Advances in Miniaturization: How Much Still To Go?

Moderator
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Panelists
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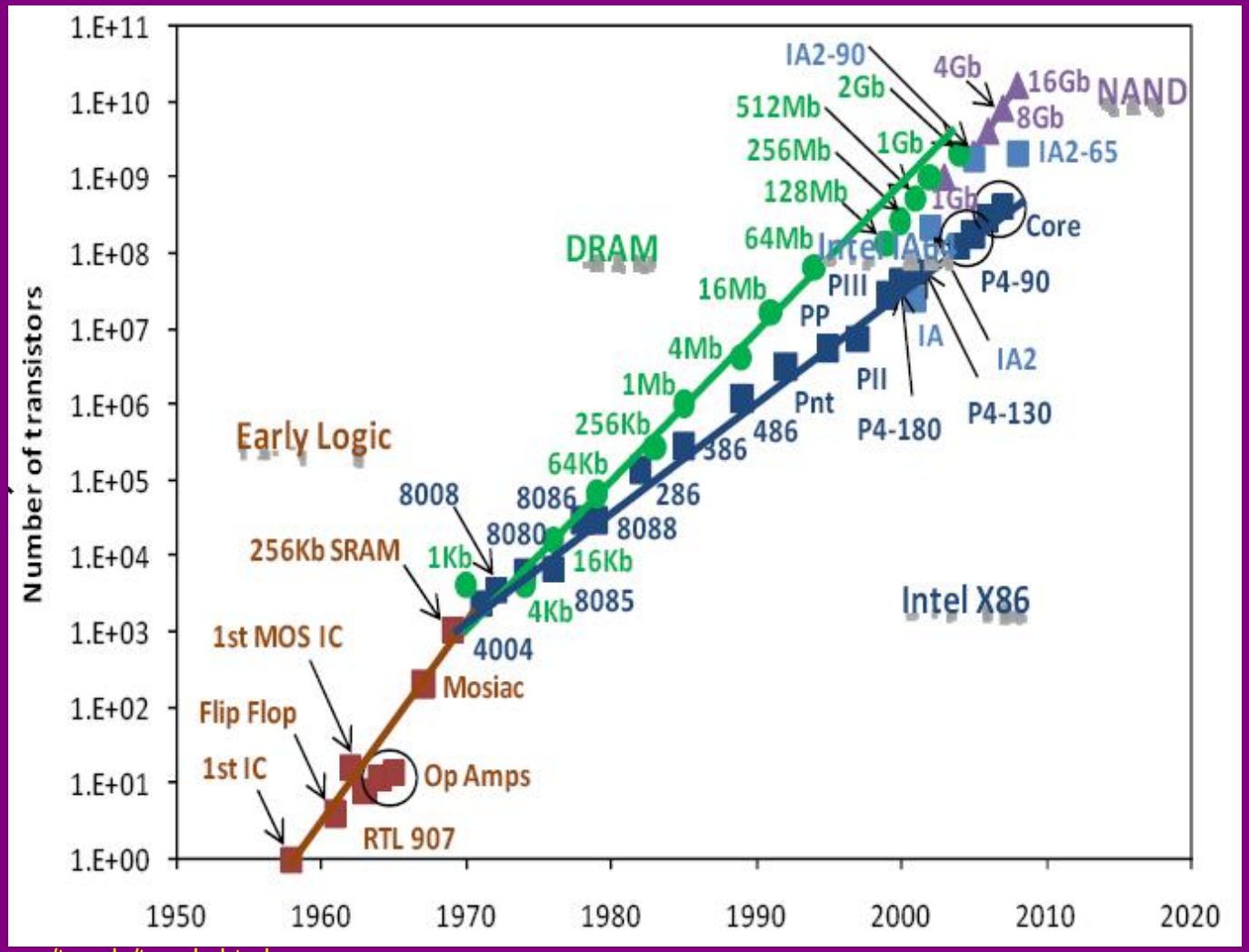
Moore's law

The number of components per IC doubles every 18 -24 months.



http://www.icknowledge.com/trends/trends.html

A! Semiconductor manufacturing processes

- 10 µm – 1971
- 3 µm – 1975
- 1.5 µm – 1982
- 1 µm – 1985
- 0.8 µm – 1989
- 0.6 µm – 1994
- 0.35 µm – 1995
- 0.25 µm – 1998
- 0.18 µm – 1999
- 0.13 µm – 2000
- 90 nm – 2002
- 65 nm – 2006
- 45 nm – 2008
- 32 nm – 2010
- 22 nm – 2011
- 19 nm – 2013
- 14 nm – Dec 2014
  - Intel “Broadwell” (stadard Si)
  - IBM SoC (SOI wafer)

Gate module

Year	Node	*L*g	EOT	status
2005	65 nm	35 nm	0.8 nm	production
2008	45 nm	30 nm	0.7 nm	production
2010	32 nm	25 nm	0.6 nm	production
2011	22 nm	25 nm	0.5 nm	limit for EOT

A! How long can this scaling continues ?

- If all goes as predicted by Moore's law, in 2059, the 100th birthday of the integrated circuit, we will have:
- 2.5 Å minimum linewidth
- 0.04 Å gate oxide thickness
- 2 mV operating voltage
- 64 exabit DRAMs (exa = 10^{18})

Possible solutions

- Quantum computing
- Optical computing
- Spintronics
  - power consumption is reduced due to non-volatile memory
- Single electron transistor
- DNA computing
  - fluorescent detection, logic is possible, but it is slow
- Superconductor logic systems
- 3D interconnections

ICQNM 2014 - Panel CENICS/ICQNM/SENSORDEVICES

Topic: Advances in Miniaturization: How Much Still To Go?

Going Small
or
Are surfaces getting more important?

Ronei Miotto
Universidade Federal do ABC
Brazil

Number of surface atoms only looks small !!

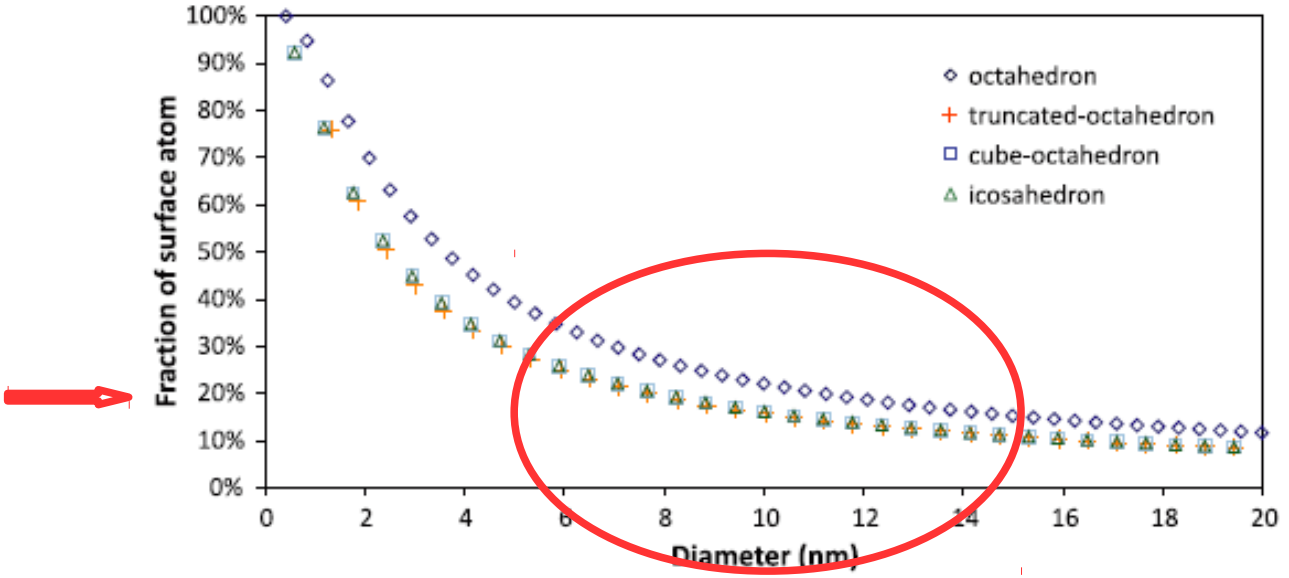


Figure 3. Evolution of the fraction of surface atoms with the nanoparticle's diameter for different shapes. The surface directions for each nanoparticle are indicated in brackets.

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… but they modulate electronic properties

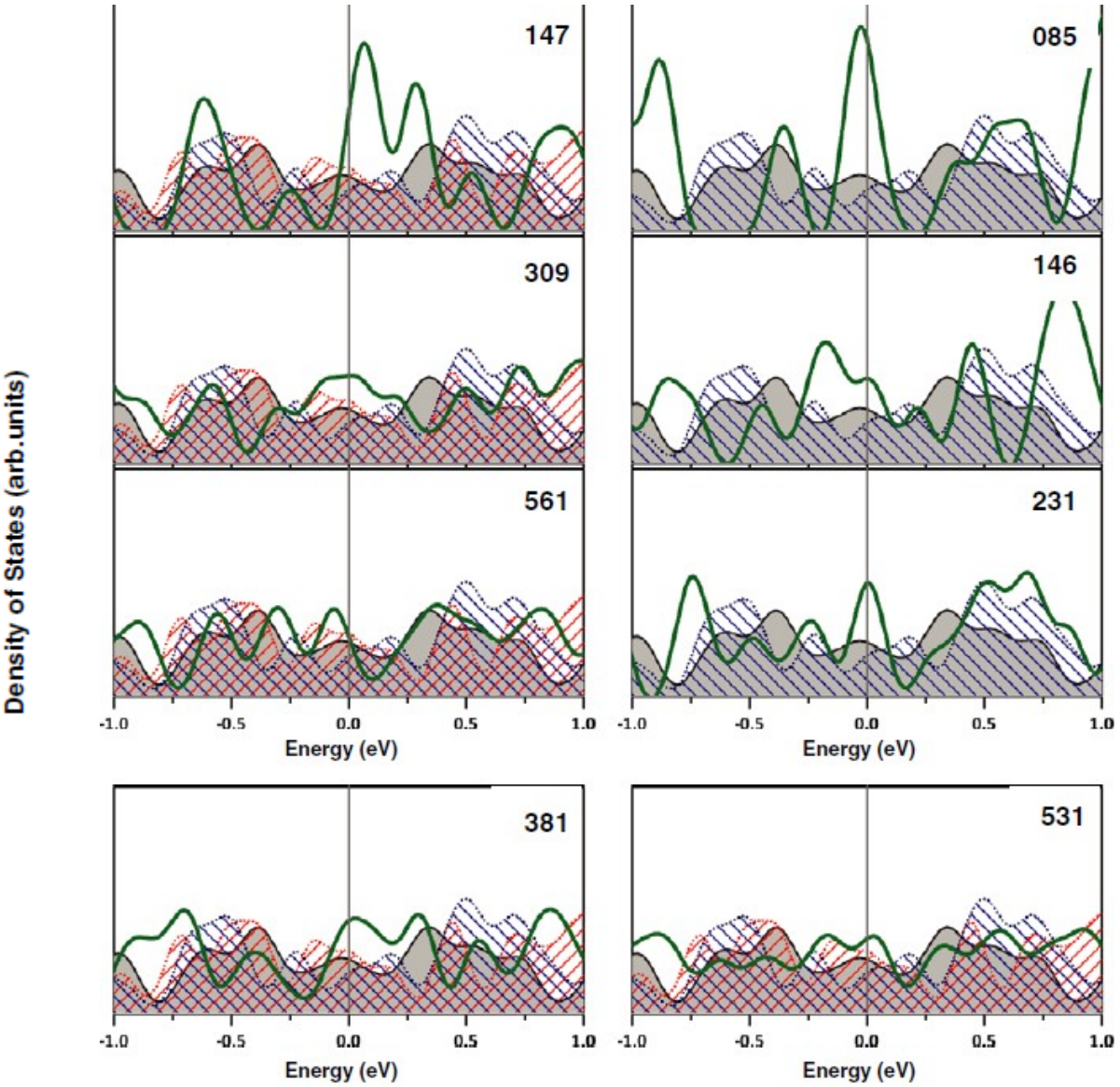

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Figure 9. Density of states (DOS) of a given nanoparticle (solid line) compared with the ideal crystal (gray region), the [001] (forward hatched) and [111] (backward hatched) bare surface DOS. Left upper panels: cube-octahedral nanoparticles (013, 055, 147, 309, and 561); right upper panels; octahedral nanoparticles (019, 044, 085, 146, and 231). Lower panels: spherical nanoparticles (381 and 531).

changes in optical properties (RAS)

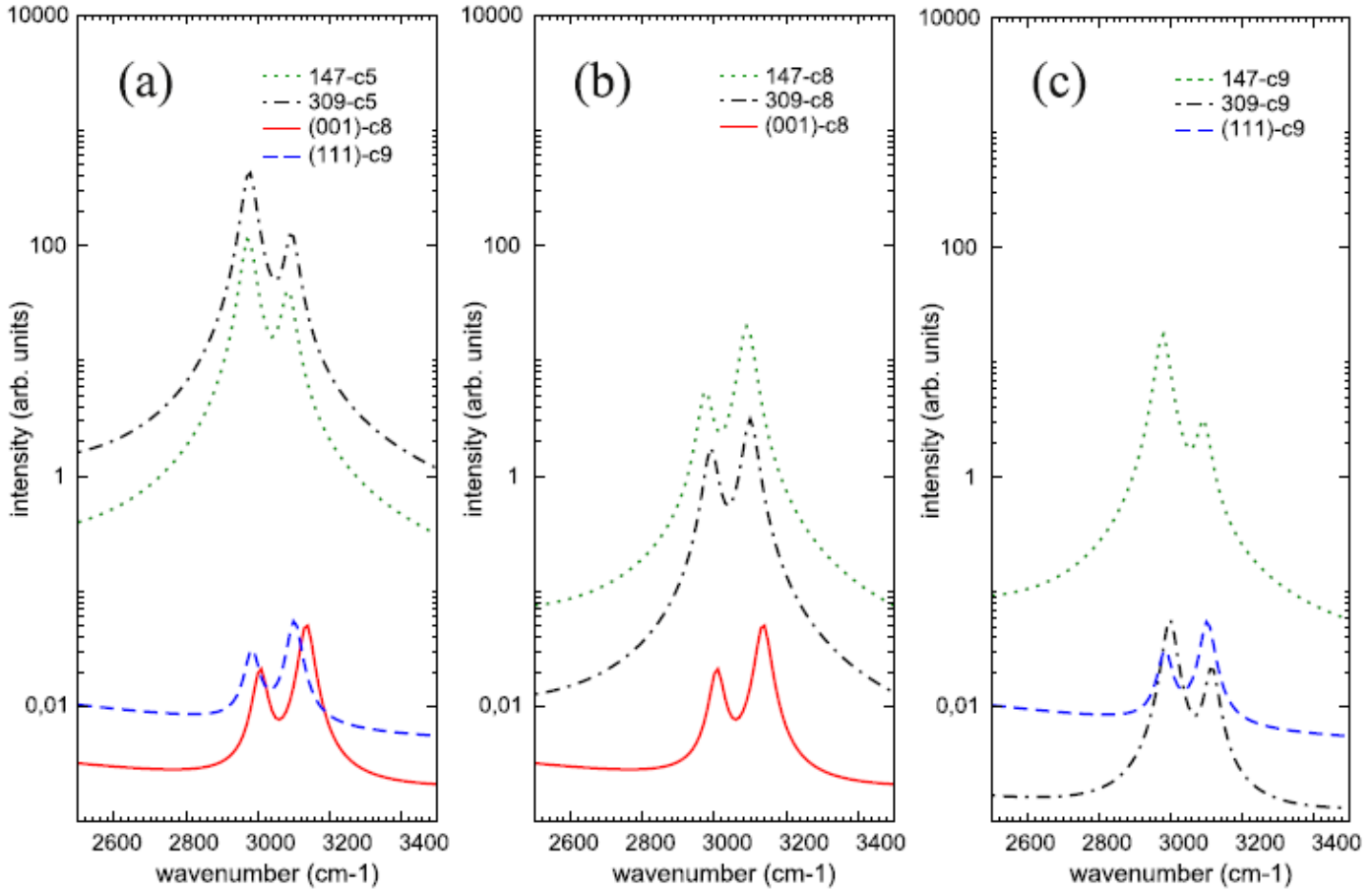

Figure 3. Vibrational loss spectra arising from the adsorption of the methyl radical on nanoparticles 147 and 309 and on the ideal [001] and [111] surfaces considering: (a) the most energetically favorable adsorption site (c5) in the case of nanoparticles 147 and 309, c8 for the ideal [001] and c9 for the ideal [111] surfaces; (b) c8 adsorption site in nanoparticles 147 and 309 and the ideal [001] surface; and (c) c9 adsorption site in nanoparticles 147 and 309 and the ideal [111] surface.

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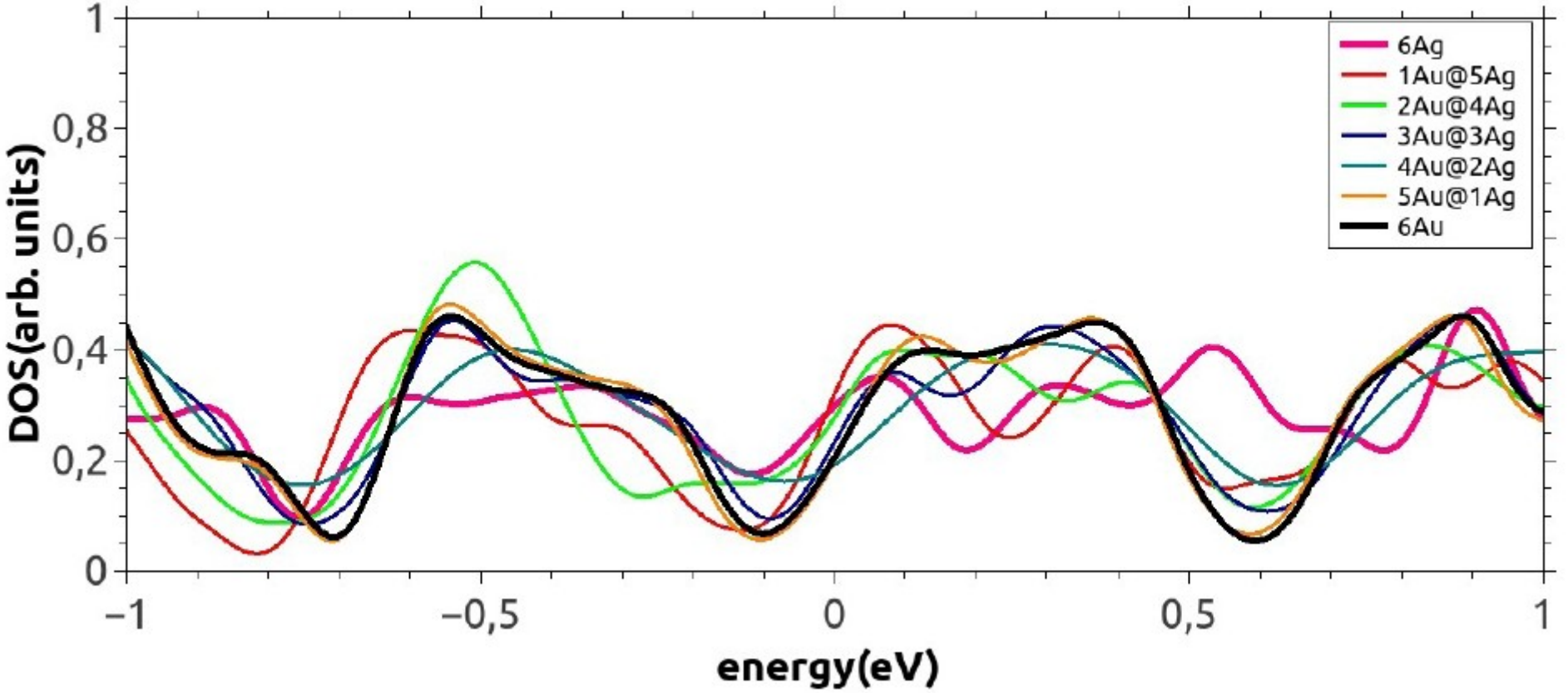
Even shell layers are important ...



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Advances in Miniaturization: How much is left?

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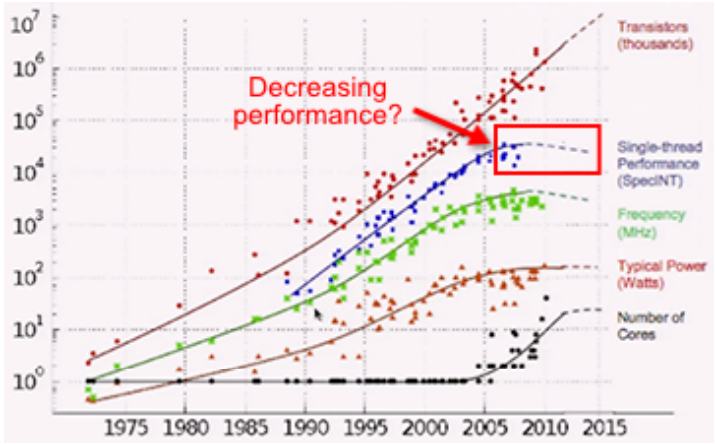
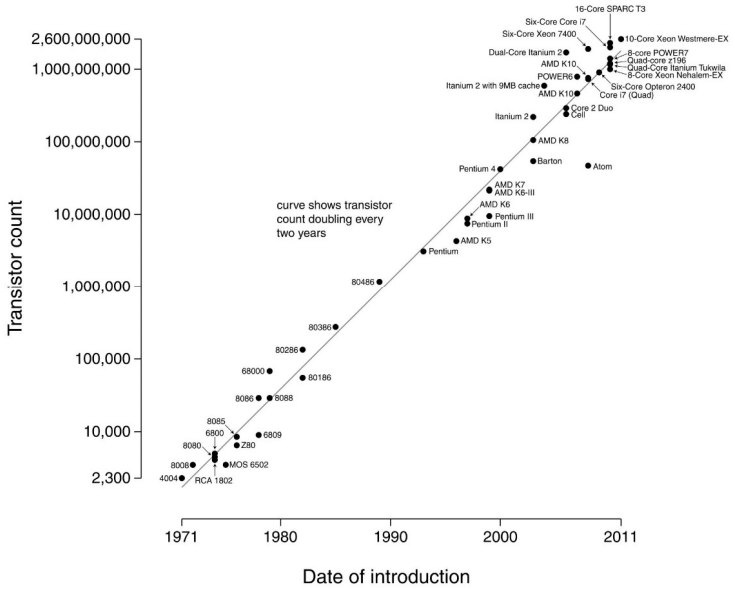
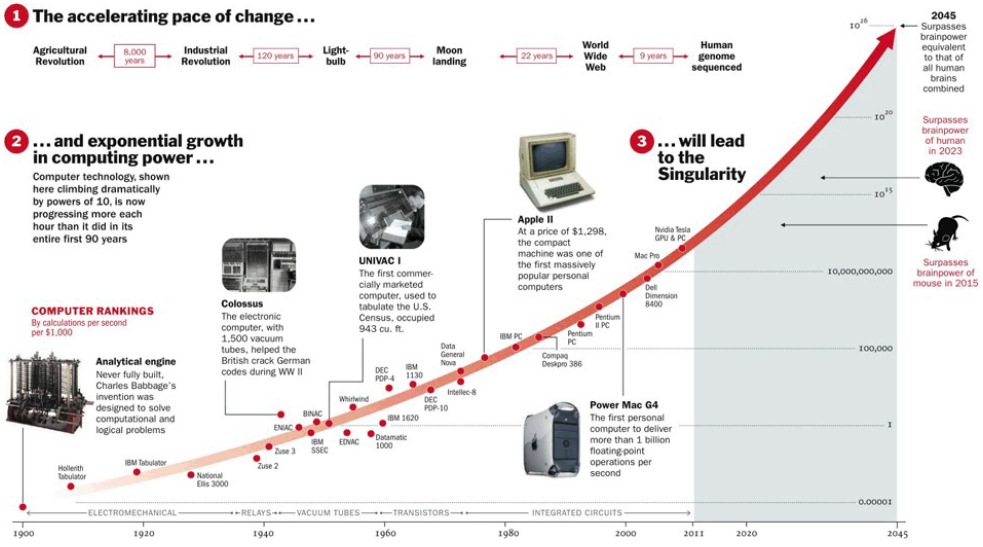
Is there more to Moore's law?

- It depends…
  - Which way to go?
  - Limits are near!!

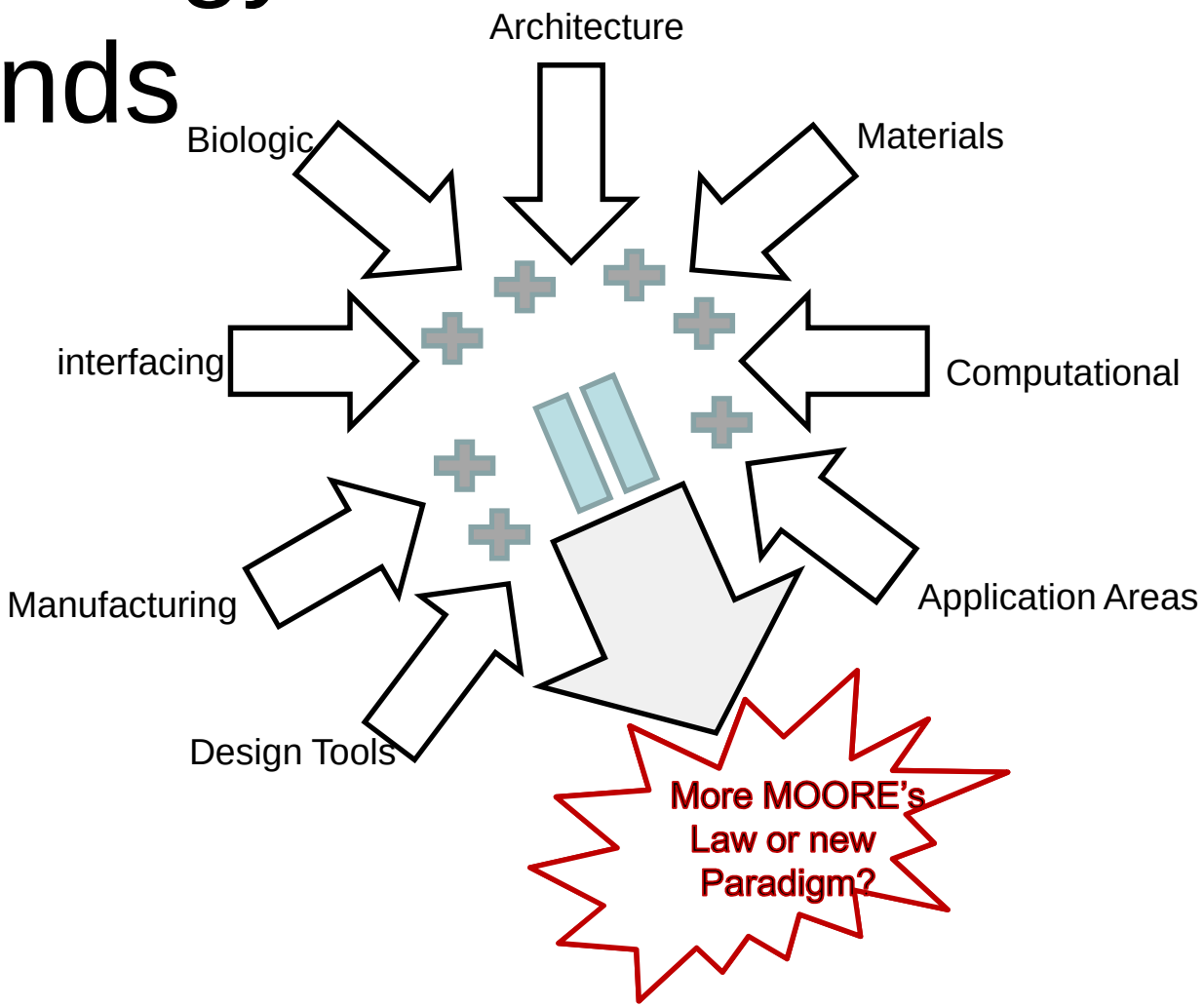


Microprocessor Transistor Counts 1971-2011 & Moore's Law





Technology Trends



Where to now??

- Look at
  - Architecture : 3D stacks and cubes +
  - Materials : graphene nano tubes +
  - Biologic models : artificial neuron to brain . . .
  - Interfacing : wires to TSV to light to ??
  - Computing : turing to distributed to quantum . . .
  - Manufacturing: nano, biologic, + . . .
  - Design Tools: Do more with less…
  - Applications: power of need driven solutions
  - Blended systems : use best of each?
- Realize a new paradigm
  - No Longer Moore's Law driven… but growth is maintained Using other measures