M+ POWER: Magnetic Sensitive (MS) Smart-Power Integrated Circuit (ICs) Technology

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Synopsis

- Background Information & Track Record
  - MS Power ICs
  - Power Devices
  - Isolation Techniques
  - Magnetic Field Sensing Devices

- M+POWER: Magnetic Field Controlled Switching Device for Power IC Technology, **EPSRC CPE Feasibility Study**, Sep 2015 – Dec 2016
Magnetic Sensitive (MS) Power IC

• the MS smart-power ICs consists of one or more magnetic sensors, high voltage/power devices (the “brawn” of the system) and CMOS logic circuits (the system’s “brain”) fabricated on a common semiconductor substrate to maximize the overall IC performance, reduce power consumption and cost. The MS smart-power ICs detect the magnetic field in environment, convert it into analogue or digital electrical signal and deliver the result to a microprocessor or logic field-programmable gate array (FPGA) by means of an on-chip serial interface, for example.

• The MS smart-power ICs could be used for detecting position or rotation of the magnetized objects, portable battery-operated magneto-dosimeters intended for monitoring the humans’ exposure to magnetic fields in particular working environments (hospitals or physics laboratories), and/or wheel speed detection in automotive applications...
Power ICs

- ASIC
- Isolation
- Low/Medium Voltage Power IC
  - Devices < 100V
- Package
  - High voltage devices
    - >600V
Power Devices for Power ICs
Power Devices for Power ICs

- SUPER-JUNCTION
- ULTRA THIN DEVICES
- RESURF
- LDMOSFET
- VERTICAL POWER DEVICES

RESURF Concept
Power Devices for Power ICs

**100V 0.35 CMOS**

**Example:**
- 100V TONIC Device (RESURF LDMOSFET)
- £1,000,000 Innovate UK (TSB) Project
- Swansea University, X-Fab, Diodes-ZETEX
  - Project outputs marked as Excellent!
  - 95% of the targets achieved!
Devices and Isolations for Power ICs

- Power Transistor
- Leakage Current
- Smart Power IC
- Logic Circuit
Devices and Isolations for Power ICs

- Power Transistor
- Isolation
- Smart Power IC
- Logic Circuit
Devices and Isolations for Power ICs

- Passive Junction Isolation (JI)
- Trench + JI
- Trench
- LOCOS
- Bulk Si
- SOI
- NFA
- MAAP
JI – NFA

Negative Feedback Activated JI
Magnetic Sensor Integration

- availability of technology
- manufacturing cost
- environment to which sensor is exposed: temperature, humidity and chemical stress, mechanical stress, vibrations
- sensor geometry
- sensitivity
- frequency response
- linearity
- temperature coefficient of sensitivity
- power consumption, size, weight
- electrical input and output impedance
- stability, reliability, lifetime.
Magnetic Sensor Integration

Magnetic Field Sensors (MFS)

- MFSs based on high-permeability materials
  - Optoelectronic MFS
- MFSs based on low-permeability materials
  - Thin-metal film MFS
  - Semiconductor MFS

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Magnetic Sensor Integration

CMOS Compatible – no Micromachining or Film deposition

Magnetotransistor (bipolar)

LDMOS with integrated Hall-plate (LD MagFET)

Double-gate split-drain split-source MagFET

Split-drain MAGFET

Hall-plate MAGFET

CDM

Magnetodiodes

CDM – Carrier Domain Magnetometers

Semiconductor MFS

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LDMOSFET with Integrated n-type Hall plate

Schematic Cross Section (a) and actual photo of the fabricated device (b)
The current-related relative magnetic sensitivity is estimated as $S = 30\% T^{-1}$ (calculated using a formula $S = \frac{|\Delta I_D| \cdot \frac{1}{I_D} \cdot F_B^{-1} \cdot 100}{100}$). This sensitivity is substantially, i.e. order of magnitude, higher than the one for the conventional split-drain silicon MagFETs reported so far to be in the range of $1.5 - 3.5 \% T^{-1}$. 

LDMOSFET with Integrated n-type Hall plate

Measured output characteristics

Measured Sensor transfer function

\begin{align*}
W &= 20 \mu m \\
L_g &= 5 \mu m \\
L_{\text{drain}} &= 40 \mu m \\
V_g &= 5V \\
V_g &= 4V \\
V_g &= 3V \\
V_g &= 2V
\end{align*}
The main project outcome would be the design, fabrication and testing of functional prototype of novel integrated current sensing device aimed for on-chip over-load/over-current protection of power devices. The current sensor will be based on a revolutionary new integrated magnetic FET (MagFET) featuring the extreme magnetic sensitivity and inherent magnetic controlled on-off switching phenomena. Since the proposed high-performance MagFET design and fabrication is compatible with CMOS SOI technology, it could be easily embedded in gate drivers that control the “on” and “off” cycling of future SiC and GaN power devices used for high temperature applications, for example.
M+POWER: Research Team and Support

*FLEXIS Details:
Operational Programme: ERDF West Wales European Regional Development Fund, Capacity Building
Operation Number (Awarding Organisation’s Reference): 80835
Operation Name (Case Name): FLEXIS - Flexible Integrated Systems
Total FLEXIS project value: £9,554,732.00

Title of the project WP lead by Dr Petar Igic (Principal Investigator) Swansea University:
Smart Energy Management/Low Cost-High Performance Smart Power Conversion
Amount sought for this WP: £782,750.00
Start date: 01/07/2015 - End date: 01/07/2020
M+POWER: Current sensing application

Galvanic-SenseFET current sensing

Double-gate split-drain split-source MagFET
M+POWER: Double-gate split-drain split-source MagFET

Current density distribution of MagFET in the on-state and the $I_D/V_{GS}$ characteristics simulated for various perpendicular magnetic field

One device solution:
- Combined function sensing + switching
- Fast response
- Small volume
M+POWER: Current project status

- Device design completed (SU, UofN)
- Process flow developed (SU, UofN, TUD)
- Mask set designed (UofN, SU)
- Silicon to be completed by the 15 July (TUD)
- Bespoke testbed designed (SU)
- Testbed manufacturing ongoing (SU)
- Device test to start August 2016 (SU)
The test system is designed to characterise the sensitivity of magnetic sensors across a wide range of field strengths and at temperatures both above and below ambient.

The magnetic field is generated in the air-gap of an iron magnetic path energised by a coil wound on a split bobbin.

The magnetic sensor is positioned in the air-gap and the magnetic field strength is controlled by varying the current through the coil.

The magnetic sensor sits on an aluminium plate which is temperature-controlled by a Peltier element. The Peltier is PWM driven to enable both forced heating and cooling of the sensor.
Assembled test system – Peltier temperature-generating module omitted for clarity. The test system has been designed to generate a magnetic field strength of +/- 100mT. Test temperatures are expected to be in the -20°C to +80°C range.

The fan/heatsink assembly and Peltier device which together form the basis of the heating/cooling system.
Thank you