# Development of Novel Functional Si-based Devices Using Self-assembled Nanostructures for Multivalued Memory Operation, Ultimate Photo-sensing and Molecular Recognition

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The serious limitations in down-sizing conventional MOS devices motivate us to develop novel functional devices operating with a few electrons and a few photons by means of an introduction of well-defined Si nanostructures into the MOS devices.

In our previous work, we have demonstrated that hemispherical Si nanocrystallites are spontaneously grown on ultrathin $SiO_2$ with a fairly uniform size distribution and a high areal density by controlling the early stages of low-pressure CVD using a $SiH_4$ gas, and confirmed the presence of quantum size effect in well-defined nanometer Si dots from a clear negative conductance at room temperature through a double-barrier structure consisting of single Si dot and ultrathin tunnel oxides and from the blue shift of the valence band top with decreasing dot size. In addition, we have shown that the control of OH bonds on the $SiO_2$ surface which act as reactive sites during $SiH_4$-LPCVD enables us to make positioning Si dots and ordering Si dot array structures.

In this project, for the advanced information processing with a few electrons and photons, we focus attention on the device application of unique physical properties of Si nanocrystals associated with quantum size effects and coulomb brocade and have been intensively studied MOSFETs with quantum dots (QDs) as a floating gate which operate even at room temperature and low voltages. Based on a deep understanding of the multivalued capability of the QDs-floating-gate, we also plan to design and fabricate optically or chemically coupling QDs-floating-gate MOSFETs. For the optically coupling devices, the gate stack structures consisting of a semitransparent metal gate, a gate dielectric with a high dielectric constant (high-k), a QDs-floating gate and the bottom tunneling oxide will be investigated to achieve operations critical to the input of a few photons. And for the chemically coupling devices, porous metal gate will be combined with a high-k dielectric as control gate insulator to selectively adsorb specific molecules on the high-k gate dielectric.

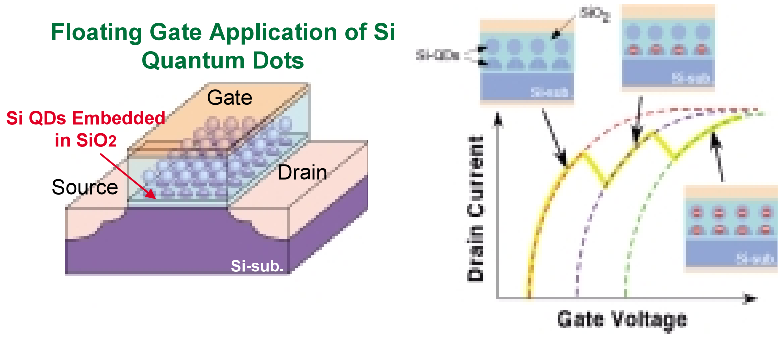
In addition, from viewpoints of the synthesis of new tailor-made electronic materials, we will extend our research work to three dimensionally stacked structures of Si-based dots with an high areal density to control unique transport properties originating from electronically coupling among neighboring dots.

### Major research issues are as follows:

1. Development of process technologies to control precisely the dot size, its distribution, and positioning and fabrication of well-ordered array and high density stacked structures of dots
2. Characterization of carrier transport through coupling dots

3. Control of energy band structures with an introduction of Ge core into Si dots
4. Valence control with impurity doping to Si-based dots
5. Fabrication and characterization of QDs-floating-gate MOSFETs for multivalued operation, high photosensitive performance and molecular recognition

## Si-QDs Functional Memories
## —Multivalued, Low Voltage & Room Temp. Operation—




**3D-Stacked Si QDs as a New Material for Optoelectronic Devices**

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**Control of Electrical Interaction & Coupling among Electronic States in Neighboring QDs**

## Photosensitive SiQDs-Floating-Gate MOS Memory
## - Optically Writing /Electrically Erasing -