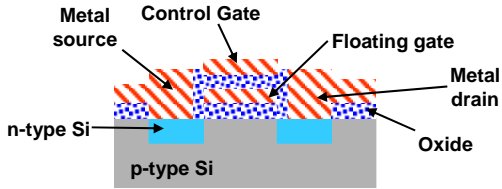
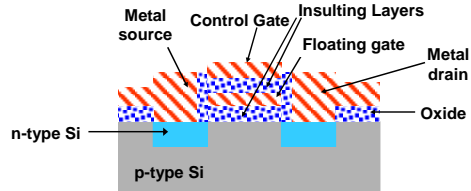


## Class 5: Capacitance How FLASH Memory Works



PRIME Modules  
Project-based Resources for Introduction to Materials Engineering

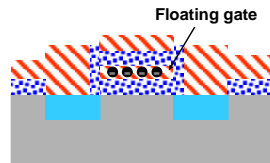
A FLASH device is an N<sup>+</sup>MS transistor with two stacked gates



The basic principle behind FLASH is that electrons can be stored on the floating gate

Electrons can be stored on the gate in a "flash" (on the order of microseconds)

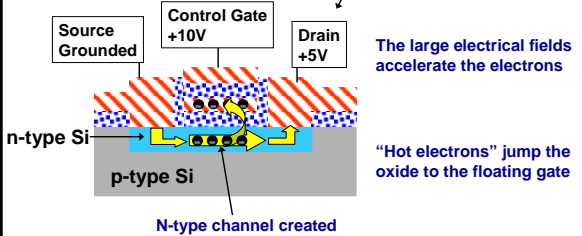
The presence of these electrons raises the turn-on voltage for the transistor



Electrons are coaxed onto the floating gate and trapped there by applying large voltages

A positive voltage to the control gate turns on the transistor

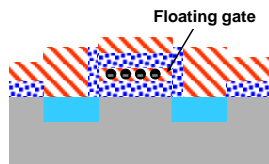
A positive voltage to the drain attracts electrons



The large electrical fields accelerate the electrons

"Hot electrons" jump the oxide to the floating gate

The presence of electrons on the floating gate creates a memory state of "0"



The electrons become stuck in the floating gate material and remain even when the voltages are removed due to the insulators

The floating gate with the stored charge becomes a capacitor

A capacitor stores a charge on two parallel plates separated by an insulator

$$C = \frac{Q}{V} = \frac{\epsilon_r \epsilon_0 A}{t_{ox}}$$

C = capacitance

Q = charge

V = voltage

$\epsilon_r$  = dielectric constant of insulator

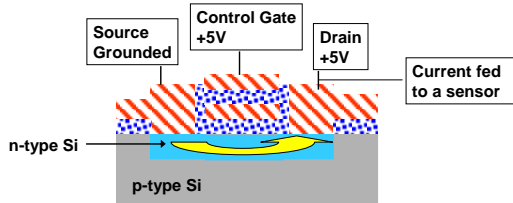
$\epsilon_0$  = permittivity of free space

A = area of gate

$t_{ox}$  = is thickness of oxide

**To read a bit, a smaller voltage is applied to the control gate and the drain current is measured**

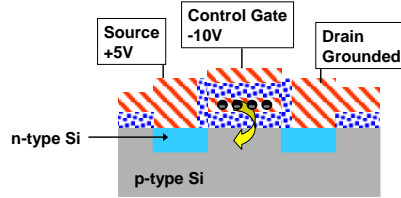
Electrons on the floating gate cancel out the small positive voltage on the control gate and the transistor remains off, "0"



Or, without electrons on the floating gate, the transistor turns on and current flows giving a reading of "1"

**Erasing a bit requires pushing the electrons off of the floating gate using a negative voltage**

The large voltages used to write are applied with reverse polarity



Erasing a bit is the longest step in FLASH memory ~ 1 second

**In summary, a FLASH device works by storing charge on a secondary, floating gate**

A very large voltage applied to the gate causes "hot" electrons to jump the oxide to the floating gate

Charge stored on the floating gate cancels out the applied turn on voltage, preventing the transistor from turning on

