Alpha Particle or Neutron SER - What Will Dominate in Future IC Technology?

- Charlie Slayman
- Sun Microsystems, Inc

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Outline

- Source of alpha soft errors
- Source of neutron soft errors
- Device scaling trends
- Deposited energy of alpa particles and neutrons
- Critical energy vs design rule
- Trend of alpha and neutron soft errors
- Conclusions

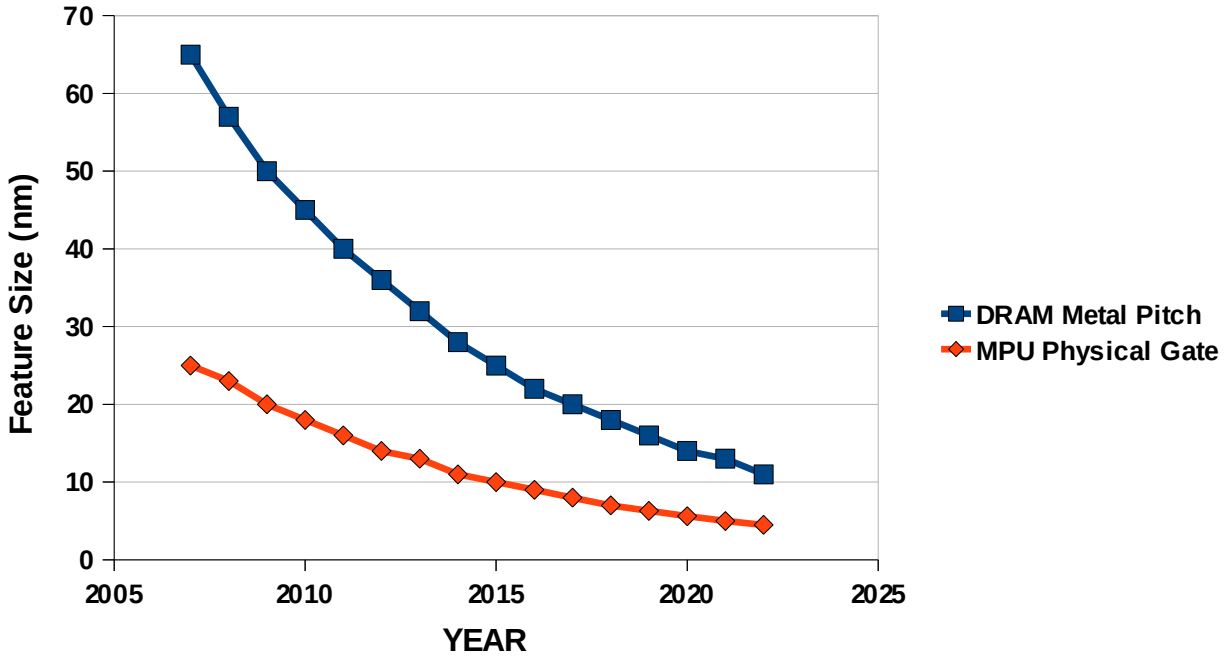
Source of Alpha SER

- Process Contamination in Wafer Fab Materials
  - happens rarely but can be catastrophic if not detected early enough
- Trace elements in plastic packaging
  - reduced with higher purity materials (cost $$)
  - reduced with low-alpa die coating materials
- Trace elements in lead bumps
  - reduced with isotopically purified Pb (cost $$)
  - Reduced with “keep out” areas around bumps and low alpha underfill

Source of Neutron SER

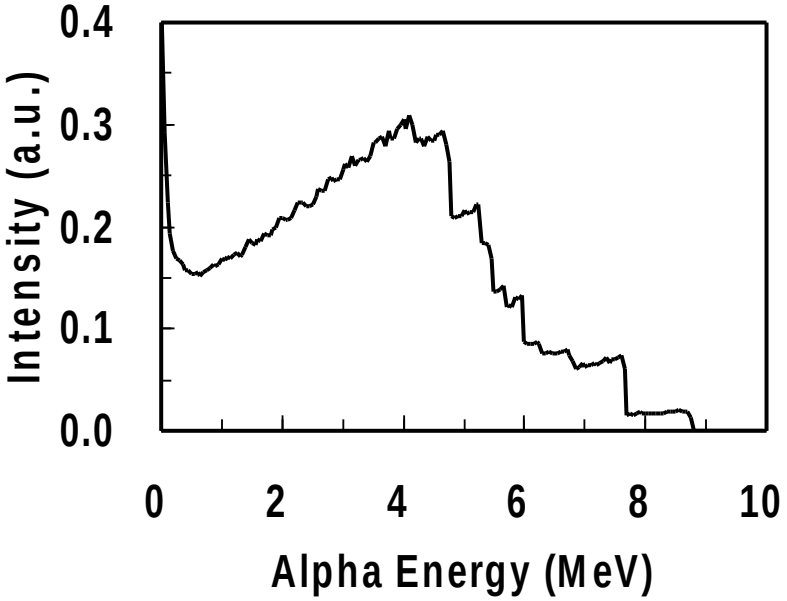
- High Energy Neutrons (100KeV - 1GeV) from cosmic ray background
  - >not practical to shield
  - >deep penetration (~10ft concrete)
  - >live with it!
- Low Energy Neutrons (10meV to 1eV) from thermalization of high energy neutrons
  - >background thermal neutron flux depends on high energy flux and building environment (some materials “absorb” thermal neutrons)
  - >large scatter cross section with ^{10}B
  - >easy to shield with ^{10}B containing materials
  - >not believed to be a problem for non-BPSG processes (???)
  - >insufficient quantitative data to indicate if boron doping causes a problem

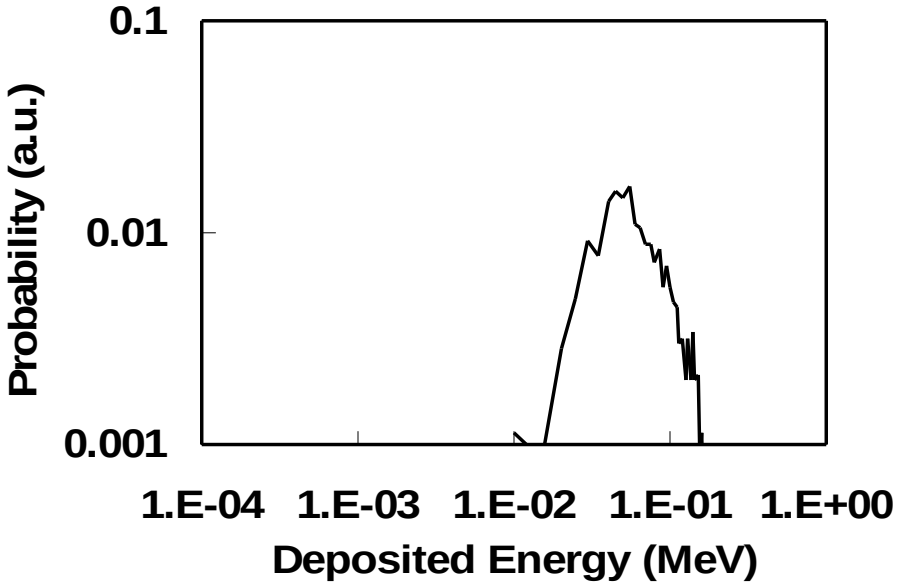
ITRS Roadmap



Source: ITRS 2007 Executive Summary (http://www.itrs.net/Links/2007ITRS/Home2007.htm)

Alpha Particle Energy Deposition



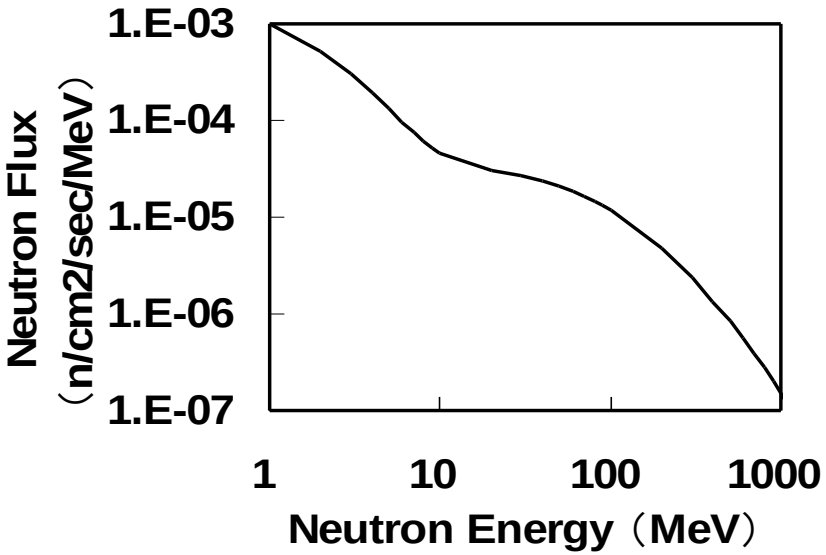


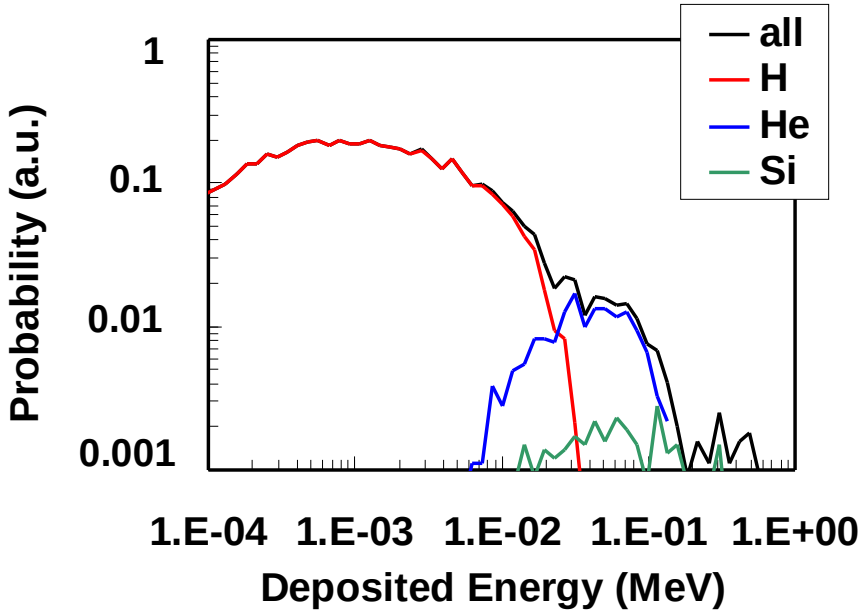
$$SER(Qc) \propto \int_{Qc}^{\infty} P(q)dq$$

- **Translate deposited energy to deposited charge (3.6eV/e-h pair)**
- **Critical Energy E_c(MeV) = 2.25 10^{-2} Q_c(fC)**

Source: H. Kobayashi et al, "Alpha Particle and Neutron-induced Soft Error Rates and Scaling Trends in SRAM", Proc. IEEE 47th Annual International Reliability Physics Symposium, Montreal, 2009, pp 206-211.

Neutron Energy Deposition

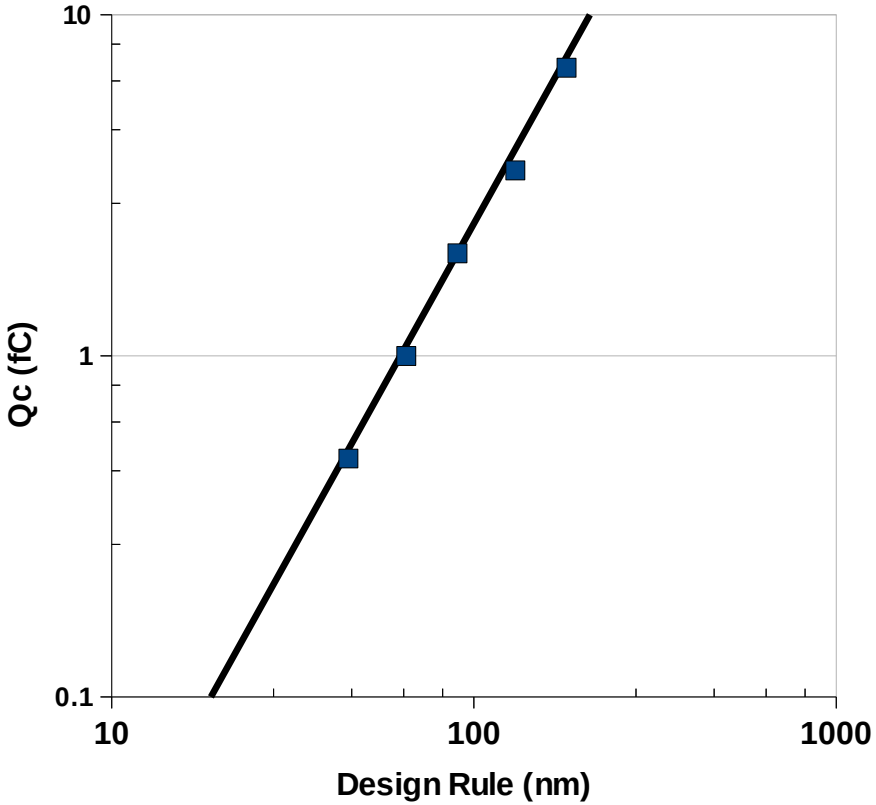


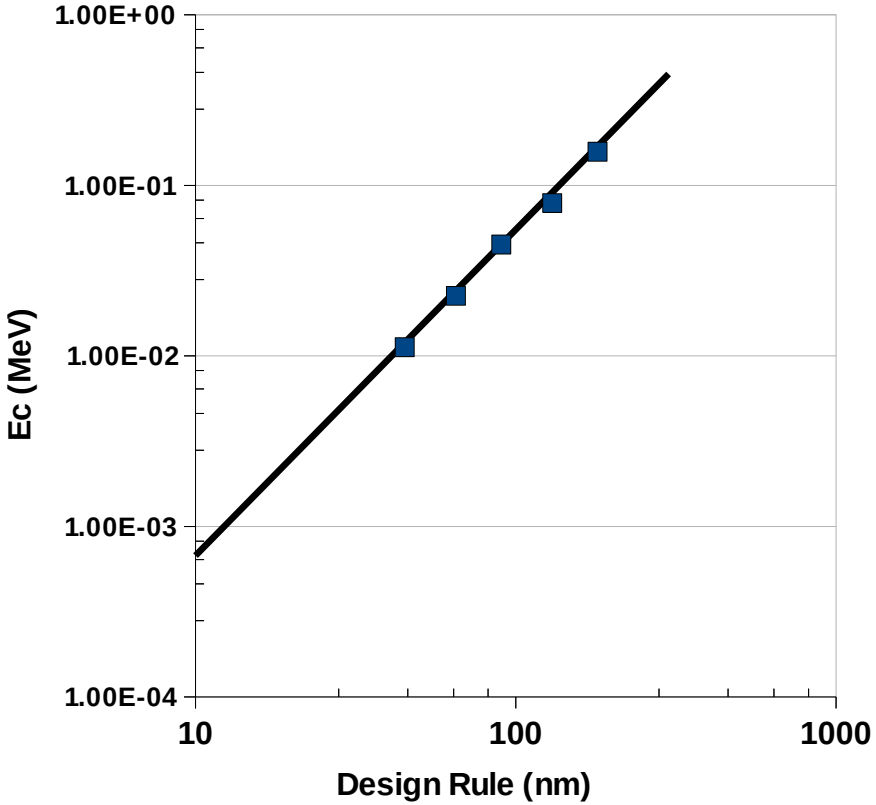


- Neutron energy deposition much broader and extends to lower energies compared to alpha particles
- Low energy contribution due to proton generation from nuclear collisions

Source: H. Kobayashi et al, “Alpha Particle and Neutron-induced Soft Error Rates and Scaling Trends in SRAM”, Proc. IEEE 47th Annual International Reliability Physics Symposium, Montreal, 2009, pp 206-211.

Critical Energy vs Design Rule

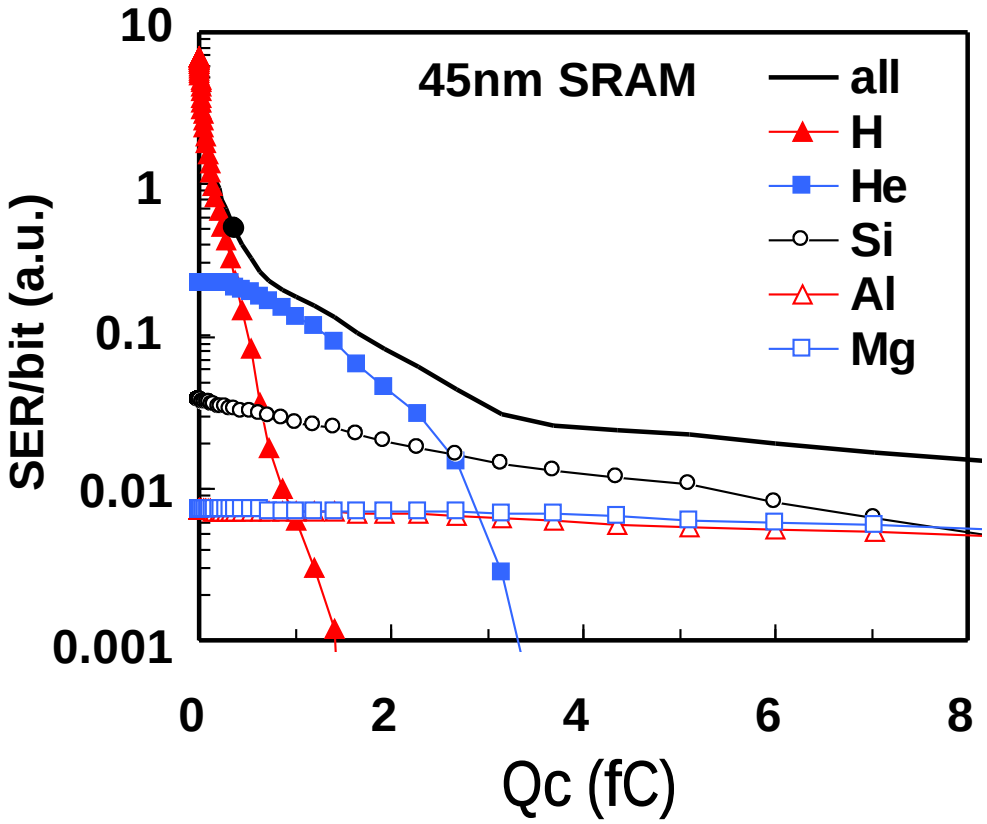




- Below 45nm, critical energy for upset is moving into proton distribution!
- Alpha SER will stay flat but neutron SER will increase

Source: H. Kobayashi et al, “Alpha Particle and Neutron-induced Soft Error Rates and Scaling Trends in SRAM”, Proc. IEEE 47th Annual International Reliability Physics Symposium, Montreal, 2009, pp 206-211.

n + Si Product Particles Contributing to Neutron Soft Errors



- The sharp rise below 0.6fC (13.5keV) is due to the direct ionization of protons

Source: H. Kobayashi et al, “Alpha Particle and Neutron-induced Soft Error Rates and Scaling Trends in SRAM”, Proc. IEEE 47th Annual International Reliability Physics Symposium, Montreal, 2009, pp 206-211.

Conclusions

- Alpha particle
  - Trade-off of $ (high purity materials and circuit design) vs acceptable SER_a
  - Remain roughly flat below 45nm
- Neutron
  - Trade-off of $ (circuit design) vs acceptable SER_n
  - Could continue to trend upward below 45nm without techniques to address proton generation

Thank You!

- charles.slayman@sun.com