Hybrid Nano-Electro-Mechanical / Integrated Circuit Systems for Sensing and Power Management Applications

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Motivation: The unprecedented sensitivity of nanoelectromechanical systems (NEMS) for resonant mass sensing has been demonstrated[1], opening a multitude of opportunities for applications from clinical diagnosis to life sciences and pharma. However, the transition from a laboratory demonstration to a practical device remains a challenge. The project *NEMSIC* addresses this point: it envisions a NEMS-based device, capable of detecting a pharmaceutically active compound or toxic gases in the environment, handheld, within seconds. To reach this milestone, *NEMSIC* targets low-power nanoscale devices, novel ultra-sensitive detection principles, large scale sensor integration, interfaced with electronics for data analysis – all on-chip.

HIGH MASS SENSITIVITY ?

resonator total mass m_{eff} ↓
operating frequency f_{res} ↑
resonant Q-factors ↑

$$\delta m \cong 2m_{eff}\sqrt{\frac{\Delta f}{Q\cdot 2\pi f_{res}}}\cdot 10^{-\frac{DR}{20}}$$

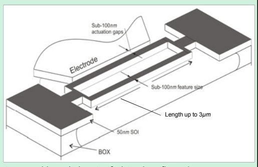


Fig. 1: Double-ended tuning fork in-plane flexural resonator.

- high aspect ratio, silicon-on-insulator NEMS
- flexible mechanical resonator design
- f_{res} above 100 MHz

HIGH SIGNAL-TO-BACKGROUND RATIO ?

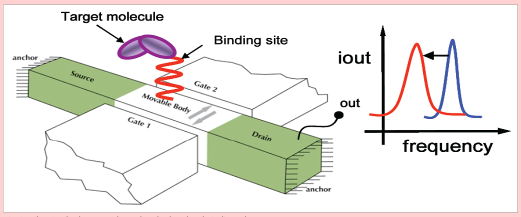
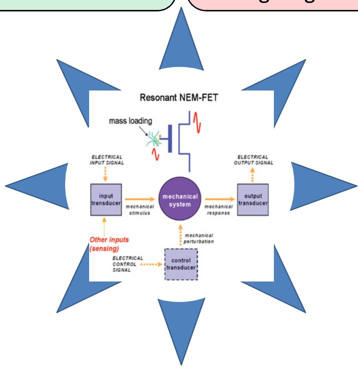


Fig. 2: Vibrating body FET, with an absorbed molecule indicated.

The vibrating body transistor as active electro-mechanical resonator provides an **intrinsic** signal gain[2].

NANOSCALE SYSTEM INTEGRATION ?

- NEMS-CMOS **co-integration,** based on large-scale SOI technology, with integrated read-out circuitry
- selective, surface functionalized **sensor arrays** → high capture cross-section



... VIBRATING BODY-FET ?

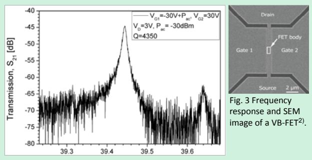


Fig. 3 Frequency response and SEM image of a VB-FET[2].

Transmission characteristics of a 8µm long and 500 nm wide doubly-clamped, in-plane flexural beam resonator (thickness 200nm), prototyped at EPFL (D. Grogg et. al). With further scaling of resonator and transistor dimensions, an improved power handling is targeted.

NEM-FET as ultra-low power switch: The characteristics of the suspended gate FET (SG-FET) is very abrupt switching and zero static power consumption. The integration of a SGFET-like devices on a CMOS platform would be a major step forward for both sensing applications and future IC system architectures targeting *low power leakages* and *advanced power management*, such as required in Wireless Sensor Networks.

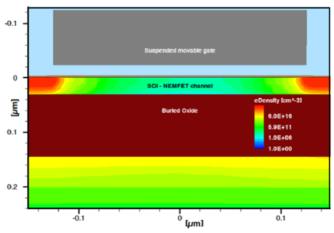


Fig.4: The FET is normally-off type. The gate is physically seperated by a sub-micron air gap.

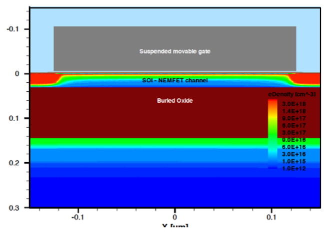


Fig.5: Carrier inversion in the FET channel in the pull-down state of the suspended gate.

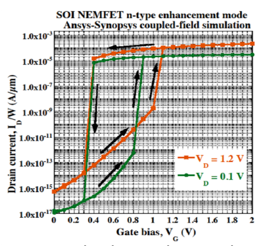


Fig.6: The logarithmic plot the drain current vs. gate bias, revealing the pull-in and pull-out characteristics of the switch.

[1] X.L.Feng et *al.,* Nature Nanotechnology, 2008.
[2] D. Grogg, A. Lovera, A.M.Ionescu, in Proceedings of DRC 2010.

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