Publishable summary

The three-year FP7 project MSP - Multi Sensor Platform for Smart Building Management started on 1st September 2013. Materials Center Leoben (MCL), an Austrian COMET K2 Competence Centre, coordinates this € 18 million project that is designed to strengthen the leadership of European industries in the highly competitive area of smart sensing systems in wireless mobile and building applications.

The MSP consortium comprises large and small companies, universities and public research centres from 6 European countries. The 17 partners include: Materials Center Leoben, ams AG and EV Group (EVG) from Austria; AppliedSensor GmbH, Fraunhofer Gesellschaft, Siemens AG and the University of Freiburg from Germany; Boschman Technologies B.V. and Holst Centre from the Netherlands; the University of Oxford, the University of Cambridge, the University of Warwick, Cambridge CMOS Sensors and Samsung R&D Institute UK from the United Kingdom; the University of Louvain and VITO from Belgium; and Universitá degli studi di Brescia from Italy.

The MSP project is focused on the development of sophisticated devices and sensors as elements of a “tool-box” that are required for the realization of innovative smart multi-sensor systems capable for indoor and outdoor environmental monitoring:

- Gas sensors for detection of potentially harmful or toxic gases
- Sensors for particulate matter and ultrafine particles
- Development of IR sensors for presence and fire detection
- Development of highly efficient photovoltaic and piezoelectric devices for energy harvesting
- Development of light sensor and UV-A/B sensors
- Development of humidity and temperature sensors.

Major objective is the development of a powerful technology and manufacturing chain enabling flexible “plug-and play” 3D-integration of devices and sensors on CMOS electronic platform chips. The MSP concept is based on rigorous employment of Through-Silicon-Via (TSV) technology and relies wherever possible on CMOS technology being the sound foundation for cost efficient mass fabrication. The multi-sensor system will include devices providing wireless communication between MSP nodes and from MSP nodes to users. By integrating different types of devices and components from the “tool-box” the following MSP demonstrator systems will be realized:

- MSP Device for Smart Building Management
- MSP Device for Wearable Wristwatch Application
- MSP Device for Outdoor Environmental Monitoring.

A lot of progress has been achieved in the first year of the MSP-project; the “big picture” to finalize with overmolded 3D-integrated MSP demonstrator devices is clear.

Work started in WP2 “Overall Concept Development” where first of all the requirement specifications have been defined by the end-users Siemens and Samsung in cooperation with all other partners according to the target applications. The relevant target gases are CO, CO_2, VOCs (Volatile Organic Compounds), O_3 and NO_2; in addition particulate matter, UV-A/B radiation as well as IR emission from humans will be detected. A preliminary

integration concept enabling 3D-stacking of the developed devices on a common CMOS platform chip has been developed. Due to technological restrictions several sophisticated devices such as the GaN-based gas sensors cannot be fabricated with TSVs. The 3D-integration concept thus includes both devices with TSV-based contact plugs as well as components requiring wire bonding, and enables realization of a “hybrid” 3D-integrated encapsulated MSP demonstrator system.

A lot of progress has been achieved in WP3 “Development of Components and Devices”, where a variety of gas sensors ranging from commercially available products and demonstrators systems to highly sophisticated devices based on graphene and nanowires are being developed. This is key for solving selectivity issues of electrical gas sensors with respect to the target applications. In addition other sophisticated devices such as piezoelectric energy harvesters based on ZnO-NWs and infrared detectors based on thermopiles are being developed. Extensive characterization and test measurements have been performed on these devices in WP4 “Characterization and Test of Components and Devices” both in the test labs of the individual device developers as well as in the specialized test labs of Siemens and Vito.

Among all fascinating developments the most important highlights are:

- Fabrication of Demo-Kit frontside photodiode device with 6 TSVs connections to the backside, which is solder ball bonded on a PCB (Fig.1a)
- Fabrication of Demo-Kit infrared sensor for people presence detection implemented on USB stick (Fig.1b)
- Successful integration of ultrathin (50 nm) SnO_2 gas sensing elements decorated with bimetallic AuPd nanoparticles on CMOS fabricated microhotplate-chips (Fig.2a) for highly sensitive CO detection in real life conditions (Fig.2b)
- Realization of AlGaN/GaN-based gas sensors, which are grown on Si substrates, implemented in a package (Fig.3a) optimized for ppb-level sensing of NO_2 (Fig.3b).

WP5 “Development of CMOS-Platform Chip (PC)” has been successfully started. Two generations of PCs are planned; the design of the 1st Generation platform chip has been already defined. The PC will provide pads for 3D-stacking of specific single sensor and is designed to provide high flexibility and to enable preliminary tests which are required for optimization loops. Key design rules and parameters of the TSV structures have been elaborated.

A lot of progress has been achieved in WP6 “Data Processing and Wireless Communication”. Based on the MSP requirements, a wireless system level architecture has been developed. This receiver has been designed, and a silicon tapeout has been already accomplished. The 2.4GHz multi-standard radio supports Bluetooth V4.0 (also known as Bluetooth Low Energy or Bluetooth Smart), as well as the IEEE802.15.4 (also known as. ZigBee) and is designed to achieve best-in-class performance at world’s lowest power consumption.

In parallel with WP2 specific packaging solutions have been elaborated in WP7 “Fabrication of 3D.integrated Demonstrator Systems”. The packaging solutions are based on Film Assisted Molding (FAM) technology developed by Boschman for the encapsulation of sensor devices. The FAM technology enables an open window in the package of the MSP demonstrator devices for direct access of the ambient environment.

In WP9 “Exploitation” an exploitation team has been set up and an exploitation task catalogue has been elaborated to ensure a sustainable exploitation of the project results.

Major goal is to expand the present MPW service facilities and to offer additional features for specific sensing functions.

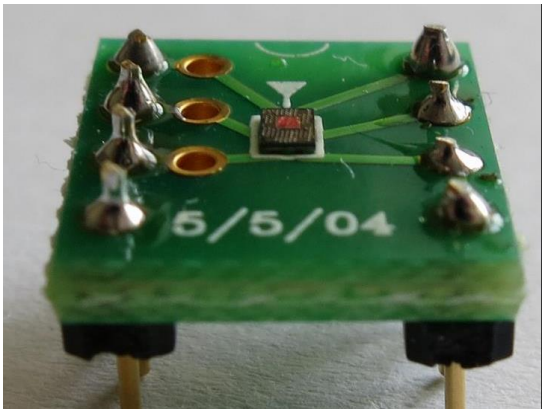

Fig.1a: Demo-Kit of frontside photodiode with implemented TSVs.

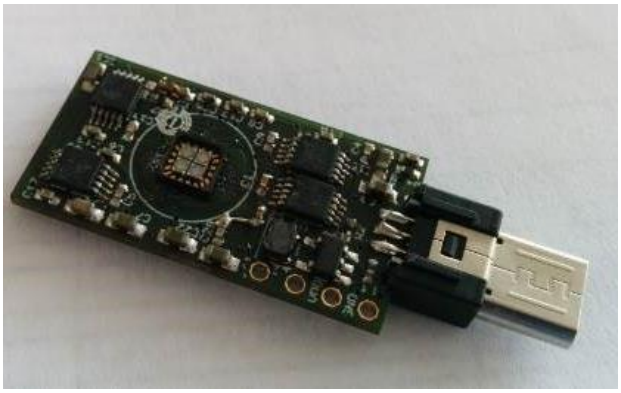

Fig.1b: Demo-Kit of IR sensor implemented on USB stick.

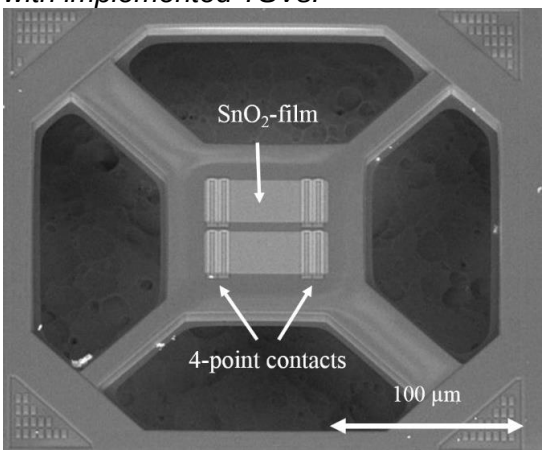

Fig.3a: Ultrathin SnO_2 gas sensing layers decorated with AuPd nanoparticles on CMOS fabricated microhotplate-chips.

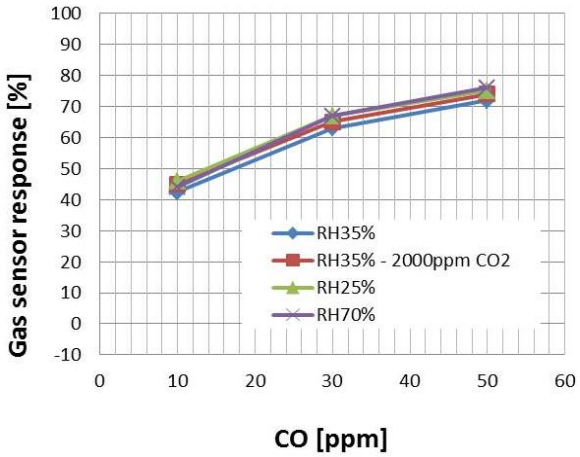

Fig.3b: Gas sensor response of SnO_2-thin film functionalized with PdAu-NPs in real-life environmental conditions.

Fig.4a: Four AlGaN/GaN sensor dies in a single package.

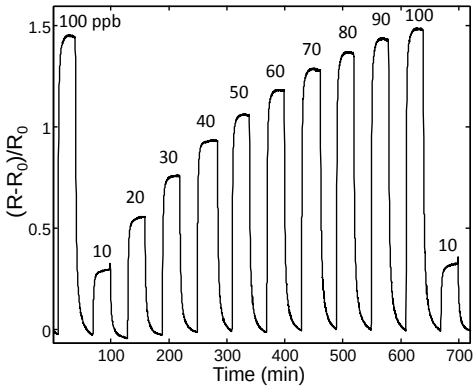

Fig.4b: Response to NO_2 concentrations in the 10 ppb to 100 ppb range in air at 50% RH

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WP10 “Dissemination” has started immediately from the beginning of the MSP-project. The design for a MSP-Logo has been elaborated and the MSP website (www.multisensorplatform.eu) has been set up. Press releases in English and German language have been elaborated and disseminated to international news agencies. More than 10 publications and conference participations have been submitted and already accepted. The new conference nanoFIS “Functional Integrated nanoSystems” which will be held in Graz, Austria, 3 – 5th December 2014 has been organized. The nanoFIS topics consider the merger of the JTIs ENIAC, ARTEMIS, and EPoSS to the new JTI ECSEL and are focused on the most relevant objectives of ECSEL. The goal of the nanoFIS 2014 conference is to contribute to the new challenges and topics of European Micro- & Nanoelectronics and to increase visibility in particular in the More-Than-Moore domain. The nanoFIS 2014 conference is an excellent platform to present the MSP project and MSP results.

The expected final result of the MSP project is the development of highly competitive production technologies enabling flexible integration of nanotechnology based multi-sensor systems with conventional electronic chips to meet the cost goals for handheld devices. The manufacturing concept of the MSP-project is based on a multi-project wafer (MPW) service approach, in which circuit designs from external users and customers are collected and fabricated together on silicon wafers. The present MPW service will be extended to provide its users with additional integrated sensing functions opening opportunities for cost-efficient innovative sensor products. Moreover the MPW service will be extended to devices based on nanotechnology, micro- & nanoelectronics, photonics, advanced materials, and advanced manufacturing technologies which constitute a major part of the Key Enabling Technologies (KETs) promoted by the EC. The impact of MSP is to contribute to reinforcing European industrial leadership through miniaturization, performance increase and manufacturability of innovative smart systems. The MSP concept is dedicated in particular to innovative SMEs to enable the early take up of KETs for highly innovative product development by post-processing on MPW devices. The MPW service concept ensures cost efficiency, fabrication of low volume products as well as flexible development on an industrially relevant wafer scale, which is a prerequisite for penetrating the consumer market.

The MSP project will have great potential impact for smart building management and lifestyle products such as smartphones. Up to 50% of energy consumption and CO_2 emissions can be saved using intelligent air conditioning systems that are controlled by air quality. Additional infrared sensors in multi-sensor nodes provide fire alarm, detect, and locate the presence of people in the building – this can set new safety standards in building technologies. Implementation of multi-sensor systems into smartphones enable detection of harmful environmental situations which may negatively affect personal health or are even potentially dangerous. A gas sensor for carbon monoxide can provide warning of a defective heating system and an increased or even deadly CO concentration - a potential source of danger in millions of households worldwide. Nitrogen dioxide, ozone or particle sensors can be used to monitor air quality and warn people, i.e. sensitive people, of adverse conditions, support athletes in planning outdoor training or assist cyclists in choosing the healthiest routes.