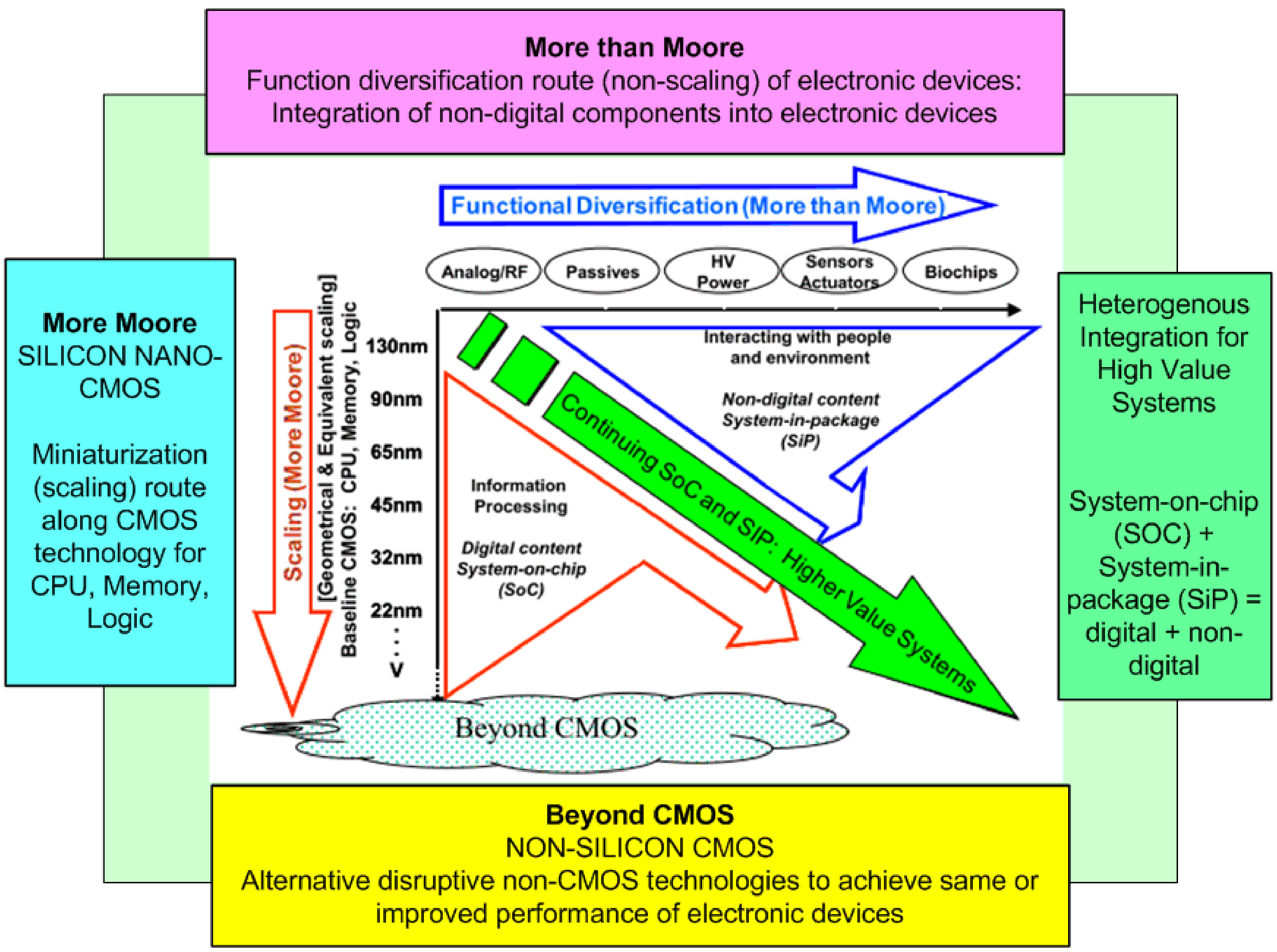
Lecture 2 contents

Topic name	Content	Material
Introduction and Overview of Nanoelectronics	What is nanotechnology and nanoelectronics? Evolutionary and revolutionary developments	www.itrs.net/ Reading : ERD, PIDS pdf and Excel files http://lamp.tu-graz.ac.at/~hadley/nanoscience/week5/5.html file: EL453_Nano_2

Future of microelectronics and nanoelectronics



Nanoelectronics Technology Development Paths .

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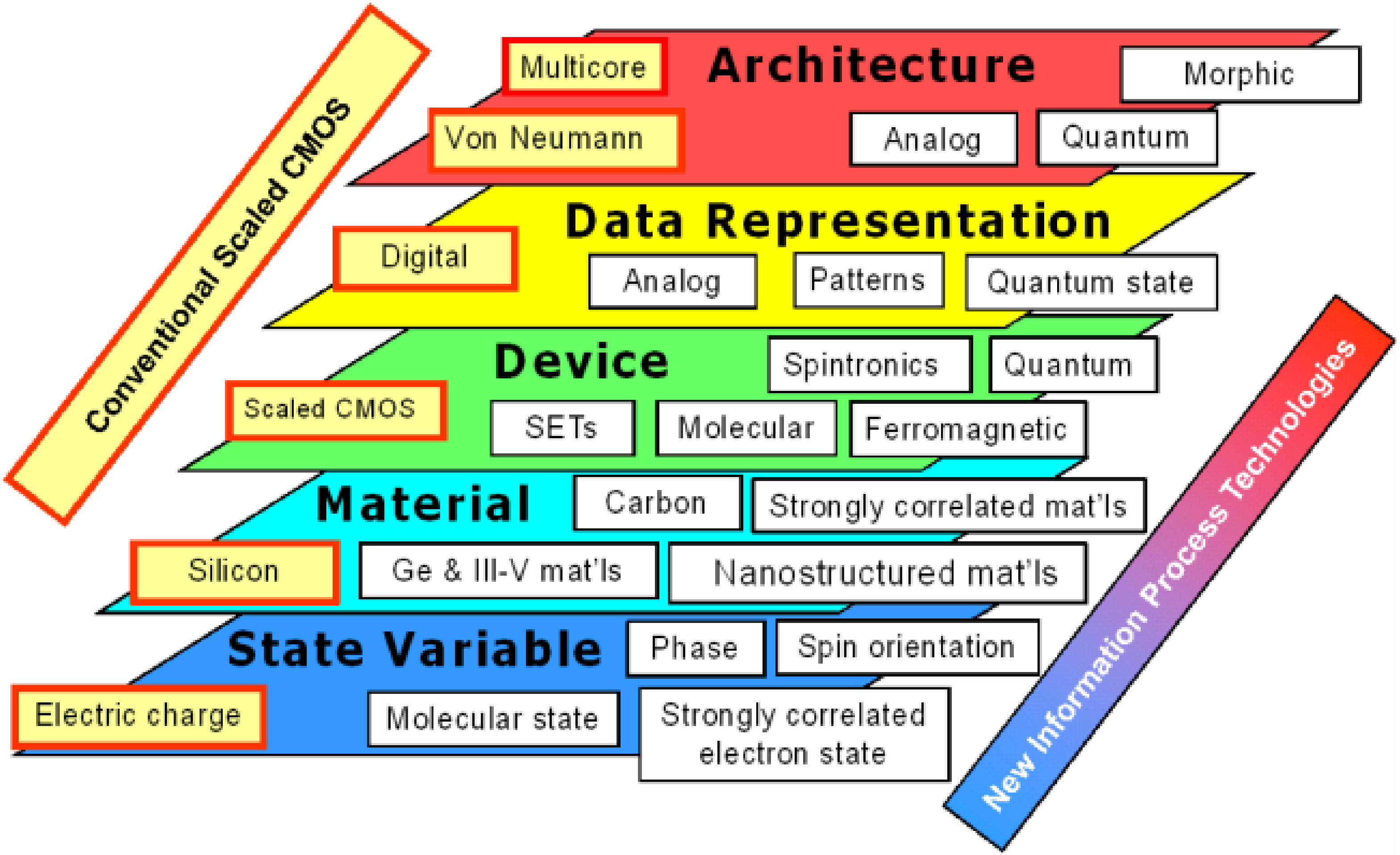
A Taxonomy for Nano Information Processing Technologies



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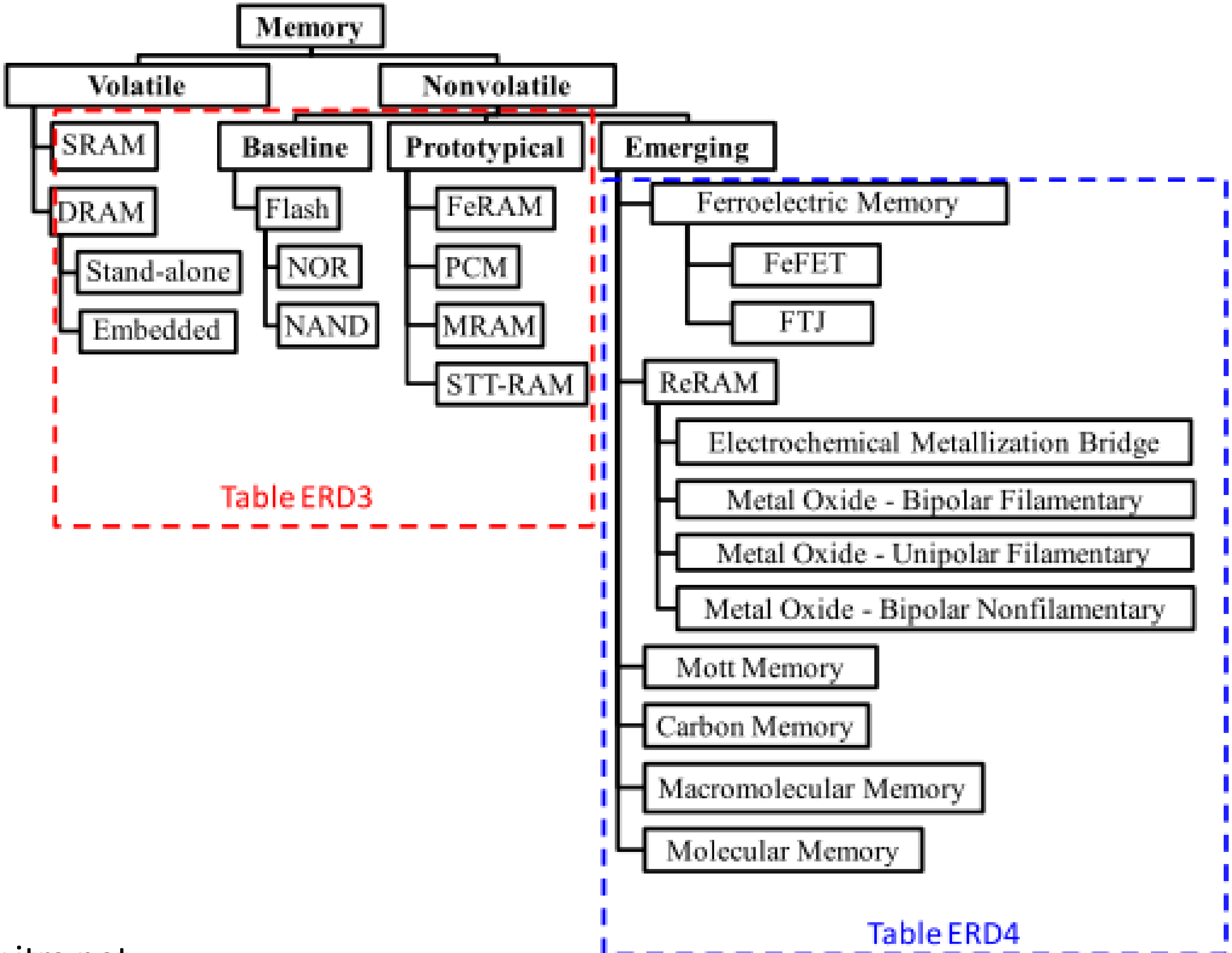
Taxonomy of emerging memory devices



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Logic Technology Tables

Table 1 – Extending MOSFETs to the End of the Roadmap

CNT FETs
Graphene nanoribbons
III-V Channel MOSFETs
Ge Channel MOSFETs
Nanowire FETs
Non-conventional Geometry Devices

Table 2- Unconventional FETS, Charge-based Extended CMOS

Tunnel FET
I-MOS
Spin FET
SET
NEMS switch
Negative Cg MOSFET

Table 3 - Non-FET, Non Charge-based 'Beyond CMOS' devices

Collective Magnetic Devices
Moving domain wall devices
Atomic Switch
Molecular Switch
Pseudo-spintronic Devices
Nanomagnetic (M:QCA)

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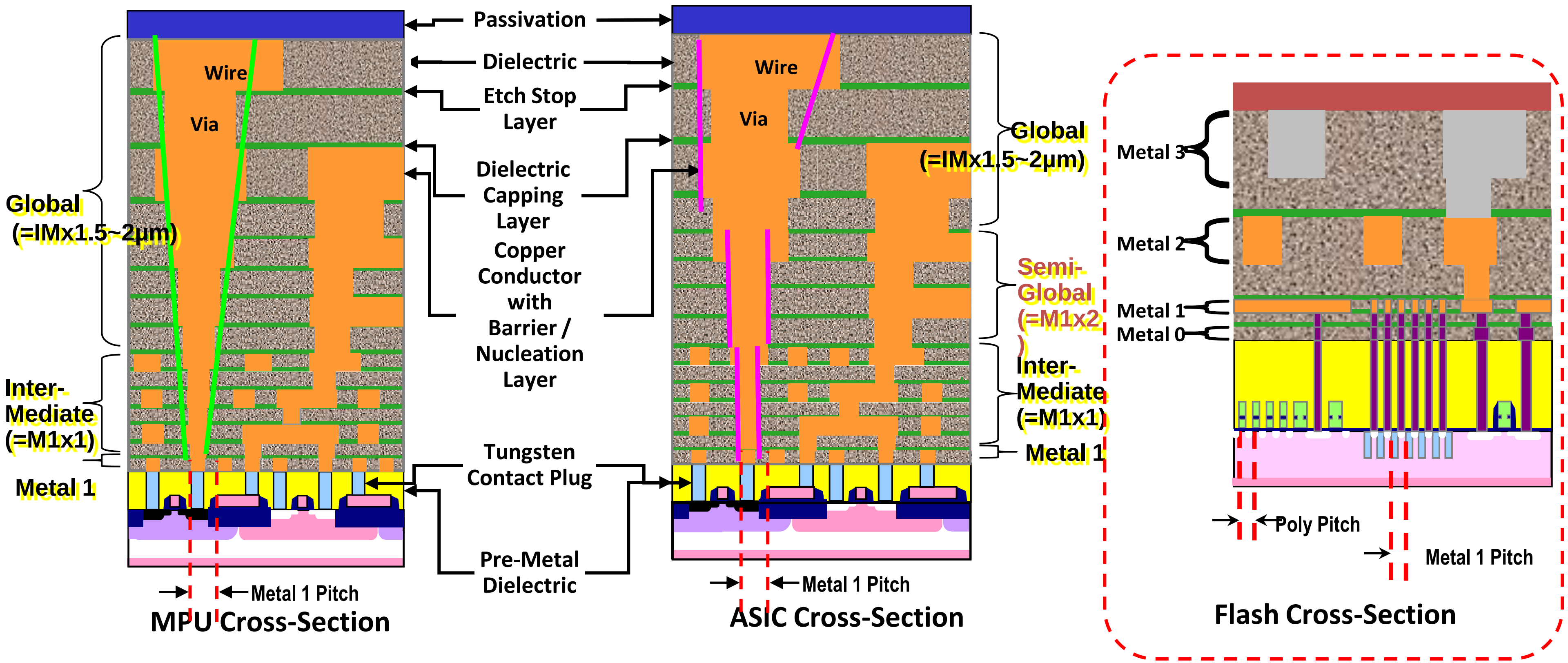
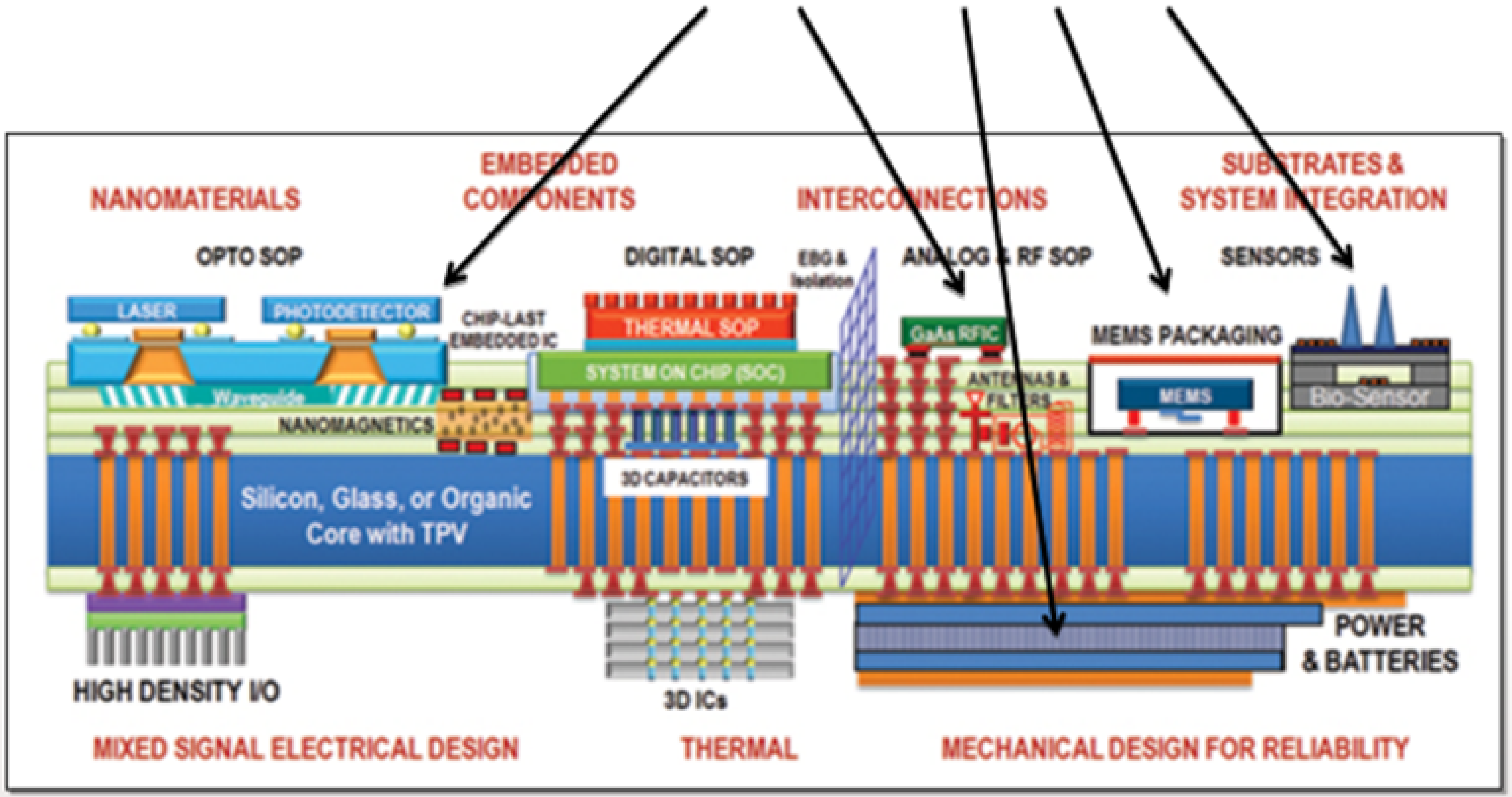
Interconnect
Hierarchical Cross Sections



Heterogeneous Components



Source: Georgia Tech PRC, http://www.prc.gatech.edu/overview/images/etpc.jpg

<u>Heterogeneous Components</u> — describes devices that do not necessarily scale according to “Moore's Law,” and provide additional functionalities, such as sensing and actuating, or power generation and management.

After definition by: A. B. Kahng,

Table ERD 10a MOSFETS: Extending MOSFETs to the End of the Roadmap

Device		FET [A]	Carbon-based Nanoelectronics		Nanowire FETs	Tunnel FET	n-type alternate channel material FET	p-type alternate channel material FET
Typical example devices		Si CMOS	CNT FET	Graphene Nanoribbon FET	Ge/Si Nanowire FET	All Si, Ge and silicide source, VLS nanowire	n-Ge FET	Ga(In)Sb
Cell Size	Projected	100 nm	100 nm	100 nm	40 nm [N]	20 nm		TBD
(spatial pitch) [B]	Demonstrated	590 nm	1.4µm[A]	1.4µm[I]	300 nm [N]	sub 60 nm[V],60nm[W]	80 nm	80 nm
Density (device/cm^2)	Projected	1.00E+10	1.00E+10	1.00E+10	5.9E+10 [N]	channel down to 20nm [X,Y]: 1E10	not known	not known
	Demonstrated	2.80E+08	5.10E+07	5.10E+07	5.2E+07 [N]	not known	1.50E+10	1.60E+10
Switch Speed	Projected	12 THz	6.3 THz [B]	7 THz [J]	9.5 THz [O]	Si /InAs TFET: 60GHz/3THz [Z]	14 THz [EE]	270 GHz [HH]
	Demonstrated	1.5 THz	153 GHz [C]	300GHz [K]	250 GHz [P]	not known	140GHz [FF]	160 GHz [II]
Circuit Speed	Projected	61 GHz	100 GHz [D]	not known	100 GHz [P]	Si/InAs TFET inverter: 20GHz, 1THz [E]	not known	not known
	Demonstrated	5.6 GHz	52 MHz [E]	22 MHz [L]	108 MHz [Q]	not known	not known	not known
Switch Energy, J	Projected	3.00E-18	not known	not known	4E-20 [R]	CGG*VDD^2 (J/um) < 2E-17 [AA]	10^{-18} J	not known
	Demonstrated	1.00E-16	1E-11[F]	not known	2.0E-17 [S]	CGG*VDD^2 (J/um) =1E-16 [AA]	N/A	not known
Circuit Energy, J	Projected	1.20E-17	1.5E-18 [G]	6.25E-18 [M]	2.0E-16 [T]	1.5E-16 [BB]	not known	not known
	Demonstrated	4.00E-16	not known	not known	not known	not known	not known	not known
Subthreshold Slope, mV/dec	Projected	60 mV/dec	60	60	60	20 [CC]	60	71 [HH]
	Demonstrated	60 mV/dec	60 [H]	not known	61 [U]	21 [DD]	90 [GG]	90 [II]
Operational Temperature		RT	RT	RT	RT	RT	RT	RT
Material Challenges		Si	CNT density, contacts	dielectrics, substrates, in situ mobility, contacts	assembly, directed placement	not known	gate insulator-Ge interfaces, metal-Ge contact	TBD

Table ERD 10b Charge-Based Beyond CMOS: Non-Conventional FETs and Other Charge-Based Information Carrier Devices

Device		FET [A]	Spin FET and Spin MOSFET	NEMS	Atomic Switch	Mott FET	Neg Cap Ferroelectric
Typical example devices		Si CMOS	Spin MOSFET	2-terminal [D] 3-terminal [E] 4-terminal [F]		MottFET	
Cell Size (spatial pitch) [B]	Projected	100 nm	100nm [A]	100nm	40 nm	10nm[O]	100 nm
	Demonstrated	590 nm	Not known	sub-1000nm	65 nm [M]	1 µm x 150 µm [P]	150µm [T]
Density (device/cm^2)	Projected	1.00E+10	1.00E+10	1.00E+10	1.00E+11	1.00E+12	Similar to Si CMOS
	Demonstrated	2.80E+08	Not known	~1E5 [G]	Not known	6.67E+05	Not known
Switch Speed	Projected	12 THz	12 THz or less [B]	~1GHz [H]	Not known	2THz (0.5ps) [Q]	500 GHz[U]
	Demonstrated	1.5 THz	Not known	0.18GHz [I]	1 ns [N]	13.3THz-0.1GHz(75fs-9ns) [Q]	Not known
Circuit Speed	Projected	61 GHz	61 GHz or less [B]	~1GHz [J]	Not known	Not known	Similar to Si CMOS
	Demonstrated	5.6 GHz	Not known	25 KHz [K]	Not known	Not known	Not known
Switch Energy, J	Projected	3.00E-18	~3E-18 [B]	<1E-17 [L]	Not known	0.1uW [R]	3.00E-19
	Demonstrated	1.00E-16	Not known	Not known	Not known	Not known	Not known
Circuit Energy, J	Projected	1.20E-17	1.2E-17 [B]	<1E-17 [L]	Not known	Not known	Not known
	Demonstrated	4.00E-16	Not known	Not known	Not known	Not known	Not known
Subthreshold Slope, mV/dec	Projected	60 mV/dec	~60 mV/dec [B]	0.00E+00	Not known	<= 60 mV/dec [S]	26 mV/dec [V]
	Demonstrated	60 mV/dec	~90 mV/dec [C]	0.00E+00	Not known	Not known	46 mV/dec [T]

Homework

Define nanoelectronics ? Discuss how it can improve electronic devices.

List issues, advantages and applications of nanoelectronics.