High-speed and nonvolatile nano electromechanical memory incorporating Si quantum dots

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Nano Electro-Mechanical Systems (NEMS) have a possibility of high-speed operation in the GHz regime since the characteristic frequencies are expected to increase with decreasing their dimensions [1]. We propose a new non-volatile memory concept based on bistable operation of the NEMS structure combined with nanocrystalline-Si (nc-Si) dots. Our new memory features a mechanically bistable floating gate beam, which incorporates the nc-Si dots as single-electron charge storage. The beam is suspended in the cavity under the gate electrode and moves via electrostatic interactions between the gate electrode and the charge in the nc-Si dots. Positional displacement of the beam is sensed via a change in the drain current of the MOSFET underneath. The switching speed between two stable states was estimated to be ~ 0.5 ns for a SiO₂ beam with the dimension of 1.0 × 1.0 × 0.1 μm³, from a mechanical analysis assuming the maximum central displacement of 35 nm. By optimizing both the beam structure and stored charge amount, we may build an extremely fast and non-volatile memory.

A free-standing SiO₂ beam was successfully fabricated using a Si undercut etching technique. Most fabricated samples showed convex-shaped beams as a result of release of mechanical stress stored in SiO₂ after removing a Si layer underneath.

Mechanical properties of the beam were investigated using a 3D finite element simulation [2]. We compared a nc-Si beam where a 2D nc-Si dot array was embedded inside a SiO₂ film and a simple poly-Si beam where a thin poly-Si sheet was placed between two SiO₂ layers. The maximum displacement obtained for the nc-Si beam under a constant uniaxial pressure was found larger than that for the poly-Si beam. This indicates that a larger displacement is achievable with the nc-Si beam when an electric field is applied via the gate bias and, therefore, the nc-Si beam has an advantage for low power operation. [1] X.M.H. Huang et al., Nature 421, 496 (2003). [2] http://www.j-insight.com/ & http://adventure.q.t.u-tokyo.ac.jp/