrodes are placed only on one side of the channel.

220-T **MICROFLUIDIC CONTROL OF INTERNAL MORPHOLOGY OF HYDROGEL FIBERS** 1061
D. Kiriya and S. Takeuchi
University of Tokyo, JAPAN and Japan Science and Technology Agency (JST), JAPAN

This paper describes a control system of nanofiber assembled morphologies in a microfluidic channel; nanofibers show i)linear alignment and ii)parabolic arrangement in a microchannel. By curing these morphological flows, we obtained hydrogel fibers with similar morphologies of the flows. Importantly, the aligned gel shows higher anisotropic conductivity than the parabolic one.

228-T **PROGRAMMABLE PROTEIN CRYSTALLIZATION IN METERED ENCAPSULATED DROPLETS** 1093
Y.-W. Hsu, C.-H. Chen, and S.-K. Fan
National Chiao Tung University, TAIWAN

We report for the first time programmable protein crystallization based on tunable evaporation and dissolution of salt and protein precipitants of an aqueous core droplet encapsulated in an oil shell. The evaporation depends on the precisely metered aqueous and oil droplet volumes and the position of the aqueous core droplet. Lysozyme protein crystal is obtained within 80 min by (1) rapid salt/protein precipitation by fast evaporation, (2) salt dissolution by heating to enhance protein crystallization, and (3) protein crystallization from the protein precipitants (seeds) by slow evaporation.

229-W **PULSED LASER TRIGGERED HIGH SPEED MICROFLUIDIC FLUORESCENCE ACTIVATED CELL SORTER** 1097
T.-H. Wu, Y. Chen, S.-Y. Park, J. Hong, T. Teslaa, J.F. Zhong, D. Di Carlo, M.A. Teitell, and P.-Y. Chiou
University of California, Los Angeles, USA

We report a high speed and high purity pulsed laser triggered fluorescence activated cell sorter (PLACS) with a sorting throughput up to 20,000 mammalian cells/s with 37% sorting purity, 90% cell viability in enrichment mode, and >90% purity in high purity mode at 1,500 cells/s or 3,000 beads/s. Fast switching (30 µs) and a small perturbation volume (~90 pL) is realized by a unique sorting mechanism in which explosive vapor bubbles are generated using focused laser pulses in a single layer microfluidic PDMS channel.

230-TH **PUMPS, NO-VALVES, NC-VALVES ON PAPER ANALYSIS CHIP** 1101
S. Okabe, K. Sakamoto, Y. Murakami, T. Ishikawa, and R. Miyake
Hiroshima University, JAPAN and Japan Science and Technology Agency (JST), JAPAN

New concept of paper-based devices (we call ''paper analysis chip'') and ink-jet printer-like analyzer for clinical diagnostics was presented. we propose new liquid-handling mechanisms realized on paper chips. By using demonstrate paper chip, the validity of the mechanisms was confirmed. It is concluded that this paper analysis chip including capillary pump, NO-valve, NC-valve is feasible.

231-M **SIZE-ORIENTED PASSIVE DROPLET SORTING BY USING SURFACE FREE ENERGY WITH MICRO GUIDE GROOVE** 1105
Y. Harada, D.H. Yoon, T. Sekiguchi, and S. Shoji
Waseda University, JAPAN

We propose a novel passive droplet sorting method depends on the variation of surface free energy. In general, droplets minimalize their surface free energy, in other words, they tend to be sphere. Flattened droplets in a shallow channel obtain minimum surface energy when they are located on a groove because a part of them become spherical shape. Therefore, droplets are trapped by a groove and when flow pressure is applied, droplets move along with the groove patterns in the micro channel. A study to control the motion of droplets by using this method has reported. As an important aspect of this principle, the 'Guiding force' which means the tendency to be located on a groove, is different by droplet size. That's because the rate of surface area reduction of small droplets is larger than that of large droplets. We prepared two outlets micro channel with different channel resistance. Flow late of the lower channel is larger than that of the upper channel due to the difference of channel resistance and the groove is fabricated along the upper channel.

232-T **THREE DIMENSIONAL MICROFLUIDIC DESIGN WITH SPINCOATED MICROMETER-THIN ELASTOMER MULTILAYER** 1109
N. Binh-Khiem, N. Thanh-Vinh, K. Matsumoto, and I. Shimoyama
University of Tokyo, JAPAN

We propose a method to fabricate three dimensional microfluidic channel systems with spincoated micrometer-thin elastomer multilayer. We use the molecular diffusion of thin elastomer layers to our advantage and propose a microfluidic fabrication process free of molding and bonding steps. We achieved various expandable three dimensional multilayer channel designs that can have interesting applications.

233-W **TRAPPING AND COLLECTION OF UNIFORM SIZE DROPLETS USING A WELL ARRAY INSIDE A MICROCHANNEL** 1113
I. Doh, E.Y. Erdem, and A.P. Pisano
University of California, Berkeley, USA

In this paper, we introduce a simple and fast method for massive droplet trapping and collection. Since trapping is size-dependent, droplets having various sizes caused by unstable inlet flows can be eliminated. There is no need for any additional controls for selective trapping of droplets, and all trapped droplets can be simply collected at the outlet by increasing the flow rate of the carrier fluid.

MICRO-ACTUATORS

234-TH **3D REMOTE CONTROLLABLE NANO ACTUATION SYSTEM FOR CELL HANDLING AND MICRO SURGERY** 1117
M. Yasui, M. Ikeuchi, and K. Ikuta
University of Tokyo, JAPAN

A new nano actuation system to handle living cells and to perform minimally invasive micro surgery was developed. Actuator size is scaled between 5 µm - 10 mm and can be actuated within any kind of liquid. We succeeded in developing a new photo-curable polymer with both "magnetism

POSTER/ORAL PRESENTATIONS

249-TH **ROBOTIC-INVESTIGATORS FOR MICROORGANISMS IN A MICROFLUIDIC CHIP** 1177
M. Sugita[1], T. Kawahara[1], M. Hagiwara[1], Y. Yamanishi[1,2], and F. Arai[1,3]
[1]Nagoya University, JAPAN, [2]Japan Science and Technology Agency (JST), JAPAN, and [3]Seoul National University, JAPAN

We succeeded in development of Robotic-Investigator (RI) which can stimulate any position of microorganisms with mN-order pushing force, and measure the applied force with accuracy of 100 μN in a microfluidic chip. RIs with force sensing structure fabricated by Si and Ni are driven by magnetic force from the outside of the microchip, and it have with the performance of 1 μm positioning accuracy, 10 Hz drive speed, and 400 mm2 movable range in a microfluidic chip.

250-M **SELF-ALIGNED FABRICATION PROCESS FOR ACTIVE MEMBRANE MADE OF PHOTOSENSITIVE NANOCOMPOSITE** 1181
T. Nakahara[1], Y. Hosokawa[1], K. Terao[1], H. Takao[1], F. Shimokawa[1], F. Oohira[1], T. Namazu[2], H. Kotera[3], and T. Suzuki[1]
[1]Kagawa University, JAPAN, [2]University of Hyogo, JAPAN, and [3]Kyoto University, JAPAN

We propose a simple fabrication technique for making active membranes as micro-actuators on a chip. By controlling three important factors consisted of the thickness of the exposure, the thickness of spin coat at surface, and the total thickness of the nanocomposite coated on a substrate, we simply form and release an active membrane layer without an alignment process. The active membrane fabricated by the proposed method actuated with the maximum displacement of 300nm at the magnetic field of 65kA/m and had good controllability.

251-T **THE CAPILLARY FORCE ACTUATOR: DESIGN, FABRICATION AND CHARACTERIZATION** 1185
H. Wang, J.T. Gaskins, C.R. Knospe, and M.L. Reed
University of Virginia, USA

We report the experimental demonstration of a new class of microactuator that harnesses the Laplace pressure inherent in the curved surface of a liquid drop: the Capillary Force Actuator, or CFA. The CFA can deliver significantly greater forces and longer actuation strokes than comparably sized electrostatic actuators. Also, the CFA can work with considerably larger electrode gaps (>100 micrometer) with applied voltages in the tens of volts, much less than would be required for an electrostatic actuator with a comparable gap.

252-W **TRENCH-FILLED CELLULAR PARYLENE STRUCTURE FOR PIEZOELECTRIC POLYMER ELECTRET** 1189
Y. Feng[1], K. Hagiwara[1,2], Y. Iguchi[2], and Y. Suzuki[1]
[1]University of Tokyo, JAPAN and [2]NHK Science & Technical Research Laboratories, JAPAN

We propose novel cellular polymer electret based on trench-filled parylene, and demonstrate its performance for low-resonant-frequency in-plane mechanical transducers. Vertical electret on the cellular parylene structure has been successfully formed by using soft X-ray charging. With our early prototype, 0.14 Vp-p output has been obtained at 28 Hz.

253-W **ULTRASONIC ELECTROSTATIC ACTUATORS ON A FLEXIBLE SUBSTRATE** 1193
S. Kim[1], X. Zhang[1], R. Daugherty[1], E. Lee[1], G. Kunnen[1], D.R. Allee[1], E. Forsythe[2], and J. Chae[1]
[1]Arizona State University, USA and [2]Army Research Laboratory, USA

We report a MEMS (Micro-Electro-Mechanical-Systems) based electrostatic actuator emitting acoustic waves in an ultrasonic frequency on a flexible substrate, made of Polyethylene Naphthalate (PEN), coupled with an integrated circuit driver, aiming for tag, track and locate (TTL) application.

ENERGY AND POWER MEMS

254-M **A NOVEL BETAVOLTAIC MICROBATTERY BASED ON SWNTS THIN FILM-SILICON HETEROJUNCTION** 1197
C.C. Chen, Y.Y. Chang, and J.W. Zhang
Peking University, CHINA

We report a novel betavoltaic microbattery made up of single-walled carbon nanotubes (SWNTs) thin film-silicon heterojunction. It's the first time that the nano-material, such as SWNTs here, is applied and plays the role of the energy conversion in the betavoltaic microbattery, including exciton generation, carriers collection and transportation.The results show the open voltage (Voc) of 6.5mV, short circuit current density (Jsc) of 13nA/cm2, current amplification of about 2000 and energy conversion efficiency about 0.15%, proving that SWNTs film-Si heterojunction is promising for application in nuclear microbatteries.

255-T **A PIEZOELECTRIC VIBRATION HARVESTER BASED ON CLAMPED-GUIDED BEAMS** 1201
Z. Wang, S. Matova, R. Elfrink, M. Jambunathan, C. de Nooijer, R. van Schaijk, and R.J.M. Vullers
IMEC/Holst Centre, THE NETHERLANDS

This paper reports the design, modeling and experimental results of a piezoelectric vibration harvester based on clamped-guided beams. Compared to the cantilever beams, our design is more reliable and less restricted by the limited space in the vacuum package. The device is studied analytically and numerically. Its fabrication process is featured by deep etching through Si wafer and vacuum packaging. Characterization on a shaker shows nonlinear behavior at higher input accelerations. The maximum power output obtained on a matched external load reaches 10 μW at an input acceleration of 1.2 g. Furthermore, the power output is doubled when the two sets of capacitors are connected electrically in series.

263-T **FLEXIBLE ENERGY STORAGE DEVICES BASED ON LIFT-OFF OF CNT FILMS** 1233
A. Kozinda, Y. Jiang, and L. Lin
University of California, Berkeley, USA

We report a lift-off process for CNT films to construct a mechanically bendable, aligned carbon nanotube (CNT) forest for flexible energy storage devices. The flexible electrode has the following salient features: 1) excellent transfer of charge from aligned CNTs to the substrate, 2) simple fabrication, and 3) can be attached to a large variety of surfaces and topographies. Preliminary testing results with CNTs of 5mm × 10mm in area on Au/Kapton® film show specific capacitance of 7.0 mF per square centimeter.

264-W **FULLY INTEGRATED MICRO ELECTROMAGNETIC VIBRATION ENERGY HARVESTERS WITH MICRO-PATTERNING OF BONDED MAGNETS** 1237
K. Tao[1], G. Ding[1], P. Wang[2], Z. Yang[1], and Y. Wang[1]
[1]Shanghai Jiao Tong University, CHINA and [2]Anhui University, CHINA

A fully integrated, fully batch-fabricated micro electromagnetic vibration energy harvester using micro-patterning of bonded magnets is fabricated and tested. The magnetic material utilized is a polymer composite, consisting of a commercially available NdFeB powder dispersed in bi-component epoxy resin to a loading percentage of 90wt%. The overall volume is very small and moderate voltage can be generated.

265-TH **HIGH-POWER DENSITY PYROELECTRIC ENERGY HARVESTERS INCORPORATING SWITCHABLE LIQUID-BASED THERMAL INTERFACES** 1241
G. Cha, Y. Jia, and Y.S. Ju
University of California, Los Angeles, USA

Low-grade waste heat harvesting represents an attractive option to power wireless sensor networks. We report a device concept and experimental data for pyroelectric thermal energy harvesting that employs switchable liquid-based thermal interfaces to rapidly cycle pyroelectric thin films between two operating temperatures and thereby achieves high power density.

266-M **INITIATION OF NANOPOROUS ENERGETIC SILICON BY OPTICALLY-TRIGGERED, RESIDUAL STRESS POWERED MICROACTUATORS** 1245
C.J. Morris[1], K.E. Laflin[2], W.A. Churaman[1], C.R. Becker[1], L.J. Currano[1], and D.H. Gracias[2]
[1]U.S. Army Research Laboratory, USA and [2]Johns Hopkins University, USA

We are developing new technologies for fully self-contained microsystems, for which integrated energetic materials can provide an alternative energy source. One requirement for the use of energetic materials is the supply of initiation energy. Here we have incorporated a single use microactuator, powered by residual stress and triggered by a laser, to provide this necessary energy. Thus we have demonstrated a system which absorbs optical energy, transmits mechanical energy, and releases a large amount of chemical energy, without the use of any external wires or batteries.

267-T **INSECT-MOUNTABLE BIOFUEL CELL WITH SELF-CIRCULATION SYSTEM** 1249
K. Shoji[1], Y. Akiyama[1], M. Suzuki[1], T. Hoshino[1], N. Nakamura[1], H. Ohno[1], and K. Morishima[1,2]
[1]Tokyo University of Agriculture and Technology, JAPAN and [2]Osaka University, JAPAN

We report the first demonstration of self-charging insect-mountable biofuel cell (iBFC) using trehalose, main sugar of insect hemolymph. The iBFC generates electric power by oxidizing glucose which is obtained by hydrolyzing trehalose enzymatically. Furthermore, in order to generate power continuously, we also develop a circulation system using motion of an insect.

268-W **INTEGRATION OF PIEZOELECTRIC ENERGY SCAVENGERS WITH FBAR RESONATORS FOR THE MINIATURIZATION OF AUTONOMOUS WIRELESS SENSORS NODES** 1253
G. Murillo[1], H. Campanella[2], J. Agusti[1], J. Esteve[2], and G. Abadal[1]
[1]Universidad Autonoma de Barcelona, SPAIN and [2]Instituto de Microelectronica de Barcelona, SPAIN

The concept "Energy Harvester in Package" (EHiP) allows the miniaturization of autonomous wireless sensor nodes (WSN) powered by vibration-driven energy harvesters. In this work, a whole wafer with several designs has been fabricated and characterized in order to develop this concept. The fabrication technology is based on a process designed to fabricate Film Bulk Acoustic Resonators (FBARs) with the purpose of integrating mass sensors and RF resonators together with the energy scavengers.

269-TH **MICRO-ROTATIONAL ELECTROMAGNETIC GENERATOR FOR HIGH SPEED APPLICATIONS** 1257
R. Cordero[1], A. Rivera[1], M. Neuman[2], R. Warrington[2], and E. Romero[1]
[1]Universidad del Turabo, USA and [2]Michigan Technological University, USA

We developed a micro rotational electromagnetic generator for high speed applications employing stacked planar coils made of 18um thick copper-clad on top of 25um thick polyimide and commercial grade NdFeB permanent magnets. This system can supply power to autonomous sensor applications for machine health monitoring on rotating equipment. A power output up to 727mW was obtained when rotating at 29,500rpm.

NANO-ELECTRO-MECHANICAL DEVICES AND SYSTEMS

282-M **DIRECT-WRITE SINGLE-WALLED CARBON NANOTUBE SERPENTINES USING MICRO CHEMICAL VAPOR DEPOSITION** 1309
Q. Zhou, J. Huang, and L. Lin
University of California, Berkeley, USA

We have demonstrated the direct write single-walled carbon nanotube (SWNT) serpentines on a quartz substrate using a micro chemical vapor deposition (μCVD) system. Controlled nanomanufacturing, such as direct deposition of one-dimensional nanostructures with nanometer-scale controllability over the size, orientation and position is presently not possible. This work presents, for the first time, the capability to grow and deposit SWNT from a MEMS growth platform to a second substrate with good position and orientation control toward fully controlled nanomanufacturing.

283-T **IN-SITU SELF-ASSEMBLED COLLOIDAL CRYSTALS WITHIN MICROCHANNELS USING ONE STEP STAMPING FOR DIRECT SEAWATER DESALINATION BY ION CONCENTRATION POLARIZATION** 1313
E. Choi, K. Kwon, S.J. Lee, D. Kim, and J. Park
Sogang University, SOUTH KOREA

This paper reports a novel method for in-situ geometrically controlled self-assembly of colloidal crystals within microchannel using 'one step stamping' and its application for seawater desalination process. Self-assembly of colloidal particles with controlled size, shape, and position is essential for fabricating a large-scale integrated microfluidic system. However, so far, the existing methods for in-situ growth of colloidal crystals in the microchannel have only been achieved through the uncontrolled evaporation-induced self-assembly. Moreover, there has been no possible technique for crystallization of colloid with the desired geometry and position in microchannels. The proposed 'one step stamping' can not only resolve the above problems, but also can be applied to develop the direct seawater desalination by ion concentration polarization (ICP). The previous work about the seawater desalination based on ICP used the Nafion nanojunction, which is difficult to control the geometry and pore-size. However, they can be controlled easily with the proposed nano-membranes based on the colloidal crystals.

284-W **INTEGRATED CARBON NANOTUBE ARRAYS FOR RELIABLE CONTACT IN ELECTROMECHANICAL MEMORY DEVICE** 1316
J. Choi, Y. Eun, and J. Kim
Yonsei University, SOUTH KOREA

We have developed an extremely reliable electromechanical memory device using aligned carbon nanotube (CNT) arrays as contact material. The memory logic was programmed based on adhesive force of the CNT array-to-array contact and actuation of the shuttle, and the reliability experiment showed durable contact characteristics in an open-air environment without any packaging.

285-TH **LARGE RANGE MEMS MOTION DETECTION USING INTEGRATED PIEZO-RESISTIVE SILICON NANOWIRE** 1320
P.E. Allain[1], A. Bosseboeuf[1], F. Parrain[1], S. Maaroufi[1], P. Coste[1], and A. Walther[2]
[1]Université Paris-Sud, FRANCE and [2]CEA-LETI, FRANCE

We demonstrate the possibility to increase (by at least one order of magnitude) the range of MEMS motion detection by using a fully integrated silicon nanowire stress/strain gauge. By adding a coupling spring, whose spring constant is controlled, between the MEMS device and the nanowire we adjust the in-plane motion of the MEMS resonator to the admissible range of the nanowire deformation. Moreover, we can obtain its in-situ characterization by applying axial stress to it.

286-M **LENGTH CONTROLLED IN-PLANE SYNTHESIS OF ALIGNED CARBON NANOTUBE ARRAY BY MICROMECHANICAL SPRING** 1324
J. Choi, S. Pyo, J.-I. Lee, and J. Kim
Yonsei University, SOUTH KOREA

We demonstrated length-controllable in-plane integration of aligned carbon nanotube (CNT) array on microstructures using micromechanical springs for precise loading during the CNT growth process. Different loading resulted in different final length of the CNT array, as well as different alignment/defectiveness of the individual CNT.

287-T **MINIMUM DETECTABLE STRAIN IMPROVEMENT IN JUNCTIONLESS NANOWIRE FET SENSORS** 1328
P. Singh[1], J. Miao[1], W.-T. Park[2], and D.-L. Kwong[2]
*[1]Nanyang Technological University, SINGAPORE and [2]Agency for Science, Technology and Research (A*STAR), SINGAPORE*

We present the piezoresistive and noise measurement results on junctionless nanowire field-effect transistor (JL-NWFET). Results reveal the channel doping and gate bias impacts on the piezoresistance, threshold voltage and low frequency noise (LFN). The JL-NWFET shows ~5 orders of magnitude lower spectral noise than the inversion mode FETs, and LFN is found less sensitive to gate bias voltage. Channel doping shows a wide tunability of threshold voltage without any influence on LFN. The picoampere drain current noise helps achieve a superior resolution (minimum detectable strain) and formulate JL-NWFET as an ultrasensitive sensing element for the nanoelectromechanical sensors.

288-W **NANOSCALE DYNAMIC VISCOELASTICITY ANALYZER BY USING OPTICALLY DRIVEN NANOBEAMS FOR STUDY OF BIOMOLECULES** 1332
N. Shimada[1], K. Kadoguchi[1], M. Ikeuchi[1,2], and K. Ikuta[1]
[1]University of Tokyo, JAPAN and [2]Japan Science and Technology Agency (JST), JAPAN

We have been developing optically driven microrobots for bio-sensing such as cellular mechanical properties. In this report, we have created a novel optically driven microrobot to analyze mechanical properties of cellular proteins. The microrobot has two parallel beams extending from base with a rectangular shaped wall on the end. One of the beams can be bended to and fro. When proteins are placed between the two walls, this movement will be transmitted through proteins to another wall causing it to move. By measuring both the input and output, mechanical properties of proteins can be identified.

289-TH **PIEZOELECTRICITY OF SUB 20-NM NANOIMPRINTED PVDF-TRFE NANOGRASS** 1336
C.-C. Hong[1], S.-U. Huang[1], J. Shieh[2], S.-H. Chen[3], and A. Chen[1]
[1]National Tsing Hua University, TAIWAN, [2]National United University, TAIWAN, and [3]National Nano Device Laboratories, TAIWAN

Sub-20 nm PVDF-TrFE copolymer nanograss structures are developed using a silicon nanograss mold structure in single step by using thermal nanoimprint. Studies have investigated the polarization process of PVDF-TrFE copolymers. This paper also characterizes piezoelectric properties of the nanoimprinted PVDF-TrFE nanostructures.

290-M **RADIAL BULK-MODE VIBRATIONS IN A GATE-ALL-AROUND SILICON NANOWIRE TRANSISTOR** 1340
M. Ziaei-Moayyed, P. Resnick, B. Draper, and M. Okandan
Sandia National Laboratories, USA

This paper reports the radial breathe-mode vibrations in a gate-all-around (GAA) silicon nanowire (SiNW) transistor at 25.3GHz, with a quality factor of ~850 measured in air. The radial bulk-mode resonance is excited capacitively in the SiNW using the surrounding gate and gate dielectric as the transducer; the output is sensed piezoresistively by modulating the drain current in SiNW. The SiNWs are defined using standard lithography in a top-down front-end CMOS process, which allows for many transistors and resonators with different frequencies to be fabricated on the same chip for fully integrated communication systems.

291-T **SILICON NANOWIRE FET ARRAYS FOR REAL TIME DETECTION OF CHEMICAL ACTIVATION OF CELLS** 1344
T.S.Y. Moh, S.K Srivastava, S. Milosavljevic, M. Roelse, G. Pandraud, H.W. Zandbergen, L.C.P.M. de Smet, C.J.M. van Rijn, E.J.R. Sudhölter, M.A. Jongsma, and P.M. Sarro
Delft University of Technology, THE NETHERLANDS

This paper reports on newly designed and fabricated Field Effect Transistor (FET) devices which contain arrays of straight and smooth silicon nanowires (SiNWs), for real time detection of the chemical activation of the Neurokinin 1 (NK1) receptors expressed in Human Embryonic Kidney (HEK293) cells. The SiNWs FETs, fabricated using conventional photolithography and potassium borate (K2B03) etchant, provide a large surface to footprint ratio recording site (transducer) and use a wafer back side gate to operate the FET.

292-W **SINGLE-STEP, HIGH-THROUGHPUT BIOFUNCTIONALIZATION OF NANOELECTROMECHANICAL SYSTEMS BY MEANS OF NANOCONTACT PRINTING METHOD** 1348
S. Guillon, S. Salomon, F. Seichepine, D. Dezest, F. Mathieu, A. Bouchier, L. Mazenq, C. Thibault, C. Vieu, T. Leïchlé, and L. Nicu
LAAS-CNRS, FRANCE

This report presents an unprecedented back-end method for biofunctionalizing a large-scale array of nanocantilevers. The method presented here relies on the use of a modified nanocontact printing (nCP) process where one monolayer of antibodies is delivered onto a chip containing up to 10e6 nanostructures/square centimeter from the high-parts of a polymer stamp while its base sits on the nanocantilevers' chip, thus providing mechanical stability.

293-TH **TRANSFER OF CARBON NANOTUBES ONTO MICROACTUATORS FOR HYSTERESIS-FREE TRANSISTORS AT LOW THERMAL BUDGET** 1352
M. Muoth and C. Hierold
ETH Zürich, SWITZERLAND

A transfer process for single-walled carbon nanotubes (SWNTs) allows for suspended, ultraclean, and hysteresis-free nanotube field-effect transistors (CNFETs) on micro-actuated electrodes without exposing the device die to elevated nanotube growth temperatures. Nanotubes are grown on a separate die between the arms of a fork and are transferred contamination-free onto receiving electrodes under light microscopy observation while placement is detected by monitoring the current.

294-M **MULTIPLE TIP NANO PROBE ACTUATORS WITH INTEGRATED JFETS** 1356
K. Amponsah and A. Lal
Cornell University, USA

We report device performance for a probe system with JFETs tightly integrated with the transducers to realize differential signal measurement. The JFET is monolithically integrated into N/MEMS devices to reduce parasitics and mismatches and provide enhanced signal transduction and low noise operation. By using electrostatic actuation, the middle probe can be displaced 200nm in both longitudinal and lateral directions and this motion is sensed through a capacitively coupled JFET. The measured transconductance parameter and pinch off voltage for the JFET were 4.1 nA/V2 and -25V respectively.

295-T **TUNABLE SHRINK INDUCED GRAPHENE COMPOSITES FOR CHEMICAL SENSORS AND MICROFLUIDICS** 1360
B. Zhang and T. Cui
University of Minnesota, USA

We develop a simple and low cost fabrication method of a tunable shrink induced graphene composites with a heat shrink film as the substrate, using self assembly technique to deposit the graphene nanoplatelets.

296-W **ULTRA-HIGH RESPONSIVITY, SILICON NANOWIRE PHOTODETECTORS FOR RETINAL PROSTHESIS** 1364

S. Lee[1], S.W. Jung[2], S. Park[1], J. Ahn[1], S.J. Hong[1], H.J. Yoo[1], M.H. Lee[2], and D. Cho[1]
[1]Seoul National University, SOUTH KOREA and [2]Korea Electronics Technology Institute, SOUTH KOREA

In this paper, we develop a novel nanowire photodetector on a flexible substrate for retinal implant, and present sufficient photoresponsivity measurement results to show that the proposed novel nanowire arrayed photodetector can indeed be used for retinal prosthesis. The results of this proposed novel method can lead to a disruptive break-through in artificial retina research.

297-TH **ULTRA-SCALED HIGH FREQUENCY SINGLE-CRYSTAL SI NEMS RESONATORS AND THEIR FRONT-END CO-INTEGRATION WITH CMOS FOR HIGH SENSITIVITY APPLICATIONS** 1368

E. Ollier, C. Dupré, G. Arndt, J. Arcamone, C. Vizioz, L. Duraffourg, E. Sage, A. Koumela, S. Hentz, G. Cibrario, P. Meininger, K. Benotmane, C. Marcoux, O. Rozeau, G. Billiot, E. Colinet, F. Andrieu, J. Philippe, F. Aussenac, D. Mercier, H. Blanc, T. Ernst, and P. Robert
CEA-LETI, FRANCE

This paper reports on ultra-scaled single-crystal Si NEMS resonators (25-40nm thick) operating in the 10-100MHz frequency range. Their first monolithic integration at the front-end level with a readout CMOS circuitry enables to extract the signal from background leading to possible direct/homodyne measurement. This work paves the way for enhanced sensing performances and portable systems.

298-M **ULTRA-SENSITIVE, LOW-POWER AND FLEXIBLE H2S SENSORS BASED ON PALLADIUM NANOPARTICLE-COATED METAL OXIDE NANOWIRES** 1372

D. Kim[1], M.A. Lim[1], D. Yang[1], Z. Li[2], C.O. Park[1], and I. Park[1]
[1]Korea Advanced Institute of Science and Technology (KAIST), SOUTH KOREA and [2]Hewlett Packard Laboratory, USA

We introduce a novel method to fabricate flexible nanosensors for the detection of hydrogen sulfide (H2S) that is generated by crude petroleum or by bacterial breakdown of organic materials and human wastes. In specific, localized heating in liquid precursor enabled direct synthesis and integration of ZnO nanowires and decoration with palladium (Pd) nanoparticles (NPs) in low-temperature and mild chemical environment.

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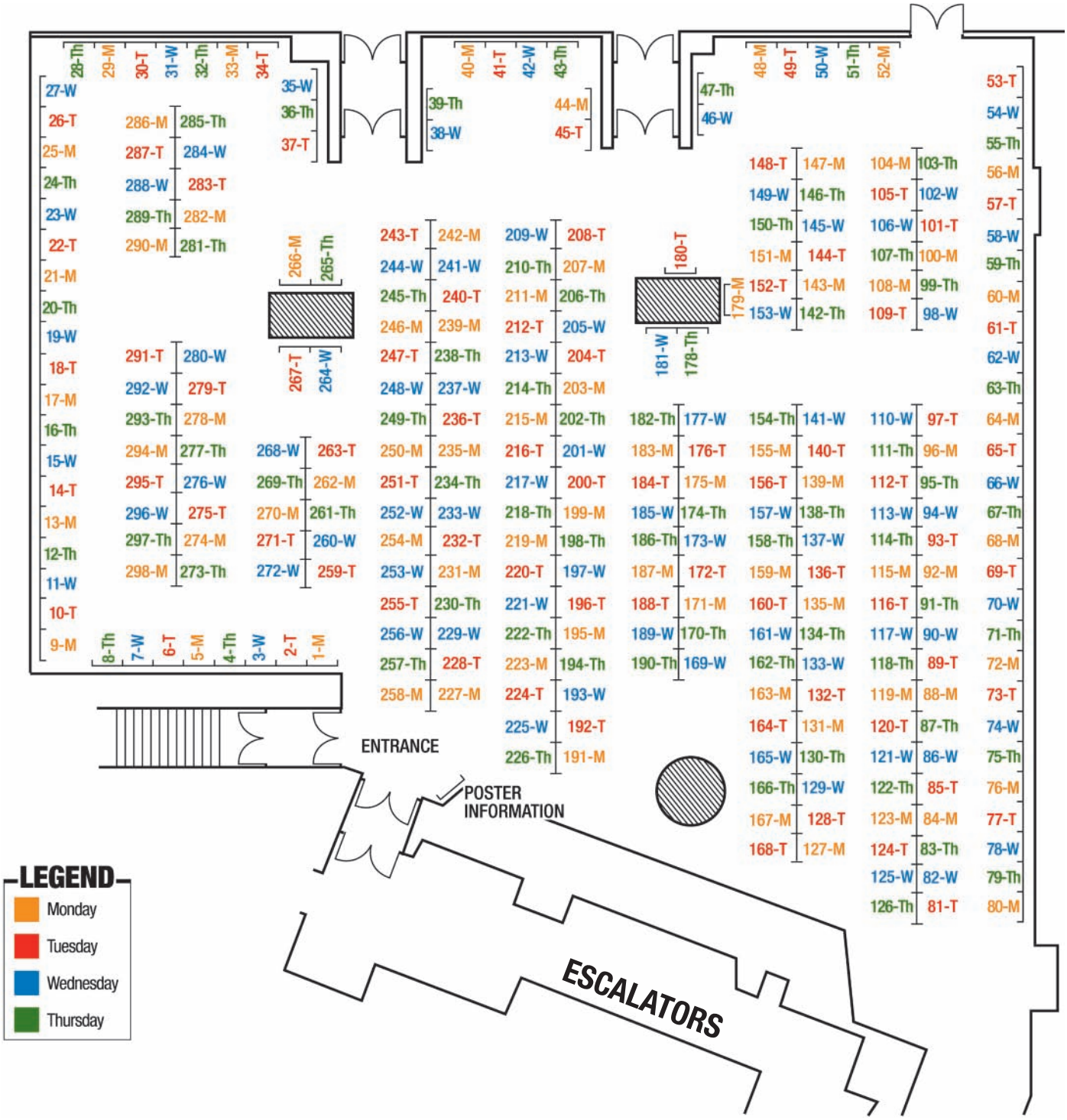
POSTER FLOORPLAN



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