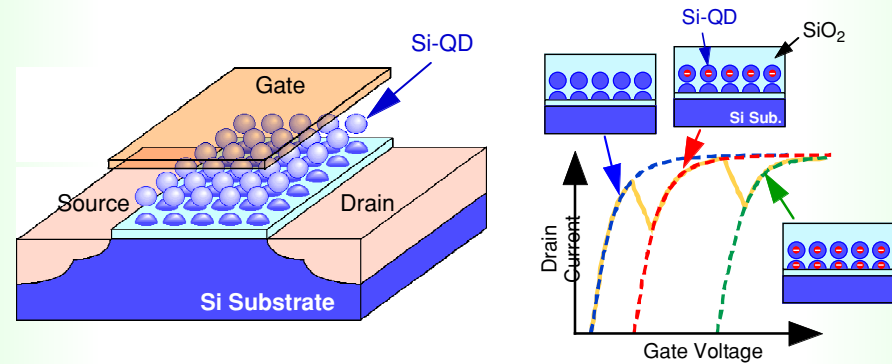


Multiple-Step Electron Charging in Si Quantum-Dot Floating Gate nMOSFETs

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Background

Si-QDs Floating Gate MOSFETs



Si Quantum Dot

● Coulomb Blockade

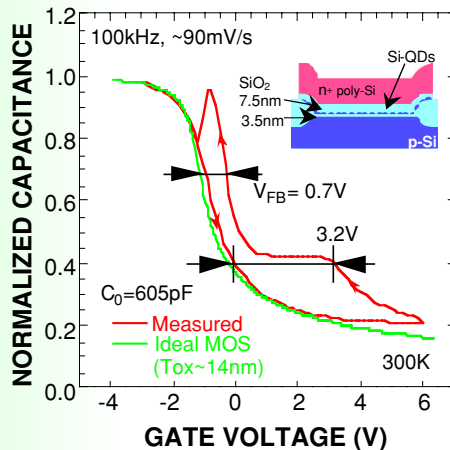
● Quantum Confinement



Multivalued Memory

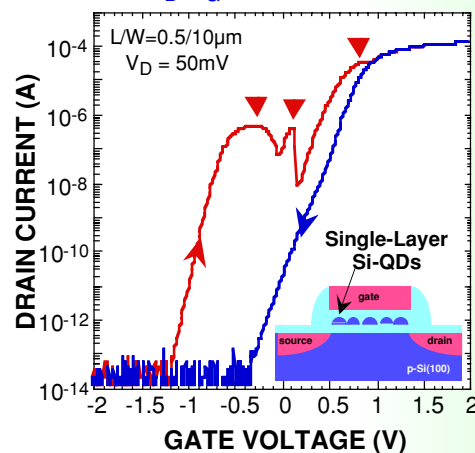
Our Previous Works

C-V Characteristics



Kohno et al. SSDM (1997)

I_D - V_G Characteristics

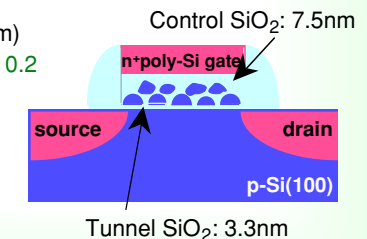
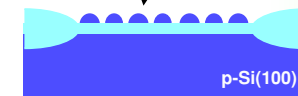


Ikeda et al. JJAP (2003)

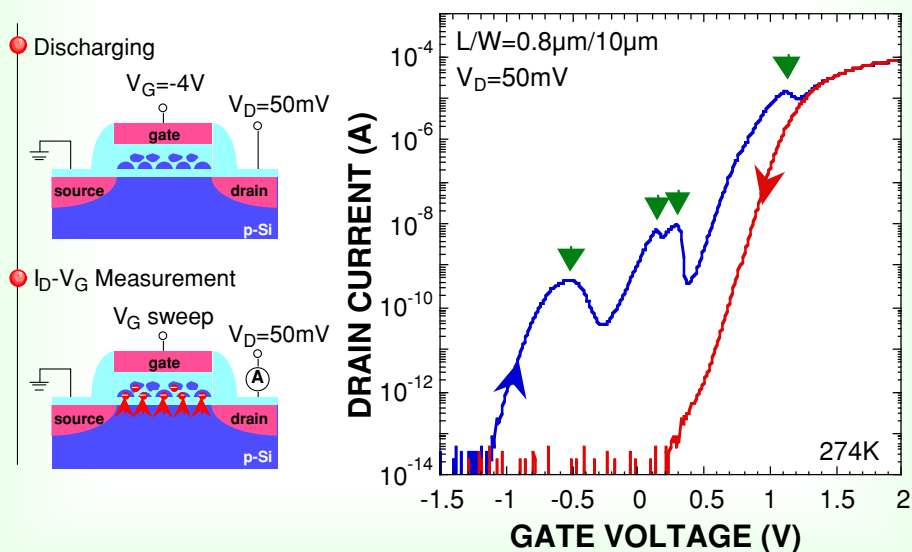
Fabrication of Si-QDs Floating Gate nMOSFETs

- p-well & LOCOS
 $N_A=1.5 \times 10^{17}$
- Oxidation (Tunnel SiO_2 : 3.3nm)
1000°C, 2% dry O_2
- 0.1% HF Treatment
- Si-QDs Formation by LPCVD
 SiH_4 (100%), 575°C, 0.2Torr, 60
- Oxidation of Si-QDs Surface
850°C, 2% dry O_2 , 1
- a-Si Deposition & Oxidation (Control SiO_2 : 7.5nm)
a-Si(3.3nm): Si_2H_6 (10% in He), 440°C, 0.2
- Torr
- Oxidation: 1000°C, 2% dry O_2
- Gate Fabrication
n+poly-Si
 $L/W=0.8\mu\text{m}/10\mu$
- Source/Drain Implantation

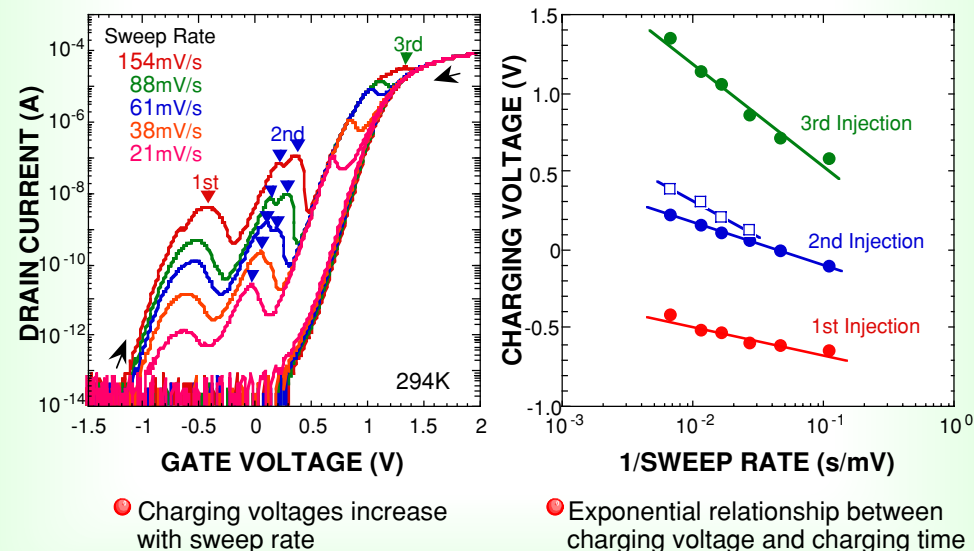
Si Quantum Dot
Density: $\sim 3 \times 10^{11} \text{X} 2 \text{cm}^{-2}$
Average Height: $\sim 7.2 \text{nm}$



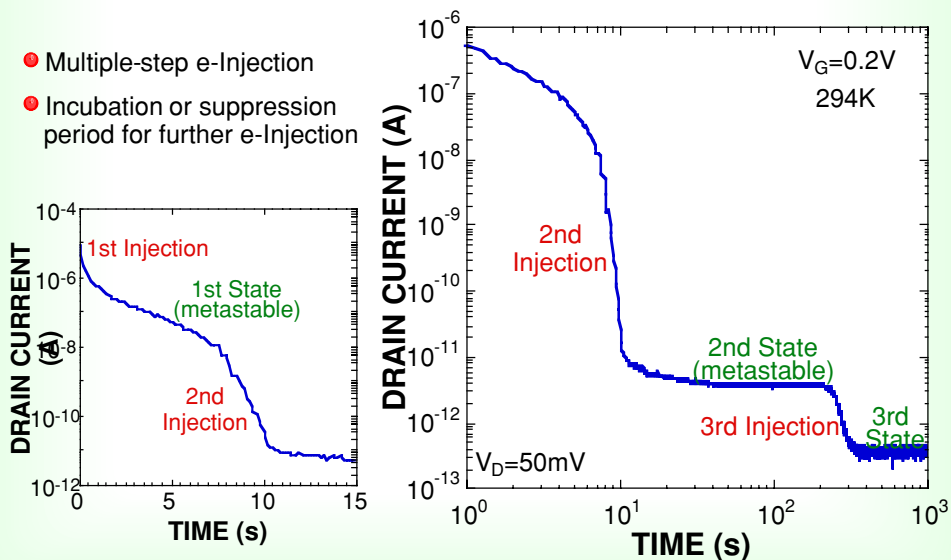
I_D - V_G Characteristics for n-MOSFET with Si-QDs Floating Gate



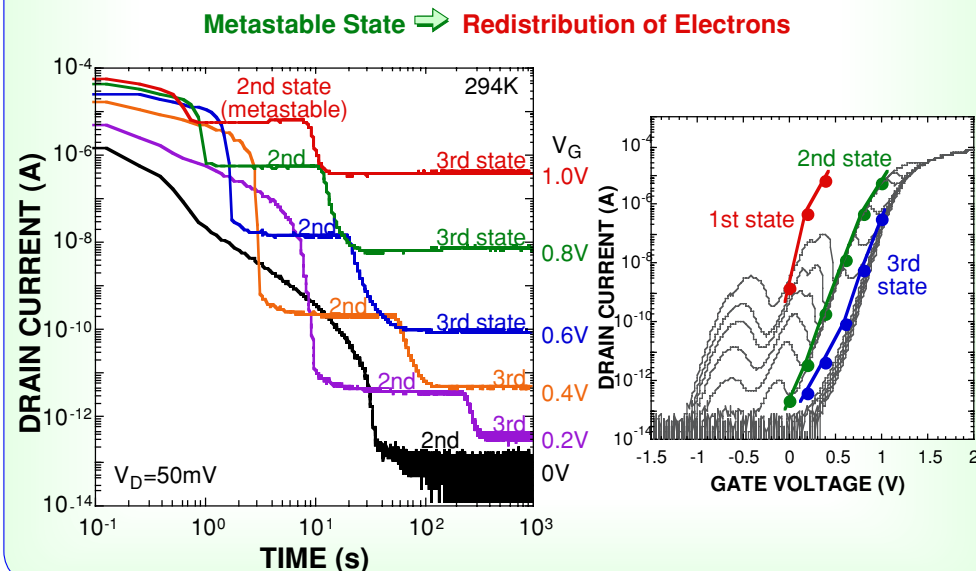
Sweep Rate Dependence of I_D - V_G Characteristics



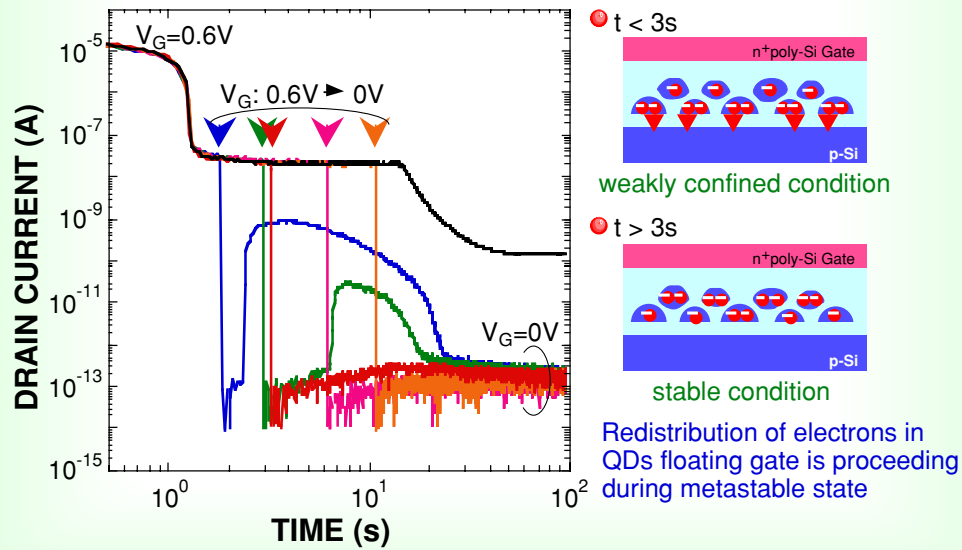
Transient Drain Current by Electron Charging to Si-QDs Floating Gate



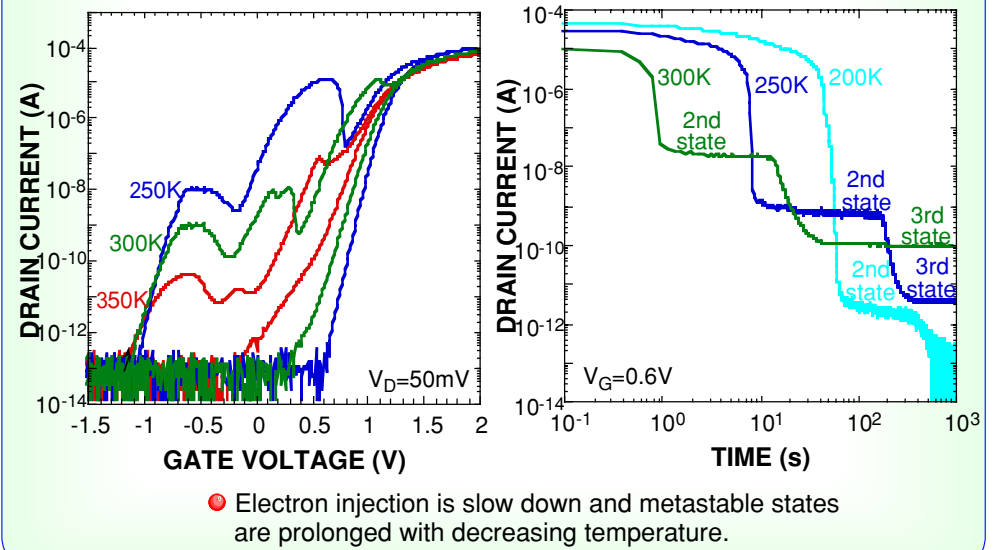
Transient Drain Current by Electron Charging to Si-QDs Floating Gate



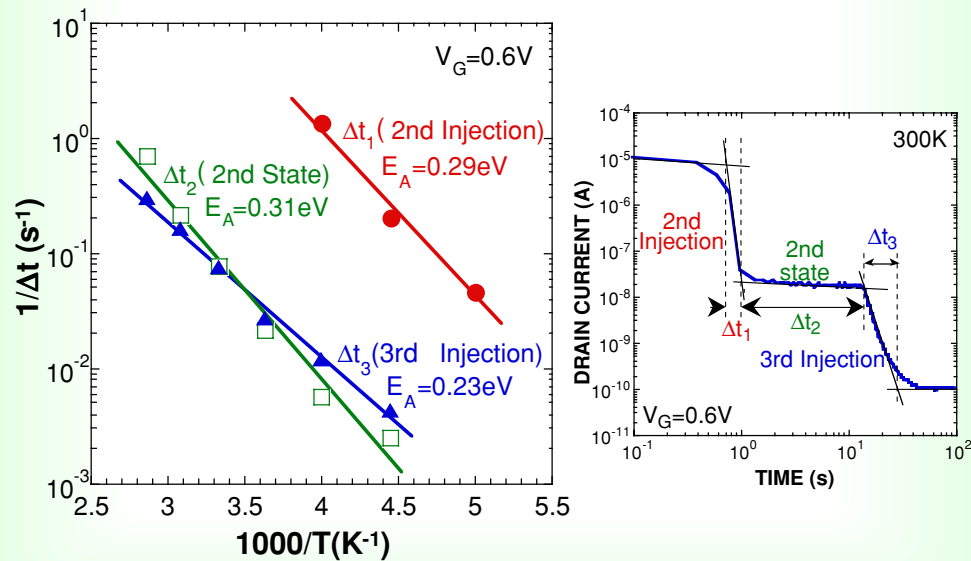
Transient Drain Current by Electron Charging to Si-QDs Floating Gate



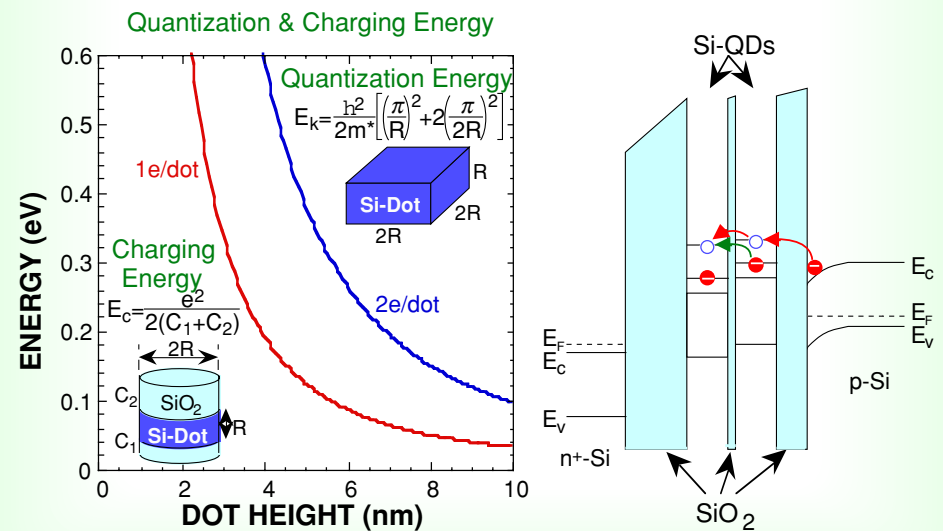
Temperature Dependence of I_D - V_G & I_D - t Characteristics



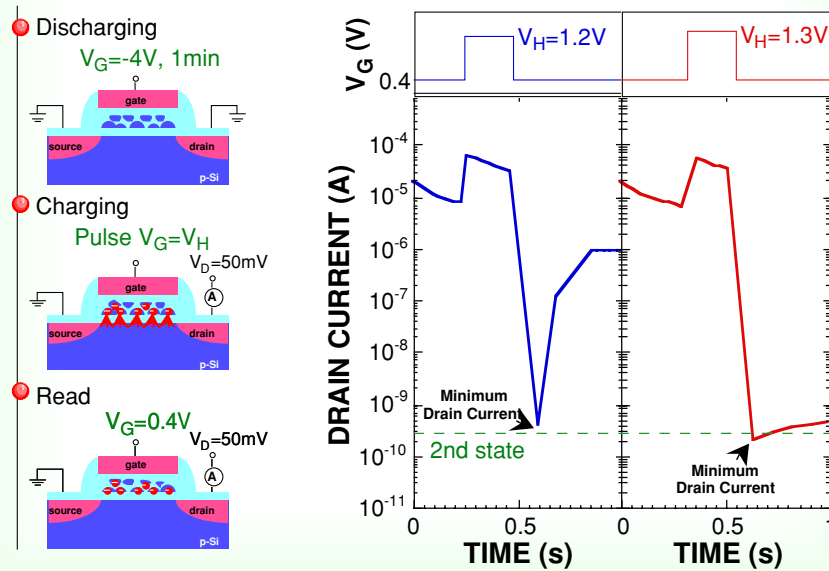
Arrhenius Plots of Injection & Metastable Time



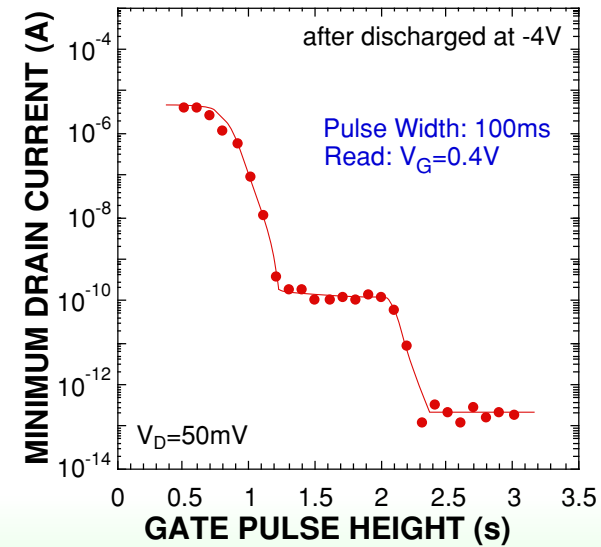
Model for Electron Charging in Si-QDs Floating Gate



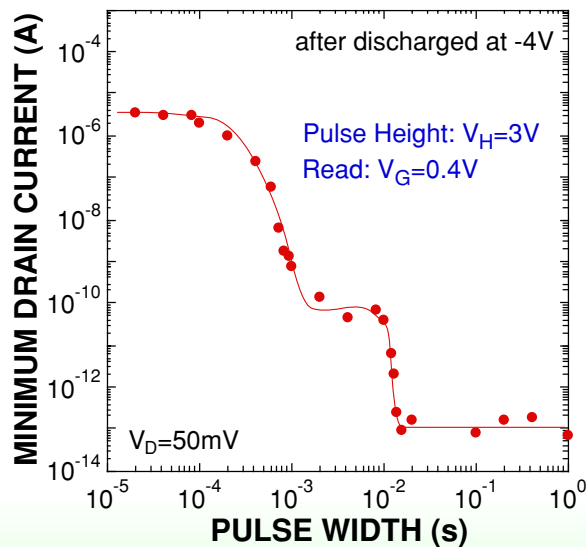
Temporal Changes in Drain Current for Pulse Gate Bias



Minimum Drain Current vs Gate Pulse Height



Minimum Drain Current vs Gate Pulse Width



Summary

- The multiple-step electron charging to a Si-QDs floating gate in the MOSFETs has been studied in the temperature range of 200-350K.
- The metastable states in electron charging at the constant gate bias are attributable to the redistribution of electrons in the Si-QDs floating gate.
- The Coulomb interaction among the neighboring charged dots may play an important role in regulation of the electron injections to the Si-QDs floating gate, which leads the generation of intermediate charged states.
- In intermediate charged states the redistribution of electrons in the floating gate proceeds without increasing charges by electron tunneling between the different energy states in the neighboring dot.