Fabrication of CMOS integrated nanomechanical devices by ion beam patterning

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Nanomechanical devices and systems (NEMS) offer good performance to construct high resolution mass sensor and very high frequency oscillators. For several applications, it is important to combine nanomechanical devices with on-chip signal processing in order to manage arrays of nanomechanical device or improve the signal to noise ratio. Monolithical integration of CMOS with NEMS is the most efficient option in terms of performance, but it complicates the fabrication process, as it requires combining different technologies.

One approach consists of using standard layer of a CMOS technology as the structural material for NEMS, and then defining the nanomechanical device in a dedicated post-process module[1,2]. In this communication, we present a novel approach based on ion beam patterning using two different approaches: (i) Direct exposure of silicon and poly-silicon surfaces (figure 1) and (ii) ion beam induced deposition (IBID) of TEOS (figure 2). In both cases, the exposed areas sustain a reactive ion etching process, resulting in robust masks for defining nanomechanical devices with sub-micron resolution. We have studied the optimal processing condition in terms of selectivity and resolution (ion beam dose and patterning mode, reactive ion etching parameters) as well as the procedure to ensure that the CMOS circuits are not damaged by the ion beam exposure. As a result, nanomechanical devices have been successfully patterned, as it is shown in figure 3. It consist of a polysilicon cantilever that it is actuated electrostatically and the read-out of the oscillation is achieved by capacitive detection

Ion beam based patterning (direct exposure and IBID) offers advantages compared to electron beam lithography: there is no need to deposit a resist on the non-flat CMOS substrate, it is a single step patterning method and it does not cause damage to the surrounding CMOS circuits .

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[1] J.Verd, G.Abadal, M.Villarroya, J.Teva, A.Uranga, F.Campabadal, J.Esteve, E.Figueras, F.Pérez-Murano, Z.Davis, E.Forsen, A.Boisen, N.Barniol. Journal of Microelectromechanical Systems, 14, 508-519 (2005)

[2] J. Arcamone, M.A.F. van den Boogaart, F. Serra-Graells, J. Fraxedas,, J. Brugger, F. Pérez-Murano. Nanotechnology 19, 305302 (2008)

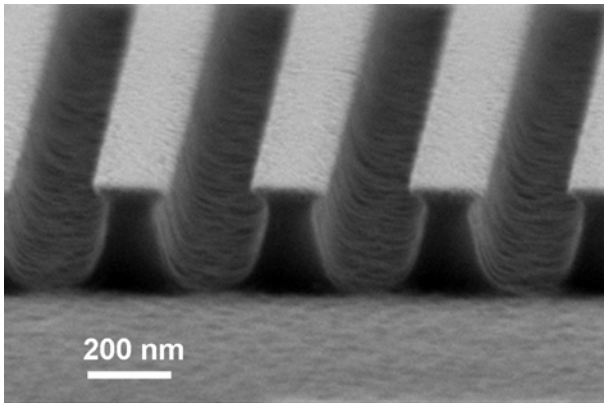

Fig 1. Example of patterning of silicon by direct exposure of a silicon surface using Ga^+ ions and reactive ion etching. A typical value for the ion dose is 50 nC/cm for an ion beam of 30 keV energy.

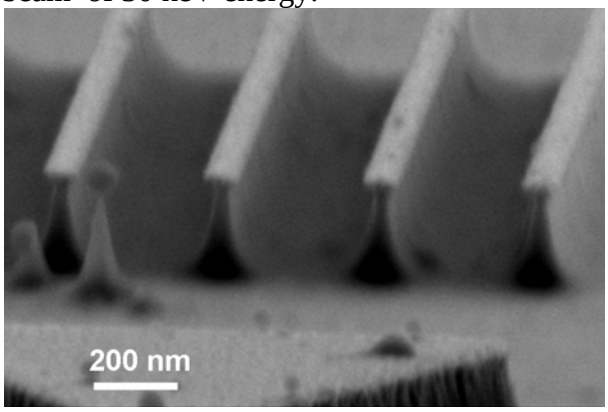

Fig 2. Example of patterning of silicon using ion beam induced deposition of TEOS and reactive ion etching. The precursor gas for beam induced deposition is 2,4,6,8,10-Pentamethyl-cyclopentasiloxane

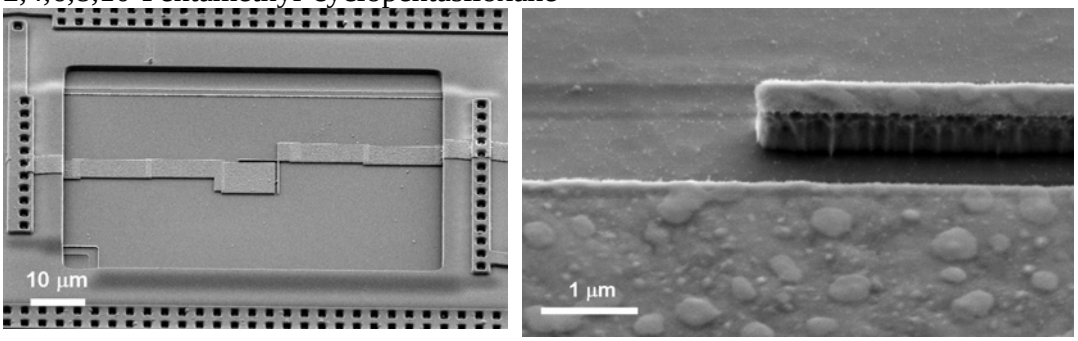

Fig 3. Example of a nanomechanical device integrated in a CMOS circuit patterned by ion beam induced deposition of TEOS and reactive ion etching.