Nanomechanical resonators integrated on CMOS defined by electron beam lithography

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Nanoelectromechanical devices (NEMS) can be used as high sensitivity mass sensors by detecting the change of resonance frequency when a small quantity of mass is deposited. A specific type of NEMS mass sensor is based on electrostatic actuation of a submicronic cantilever and capacitive detection of its oscillation [1] The mechanical structures are combined with CMOS circuits, so that the circuitry is responsible of readout of the resonator motion by avoiding parasitic capacitances. Direct connection of the mechanical element with the circuit allows optimal signal transduction. In this way, the mass resolution of the device is highly improved.

We present a fabrication process based on electron beam lithography (EBL). It consists of the combination of CNM CMOS circuit technology with the definition of the nanomechanical structure as a post process, as shown in Figure 1. The use of EBL presents the advantages of assumable cost, high resolution and it is adapted to pattern surface with any topography. In this case, the definition of the cantilever after being completed the fabrication of the CMOS circuits give additional flexibility to the design either for the selection of materials and processing at chip level.

Details of the fabrication of integrated cantilevers on CMOS as a post-process module can be found in [2] and are represented in Figure 2. A dedicated area, the integration area, is used for the monolithical integration of the resonator. The layers that constitute the CMOS circuit are used to define the structure. Hence, one of the polySi layers (0.6 µm thick) acts as the structural layer, whereas the field oxide layer (1 µm thick) is used as a sacrificial layer for the release of the structure. After the CMOS circuit fabrication, openings in the pasivation layer are done in the integration areas and the wafers are diced. A PMMA layer is spin coated on the chip for the EBL step. One of the crucial aspects of the fabrication concerns to EBL, where low electron beam energy (3 keV) is used in order to avoid damage of the circuit. A thin layer of Al (32 nm) is deposited after resist development and the resist lift off is done. RIE is used to transfer the Al pattern to the polySi layer and the structures are released by wet etching. In order to protect the circuits during the SiO_2 etching, a negative photoresist mask, patterned by UVL is employed.

Several examples of device fabrication and operation are presented in figure 3. In particular, a system of two cantilevers (lateral motion) has been used for differential measurements of Pt mass deposition in the attogram range [3] (Figure 3, left). Vertical motion plates have been used to monitor the evaporation rate of femtoliter droplets of glycerol [4] (Figure 3, center). In addition, a novel concept of cantilever actuation is presented, using the charging effects induced by electron beam (Figure 3, right).

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References:

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[3] J. Arcamone et al, IOP Journal of Physics: Conference Series (Accepted)
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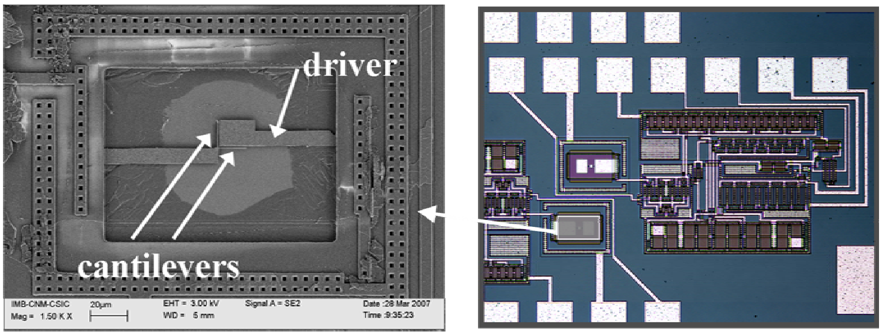
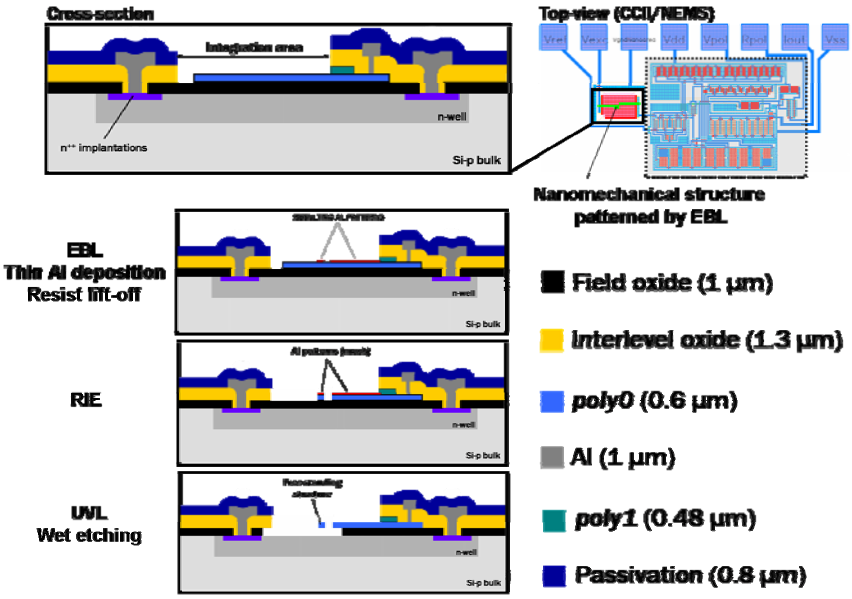


Figure 1 Nanoresonator is monolithically integrated into the CMOS circuitry. Direct connection allows optimization of electrical signal.



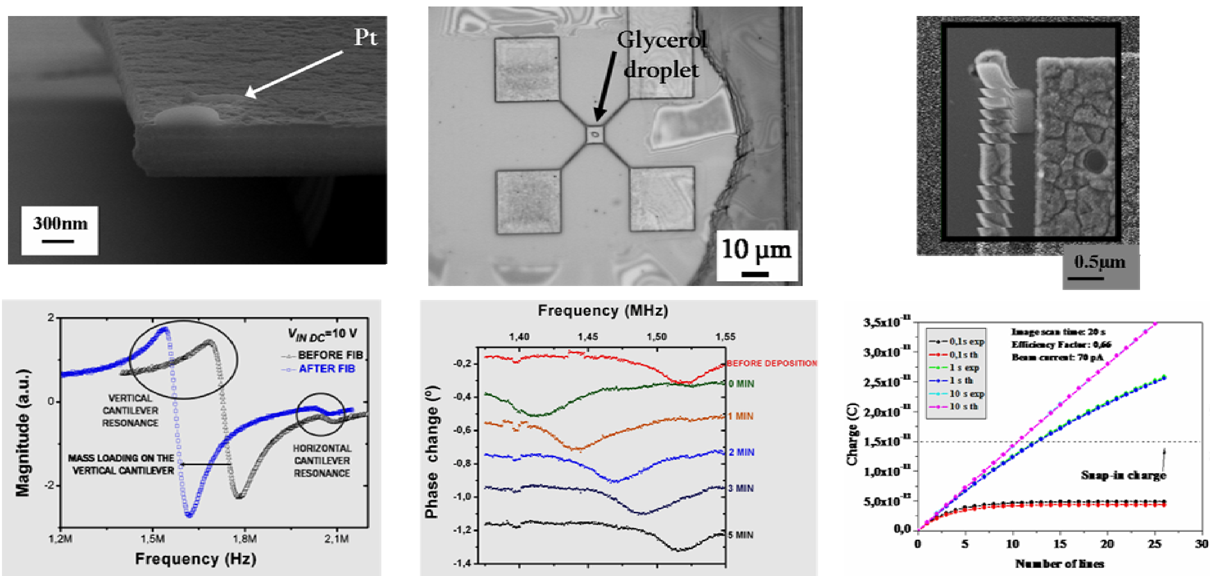


Figure 3 Three examples of applications using nanomechanical structures integrated on CMOS circuits. (Left) Mass sensing in the attogram range [3]. (Center) Monitoring of the evaporation rate of glycerol droplets [4]. (Right) Novel concept of actuation based on electron beam.