Ultra Low Power Integrated FET for Gas Sensing Applications

Ecole Centrale de Lyon + STMicroelectronics

NICOLAS BAUDIN
INTERNSHIPS IN FRANCE INITIATIVE

Name of the hosting institution in France	Ecole Centrale de Lyon
Name of the host laboratory / research team	Institut des Nanotechnologies de Lyon
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Internship offer

Topic of the internship (title)	Ultra Low Power Integrated FET for Gas Sensing Applications			
Proposed dates of the internship	**Start:**	2019-04-01	**End**	2019-07-01

Scientific and academic objectives of the internship (detailed description of the internship content, work expected from the intern and expected outcomes):

In the last decade, high efforts have been done for adding new functionalities to the nanoelectronics, which continued its scaling down process, according to Moore's law, towards its physical limits. In this direction, wireless sensor networks for monitoring air quality based on miniaturized gas sensors have been actively researched. Today, this domain is becoming even more relevant with the emergence of sensing scenarios for Internet-of-Things nodes and new sensing functionalities required by smart hubs (smart phones and smart watches) for which such gas sensors with low power consumption, high sensitivity and selectivity are an enabling technology for new services in Quality-of-Life. The final goal of the project is to study the proof-of-concept of gas sensors operating at room-temperature integrated on industrial FDSOI platforms. Many past studies indicated that the response and recovery times of many environmental gas sensors can benefit from specific material properties and chemical reactions, such as metal oxides (MOX) rather at high controlled temperatures than at room temperature. However, such high temperature operation would require more power supply to the integrated heaters. Another fraction of the power is consumed by the read-out electronics and by the sensor itself, making challenging the long-time operation of large arrays of sensors integrated in battery powered smart-hubs. Therefore, there is a scientific and technological quest for integrated gas sensors that can fulfil all the requirement of smart hubs. Field Effect Transistor (FETs) form the most advanced and established technology for computing and, very recently, one of our consortium partners has demonstrated and suggested that high-k multi-gate FET transistor technology could also form the most credible way to go for combined high sensitivity, low power, robustness and reliability, together with the potential of having sensor operation in large arrays with small footprint. The main objective is to study several approaches for gas sensing systems directly integrated on CMOS SoCs in order to give more functionality and include e-noses in low power and low costs mobile electronics. The transducers will be based on field effect transistor with MOX sensitive layer as FET gate. In the scope of the project, one of the challenges is to develop sensing layer that will be able to detect CO, NO2, volatile organic compounds (VOCs) at room temperature. This challenge will be the internship goal. This will enable the integration of sensors without any heating layer; this will be a great opportunity to reduce the power consumption of the system. INL will use IC compatible deposition methods for sensing metal oxide film: physical vapor deposition (PVD), more precisely reactive sputtering of MOX layers on FDSOI wafers. Deposition temperature from room temperature to 450°C, post annealing treatment, gas pressure and composition will be the main parameters on which to play in order to optimize the growth and properties of the metal oxide films. The main latch is obviously to obtain a polycrystalline MOX sensing film with a high specific surface area and small grain. Targeted metal oxides are SnO2, TiO2 and WO3. Surface functionalization of the metal oxide films will be performed by catalytic activation of the sensing surface with Pd and Pt nanoparticles, with an optimum distribution/ coverage. The effect of the catalytic metal nanoparticles or nanoporous sizes on the room temperature sensing characteristics will be systematically studied as well as the noble metal choice on the gas sensibility (what is the best metal oxide and catalytic metal combination for each targeted gas, e.g. CO and NO2). For the selection of the MOX materials and the deposition method aiming room temperature detection, a metrics will be used as follows. • The stoichiometry of the sensing layers will be evaluated by X-ray photoelectron spectroscopy (XPS) • The crystallite (grain) size in the MOX ensing layer will be evaluated by X ray-diffraction (Debye-Scherrer equation). For a maximum sensitivity at room temperature, crystallite size should be in the range of Debye length for those materials, i.e. below 10nm. • The morphology of the MOX sensing layer will be assessed by atomic force microscopy (AFM) and transmission electron microscopy (TEM), which will give qualitative information about specific surface area and porosity. The functional characterization of the MOX sensing layers will be a part of the performance optimization process. For this purpose, the partners will use simple chemoresistive test structures for the evaluation of the sensing performance of their MOX sensing layer as a function of the temperature. This characterization will be performed at RMIT.

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Name of industrial partner	STMicroelectronics (STM-Crolles)
Role of the industrial partner in the internship project	STMicroelectronics will provide the FDSOI wafers with dedicated structures for transduction (with different sizes) in 14nm technology node. Dedicated layout will be implemented to optimize the sensing configuration. The passivation layer, the sensing layers, the control gate metallization and its interconnections will be performed at INL above the BEOL of CMOS devices provided by ST Microelectronics.
Main contact at the French industrial partner	MONFRAY Stéphane
Name of the Australian partner institution	RMIT Melbourne
Name of lab/department/team involved in the collaboration at the Australian partner institution	Centre for Advanced Electronics and Sensors (CADES)
Main contact in the Australian partner institution	OU Jianzhen
Function of the main contact in the Australian partner institution	Acting director
Email address of the main contact in the Australian partner institution	jianzhen.ou@rmit.edu.au
Outside of this ongoing collaboration, will applications coming from students of other eligible Australian universities be considered by the hosting institution in France?	No

Expected profile of applicant

Level of study	Master’s student
Discipline	Physics ; Electronic Engineering; Material Science and Engineering
Required qualities, knowledge and skills	The candidate should have good knowledge in material science and technology. Skills in structural characterizations and clean room will be appreciated but is not formally needed.