Session 12: Sensors, MEMS, and BioMEMS - Integrated Ion and Gas Sensors
Tuesday, December 4, 9:00 AM
Continental Ballroom 1-3
Co- Chairs: J-W Han, NASA
X. Wang, Tsinghua University

9:05 AM - 9:30 AM
12.1 All CMOS Integrated 3D-Extended Metal Gate ISFETs for pH and Multi-Ion (Na+, K+, Ca2+) Sensing, *J.-R. Zhang, M. Rupakula, F. Bellando, E. Garcia Cordero, J. Longo*, F. Wildhaber*, G. Herment, H. Guérin*, A.M. Ionescu, Ecole Polytechnique Fédérale de Lausanne, *Xsensio S.A., EPFL*

This paper reports for the first time, smart 3D-Extended-Metal-Gate Ion-Sensitive-Field-Effect-Transistors (3D-EMG-ISFETs), with unique figures of merit: (i) extremely-low-power (down to a record value of 2 pW per sensor under excellent linearity), (ii) all CMOS integrated, (iii) high performance pH and multi-ion (Na+, K+, Ca2+) sensing, and, (iv) uniquely low cross sensitivity experimentally proven. Detailed electrical DC and dynamic characterizations show excellent sensitivities (56.8 mV/pH, -58mV/dec for Na+, -49.5 mV/dec for K+, and -21.9 mV/dec for Ca2+) and high selectivity of each ion sensor against 4 different ions that usually coexist in biofluids, all achieved on same CMOS die. Furthermore, unprecedented results show that the threshold voltage (Vth) variability of such CMOS ISFET is reduced by 78 times. We report a Vth drift rate in liquid conditions of 0.67 mV/h, decreased by one order of magnitude compared to other state of the art CMOS ISFETs. Overall, the reported experimental achievements, supported by SPICE calibrated behavioral model simulations results shown in this paper, are expected to greatly enhance the predictability of high performance multi-analyte ISFETs, which is a big step towards ISFET sensor system mass production.

9:30 AM - 9:55 AM
12.2 High Resolution Ion Detector (HRID) by 16nm FinFET CMOS Technology, *P-C Liou, T-H Lee*, C-P Wang, Y-L Chueh*, Y-D Chih**, J. Chang**, C J Lin, Y-C King, Institute of Electronics Engineering, National Tsing Hua University, *National Tsing Hua University, **Taiwan Semiconductor Manufacturing Company*

A novel approach for the ion-sensing of electrolyte solution, using specially designed CMOS FinFET process compatible floating-gate (FG) device is proposed. With the self-balancing readout scheme, the floating gate based pH sensor shows a maximum pH readout sensitivity of 115 mV/pH. Through a laterally coupling structure to the metal floating gate of a FinFET, its channel potential can be controlled both by the read gate as well as the sensing gate. In additional, this novel scheme also enables high linearity pH sensing in the target sensing range, readily adjusted by coupling ratios and biasing levels.

9:55 AM - 10:20 AM
12.3 Highly Performant Integrated pH-Sensor Using the Gate Protection Diode in the BEOL of Industrial FDSOI, *G. T. Ayele, S. Monfray, S. Ecoffey**, F. Boeuf, J-P. Cloarec*, D. Drouin**, and A. Souifi*, STMicroelectronics, *INL-Université de Lyon, **LN2, **IT-Université de Sherbrooke*

This is the first demonstration of a CMOS pH-sensor using the gate protection diode of standard FDSOI transistors in the BEOL. The extremely steep switching of the drain current induced by an exploitation of the DIBL effect is used for fabrication of extremely sensitive pH-sensors. The back gate voltage at which the abrupt switching of drain current occurs depends on the potential at the gate protection diode. Integrating the pH sensing film on this diode BEOL metal, the shift depends on the pH value of the liquid which creates a proportional potential. The abrupt switching (as small as 9 mV/decade) of the drain current can give a theoretical maximum sensitivity of 6.6 decade of drain current change per unit pH. In this paper, we report an experimental sensitivity of 1.25 decade/pH which is superior to state-of-the-art CMOS pH sensors which have a maximum sensitivity of 0.9 decade/pH.

10:20 AM Coffee Break

10:45 AM - 11:10 AM

12.4 Very Large Scale Integration Optomechanics: a cure for loneliness of NEMS resonators*?* (Invited)*,* *M. Hermouet, M. Sansa, M. Martial Defoort, L. Banniard, S. Dominguez-Medina*, S. Fostner, U. Palanchoke, A. Fafin, M. Gely, L. Hutin, C. Plantier, E. Rolland, C. Tabone, G. Usai, T. Ernst, P. Villard, G. Billiot, P. Mattei, G. Nonglaton, C. Fontelaye, C. Barrois, O. Castany, E. Gil Santos***, P. E. Allain***, E. Vernhes#, P. Boulanger#, A. Brenac##, C. Masselon*, I. Favero***, T. Alava, G. Jourdan and S. Hentz*, Univ. Grenoble Alpes, CEA LETI, *CEA, BIG, **Inserm, ***Université Paris Diderot, #Université Paris-Saclay, ##Univ. Grenoble Alpes*

The first Very Large Scale Integration process with variable shape beam lithography for optomechanical devices is presented. State of the art performance was obtained with silicon microdisk resonators showing 1 million optical quality factors and 10-17m.Hz(-1/2) displacement resolution. Single-particle mass spectrometry could be performed with these optomechanical resonators in vacuum. The devices retained high performance when directly immersed in liquid media, allowing for biosensing experiments. These results open the door to large, dense arrays of optomechanical sensors.

11:10 AM - 11:35 AM

12.5 SiC-FET-type NOx Sensor for High-Temperature Exhaust Gas, *Y. Sasago, H. Nakamura, T. Odaka, A. Isobe, S. Komatsu, Y. Nakamura, T. Yamawaki, C. Yorita, N. Ushifusa, K. Yoshikawa, K. Ono, Y. Anzai, S. Machida, M. Kinoshita, K. Fujisaki, T. Usagawa, K. Okishiro*, and Y. Sugiyama* , Hitachi, Ltd., *Hitachi Metals, Ltd.*

We have developed a SiC-FET-type gas sensor that enables highly sensitive NO detection in high-temperature exhaust gas. The gate of the FET is a gas detection layer consisting of yttria-stabilized zirconia, nickel oxide, and platinum, which are deposited on the SiC substrate. The threshold voltage of the FET depends on the NO concentration. Experimental results demonstrate that the FET-type sensor can detect NO concentration less than 1 ppm, thus meeting the specifications required to satisfy the strict regulations for exhaust gas in the next generation.

11:35 AM - 12:00 PM

12.6 A Si FET-type Gas Sensor with Pulse-driven Localized Micro-heater for Low Power Consumption, *Y. Hong, S. Hong, D. Jang, Y. Jeong, M. Wu, G. Jung, J-H Bae, J. S. Kim, K. S. Chang*, C. B. Jeong*, C. S. Hwang, B.-G. Park, and J-H Lee, Seoul National University, *Korea Basic Science Institute*

A poly-Si localized micro-heater for Si FET-type gas sensor is proposed in this paper. The fabricated gas sensor has an air gap under the heater to prevent the heat dissipation. It is found that the micro-heater itself can read the temperature by applying a read bias of less than 0.5 V. The heating and cooling times of the heater are ~200 μs and ~100 μs, respectively. Measured temperatures are verified by infrared thermal microscopy. The NO2- and H2S-sensing tests with the heater are successfully performed by using a pulse scheme.