COMET SEE Tools 13-12-2022

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Classical SEE rate estimation : ions, CREME

Cosmic Rays Effects on MicroElectronics

NRL, 1986 updated 1996 (but not the rate estimation technique)

Based on energy deposition into a “sensitive volume” (SV)

SV taken as a rectangular parallelepiped

Deposited energy Ed → Deposited charge Qd

Compared with critical charge Qc : Qd > Qc → SEE

All species / energies folded into a unique LET spectrum

LET = $1/\rho$ dE/dx where ρ = volumic mass, usual unit MeV/mg/cm²

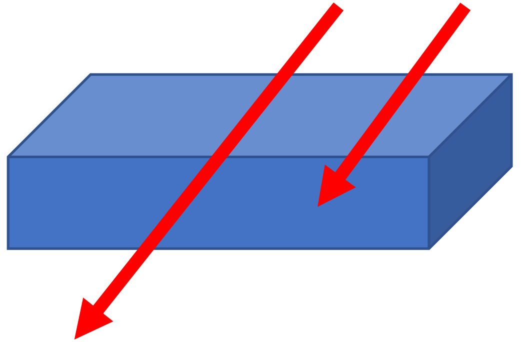
Ed ~ LET x z where z = path length into SV

Calculation made over cross-section vs LET curve

Qc determined by threshold LET x SV thickness

Advantages :

- **Simple and fast calculation**
- **One unique physical value : LET**



Disadvantages :

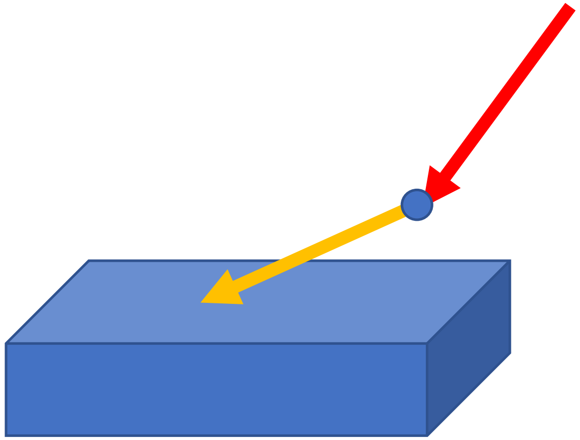
- **Arbitrary parameters such as SV geometry, thickness, number of SVs**
- **LET may vary along path length**
- **Ion track is unidimensional**
- **Collected charge vs deposited charge**

Classical SEE rate estimation : protons

Indirect ionization through recoil atoms generated by proton – target atom nuclear reaction : analog to an ion source inside the device

Direct convolution of proton energy spectrum with cross-section vs Energy curve (implicit hypothesis : recoils are emitted in all directions)

Techniques to reconstruct proton cross-section from heavy ion cross sections (PROFIT, SIMPA, METIS,…)

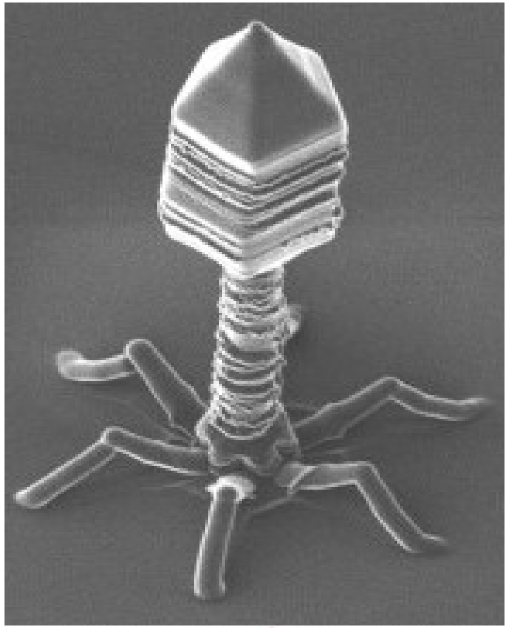


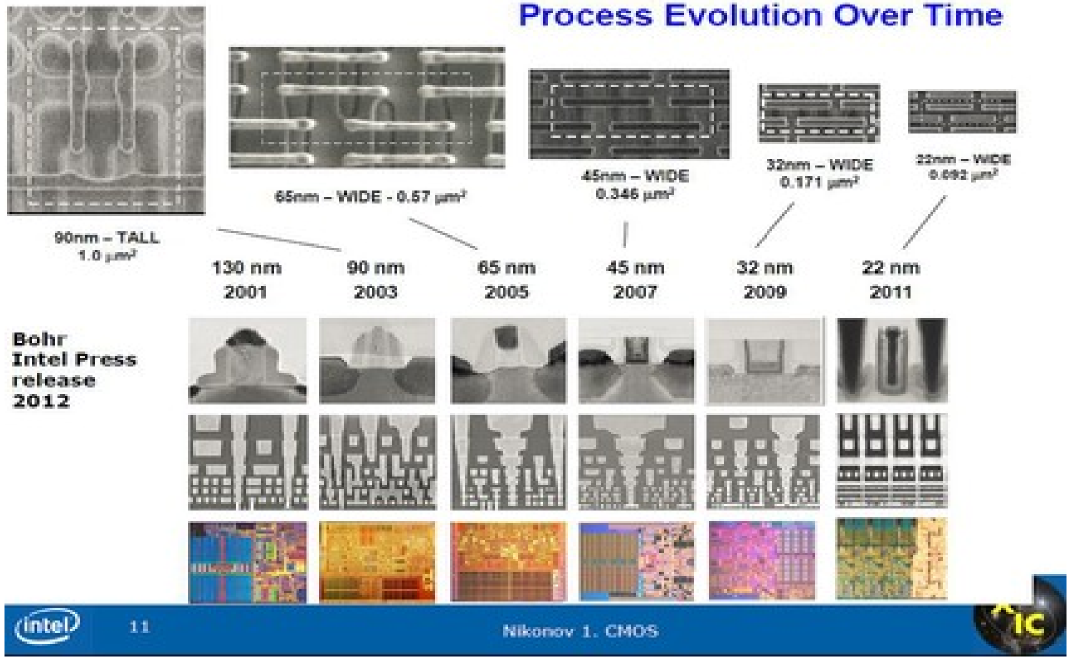
Disadvantages :
- Some fixed parameters into some reconstruction codes
- Usually only Si recoils
- Only the heaviest recoil atom

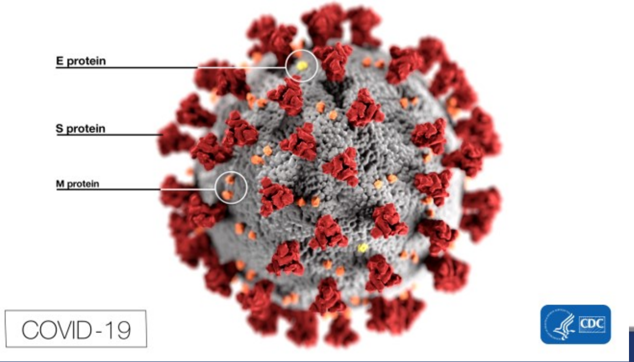
Advantages :
- Simple and fast calculation
- Few arbitrary hypothesis & parameters
- Works well against flight data

Dimensions

About the same scale of structuration than elementary living matter

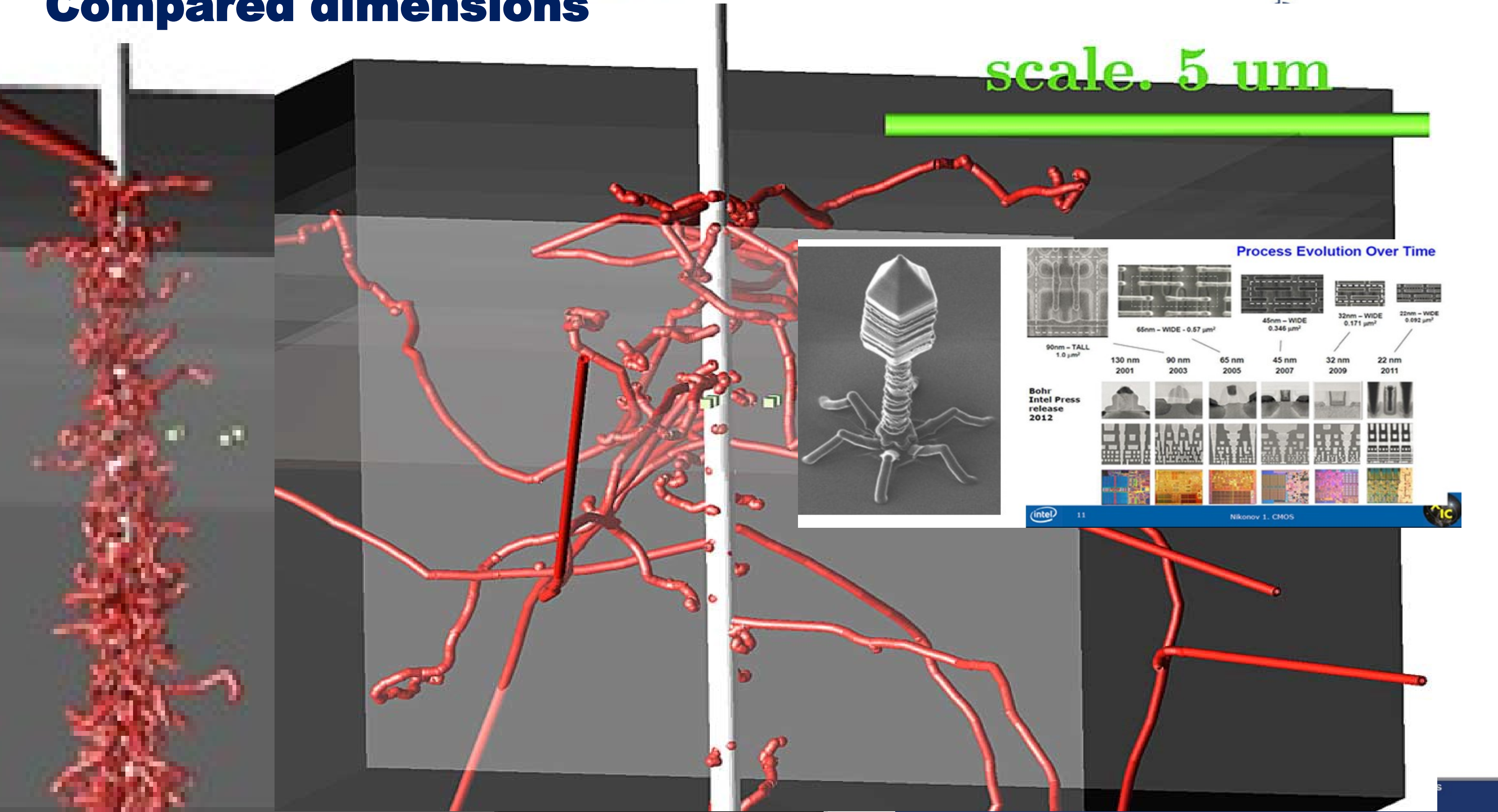






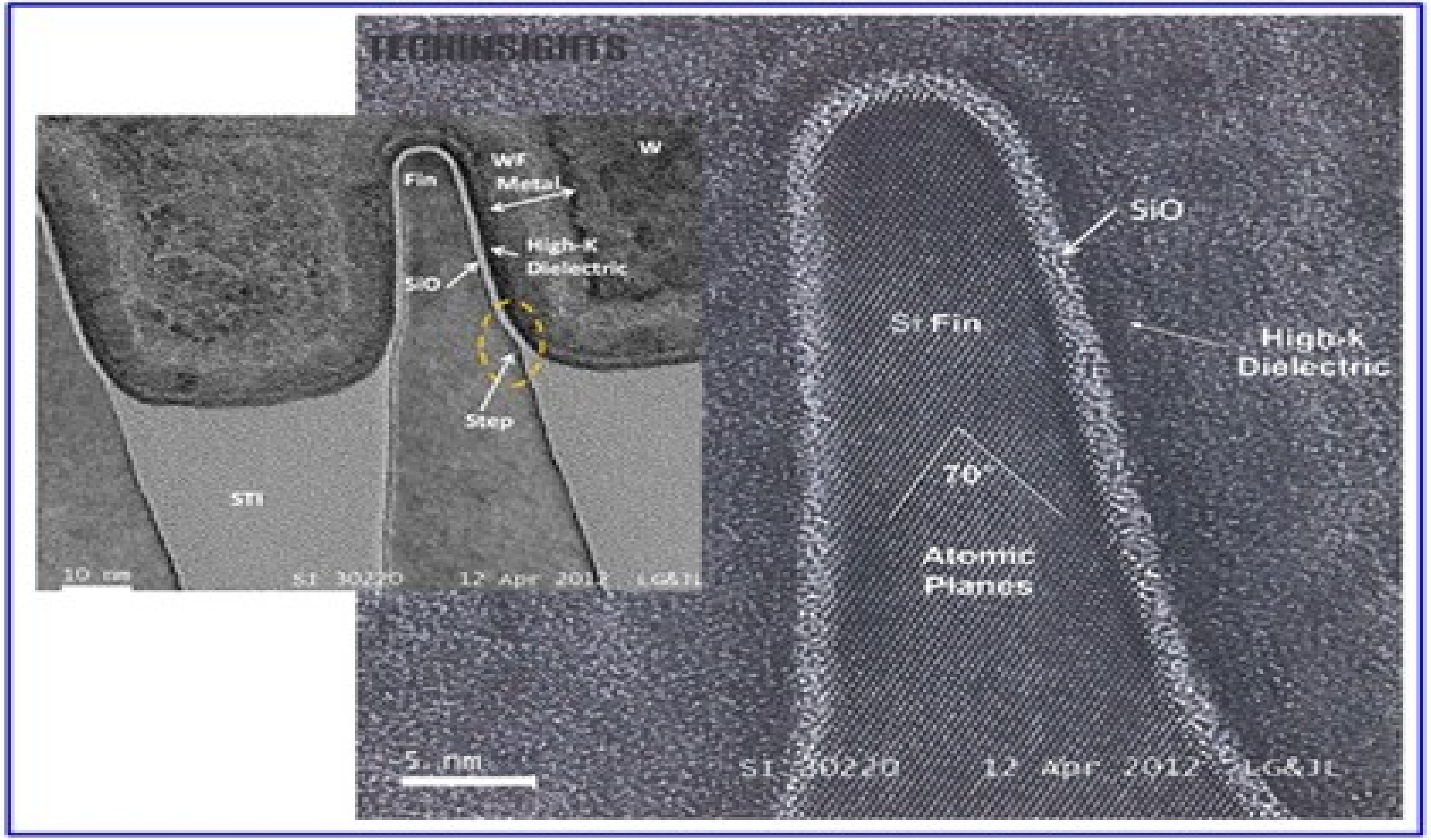
The bacteriophage virus is about 200 nm tall and 65 nm wide. SARS-COV2 about 125 nm.

Compared dimensions



Dimensions

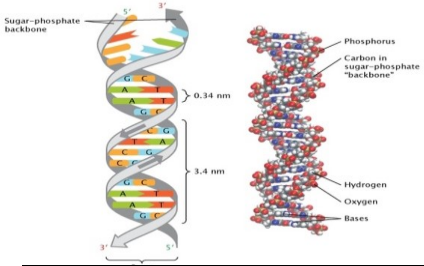
About the same scale of structuration than elementary living matter

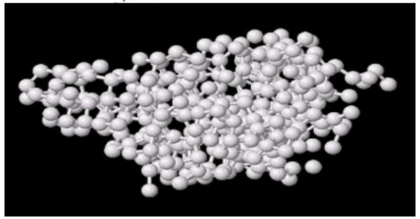


http://www.edn.com/Home/PrintView?contentItemId=4395587

Width of DNA helix ~2 nm

www.nature.com



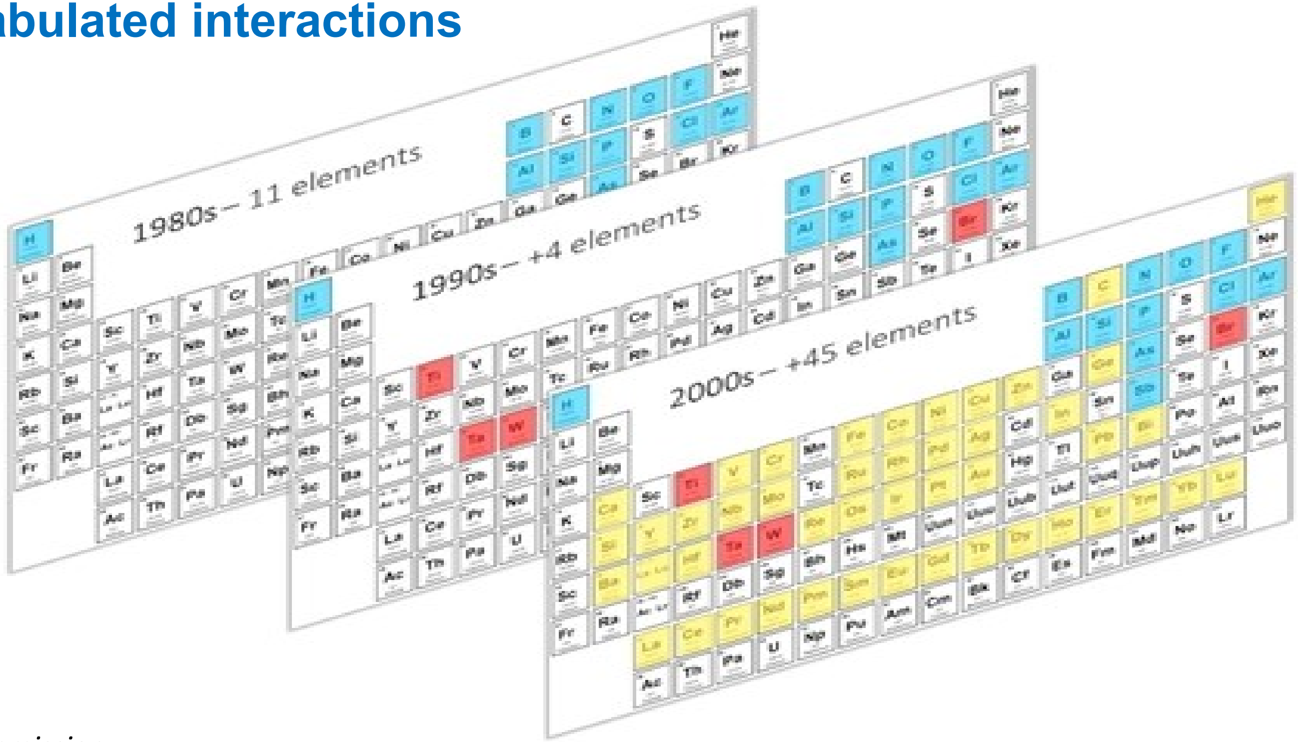


Defects cluster

Intel 22 nm node gate fin

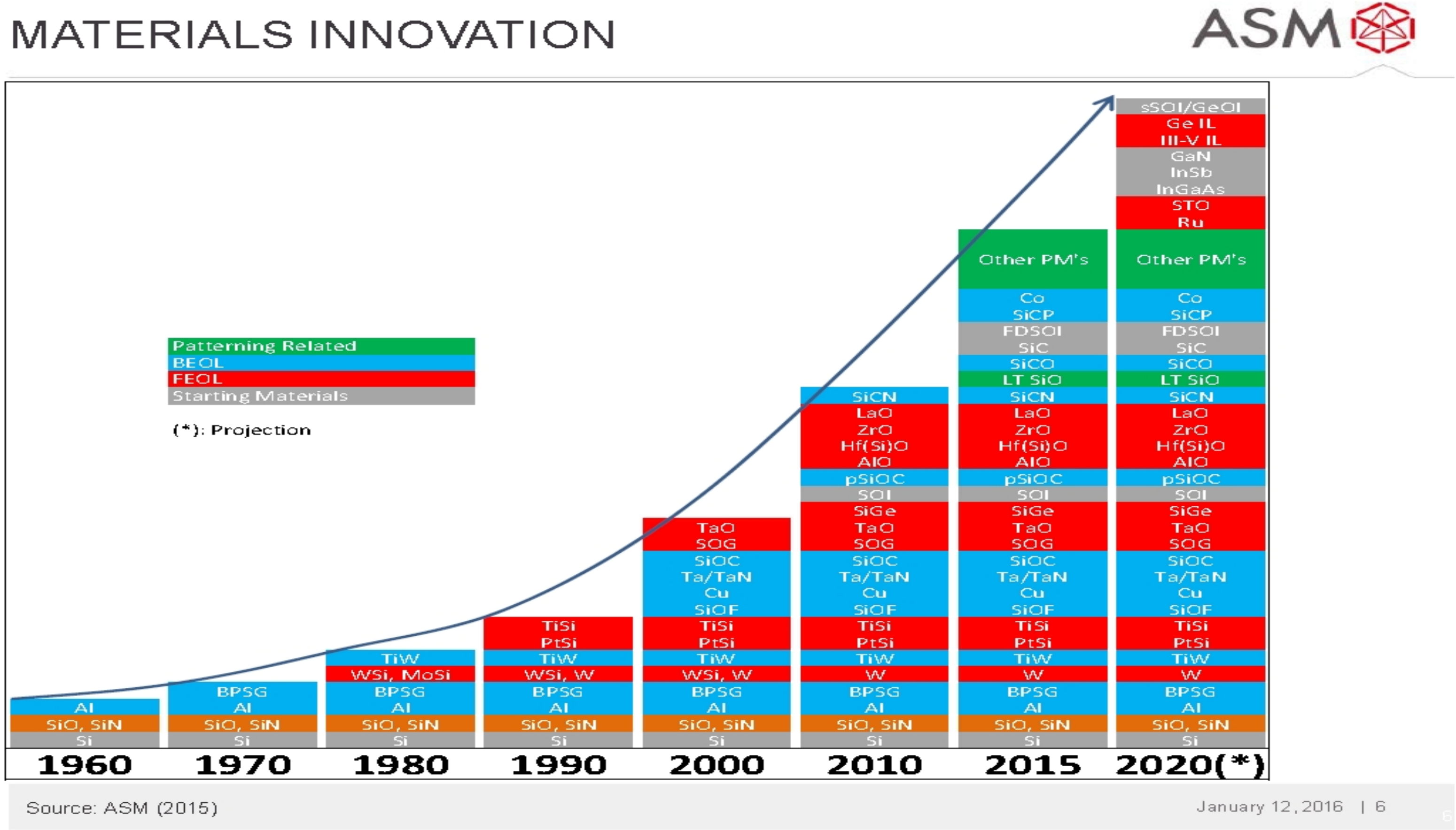
“New” materials : elements

- A large part of the periodic table is now used in technology
  - ✦ May become a strategic procurement issue (+ ethical and environmental issues)
  - ✦ Large part of non tabulated interactions



US Securities and Exchange Commission
https://www.sec.gov/Archives/edgar/data/1101302/000119312516645958/d225180dex991.htm

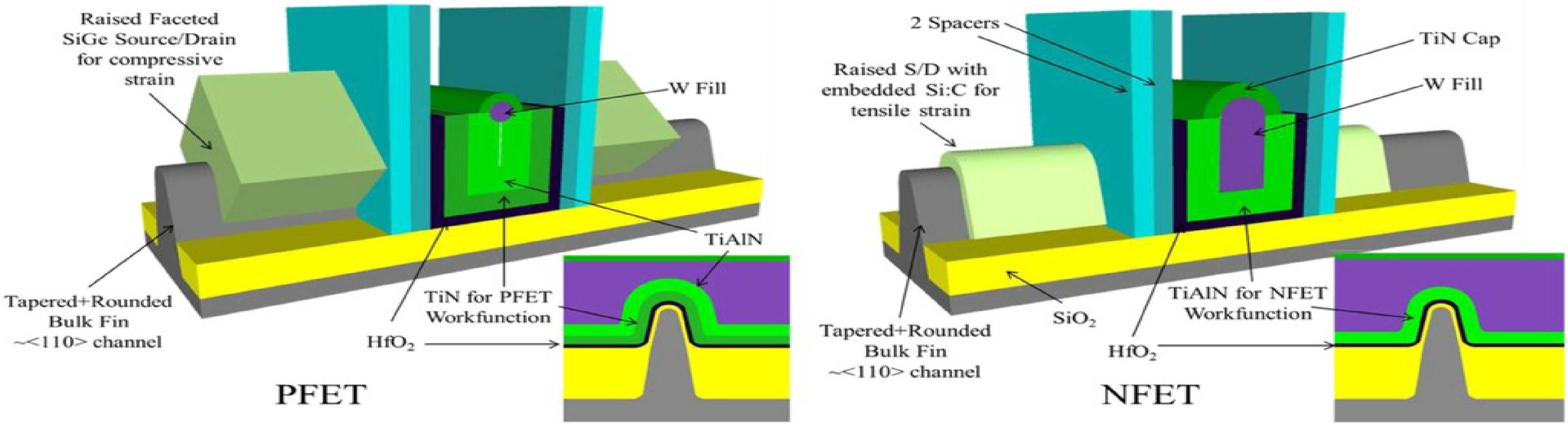
"New" materials : compounds



ASM International (American Society for Metals), Electronic Materials Handbook

Micro-structuration : today

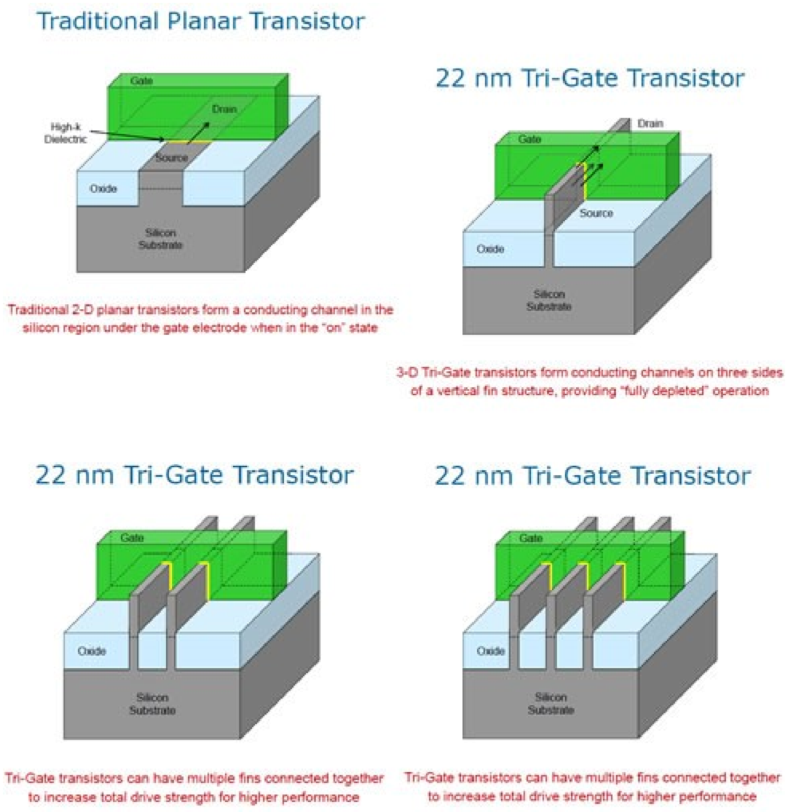
- Intel 22 nm node
  - 9 Cu metal layers, W contacts, Ge and C implants

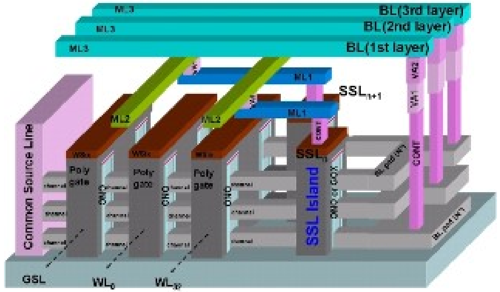


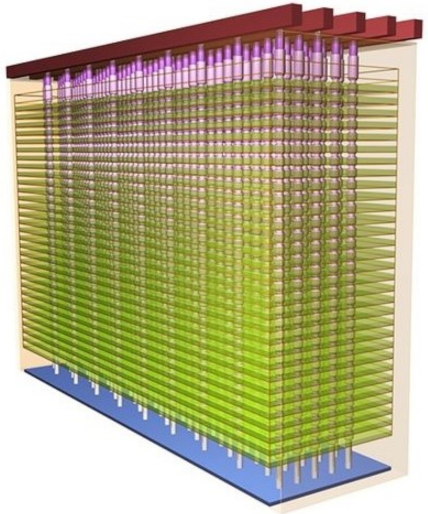
Those technologies are already in your smartphone

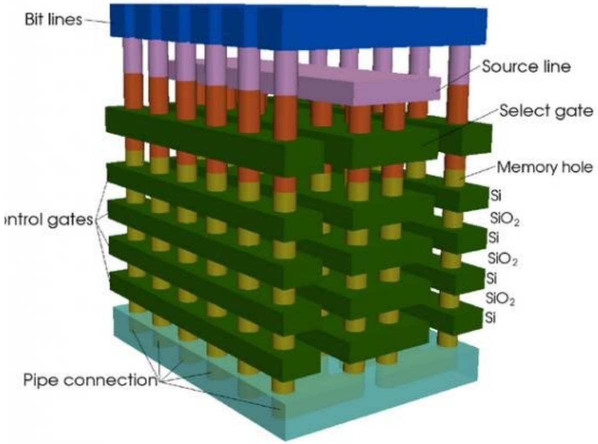
Robert D. Clark, Emerging Applications for High K Materials in VLSI Technology, Materials 2014, 7(4), 2913-2944; doi:10.3390/ma7042913

Complexity : 3D patterns



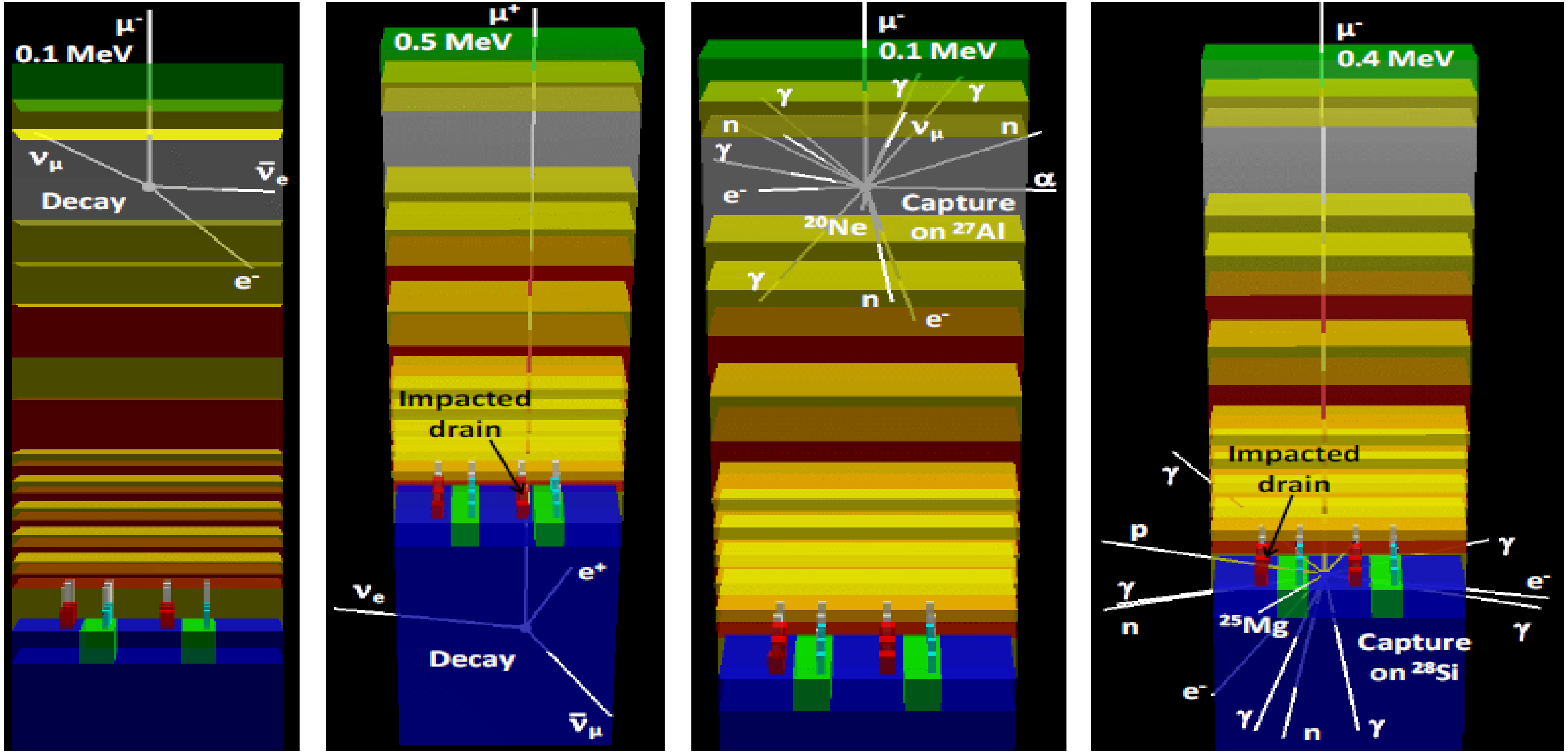






https://electroiq.com/2012/09/horizontal-channels-key-to-ultra-small-3d-nand/
http://www.eenewsanalog.com/news/toshiba-takes-3d-nand-96-layers-4-bits-cell
https://www.notebookcheck.net/Micron-intros-its-first-3D-NAND-memory-for-mobile-devices.171198.0.html

Impacts on radiation effects : more interactions



Courtesy Jean-Luc Autran, RADECS 2013 Short Course

What types of SEE tools do we need ?

SEE rate estimations for space projects

- **This is an engineering tool, massively used : must be simple and fast**
- **Extreme accuracy is not needed : SEEs are probabilistic phenomena**
  - E.g. IASI mass memory : mean SEU period 90 days, but also 2 events separated by 5 days and 480 days without any event – Poisson law, statistical distribution
- **Better have an exhaustive characterization of hazardous events : MBUs, SEFI, HCE, stuck bits, to adapt mitigation techniques**

System-level sensitivity determination

- **This is an engineering tool but used to check and eventually improve the robustness of ASIC or other dedicated circuit / system design – typically works at register and function levels**

Technology development, characterization and hardening

- **This is an expert tool : needs technology physical information (doping levels, materials, structure, spacing, lay-out, circuit) and detailed particle-matter interaction descriptions – generally uses MC codes such as G4**

Thanks for your attention