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

Y. TSUCHIYA, K. TAKAI, N. MOMO, S. ODA, Research Center for Quantum Effect Electronics, Tokyo Institute of Technology, S. YAMAGUCHI, T. SHIMADA, Central Research Laboratory, Hitachi Ltd., H. MIZUTA, Department of Physical Electronics, Tokyo Institute of Technology ---

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 SiO_2 beam with the dimension of $1.0 \times 1.0 \times 0.1\ \mu m^3$, 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 SiO_2 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 SiO_2 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 SiO_2 film and a simple poly-Si beam where a thin poly-Si sheet was placed between two SiO_2 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/