2009 ITRS

Emerging Research Materials [ERM]

July 15, 2009

Michael Garner – Intel
Daniel Herr – SRC

Work in Progress: Not for Distribution

2008 - 2009 ERM Participants

Name	Affiliation
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Takashi Kariya	Ibiden
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Toru Yamaguchi	NTT
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Yuegang Zhang	LBNL
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Chuck Zmanda	Rohm Haas

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ITRS ERM Team

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2009 Key Messages

- 2009 ERM Chapter will focus applications
  - Materials for ERD Devices
  - Lithography
  - Front End Processes
  - Interconnects
  - Assembly and Package
- Establish Critical Assessment Process
  - Alternate Channel Materials, etc.

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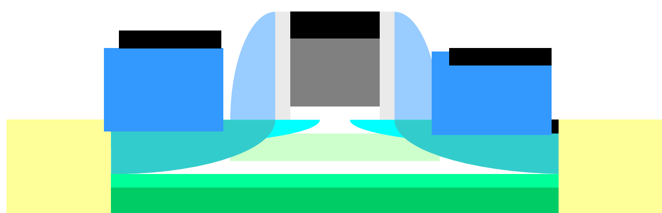
Extending CMOS
Alternate Channel Materials

MOS



Assess

Materials Performance

Gate materials

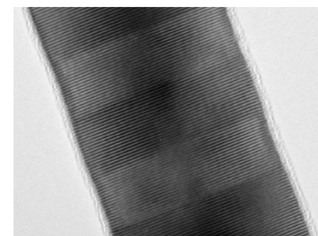
Contacts

Interfaces

Alternate Channel Materials

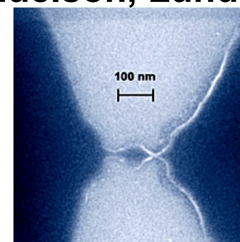
-Ge & III-V Compounds

-Nanowires



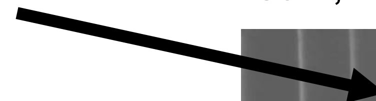
III-V Heterostructures
(L. Samuelson, Lund Univ.)

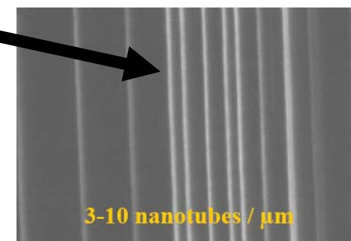
-Graphene



A. Geim, Manchester U.

-Carbon Nanotubes





D. Zhou, USC

-Also Identify Novel Metrology & Modeling Needs

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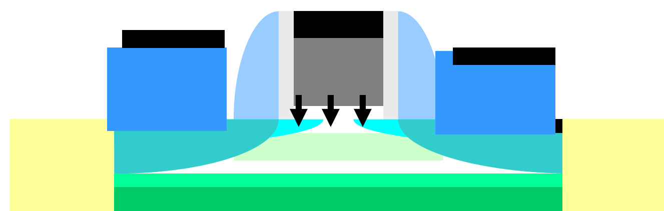
Beyond CMOS Materials & Interfaces

Charge Based

Ferroelectric

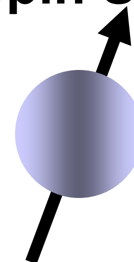
Polarization



Negative Capacitance FET

States Other Than Charge Only

Spin State



•Individual or Collective

Assess

- Ferromagnetic Materials, Dilute Magnetic Semiconductors
- Complex Metal Oxides
- Strongly Correlated Electron State Materials (FE, FM, FE & FM)
- Molecules
- Interfaces

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Memory

- Capacitive
  - FeFET
- Resistive Memory
  - Nanoelectromechanical
  - STT
  - Nanothermal
  - Nano-ionic
  - Electronic Effects
  - Molecular

Complex Metal Oxides & Transition Metal Oxides

Ferromagnetic Materials

Chalcogenides

Nanotubes & Nanowires

Macromolecules

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Lithography

Evolutionary Resist Design

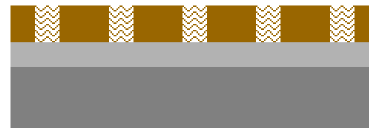
-Positive Resist

New Applications of Old Resist

Non-Chem Amp (193nm)

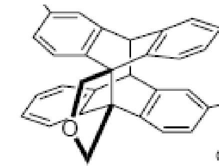
Negative Resist (EUV)

Novel Molecules for Double Exposure



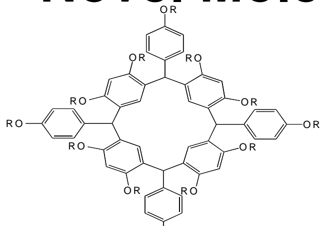
Intermediate State

Tethered Anthracene



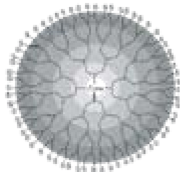
Bristol, Intel

Novel Molecules Resist



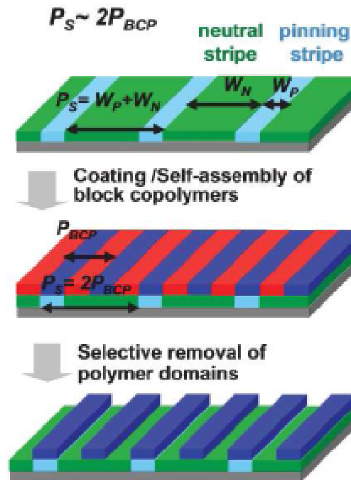
Molecular Glasses

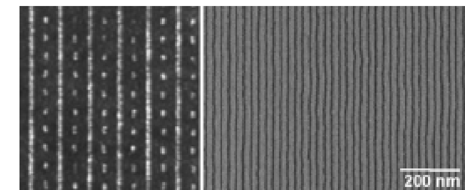
Ober, Cornell



Dendrimers, Frechet, UC-B

Directed Self Assembly





Hinsberg, IBM

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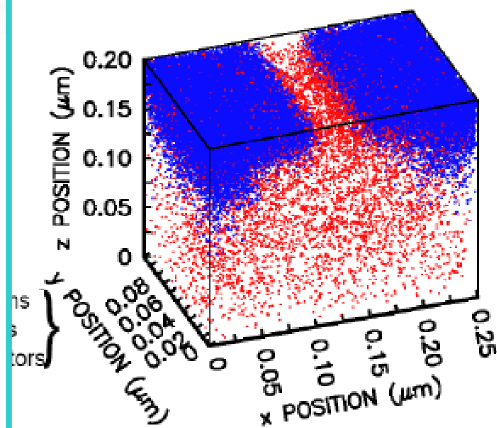
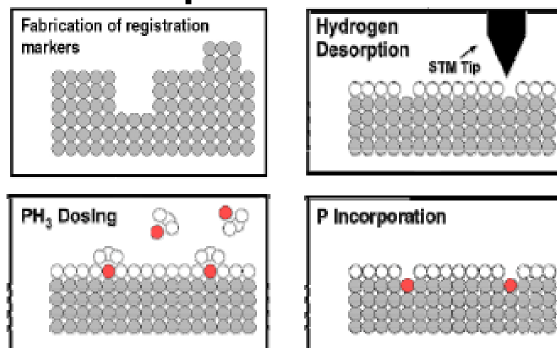
Front End Processing & PIDS Materials

Deterministic Doping

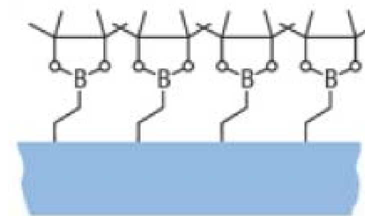
STM Dopant Placement



D. Frank, ISSCC 2004



Monolayer Doping



Javey, UCB

Vt set by the number of dopant atoms in the channel depletion region

•Proposals for Massive parallel precision implants

- Directed Self Assembly for
  - Selective etch
  - Selective deposition
  - Selective protection in clean operations

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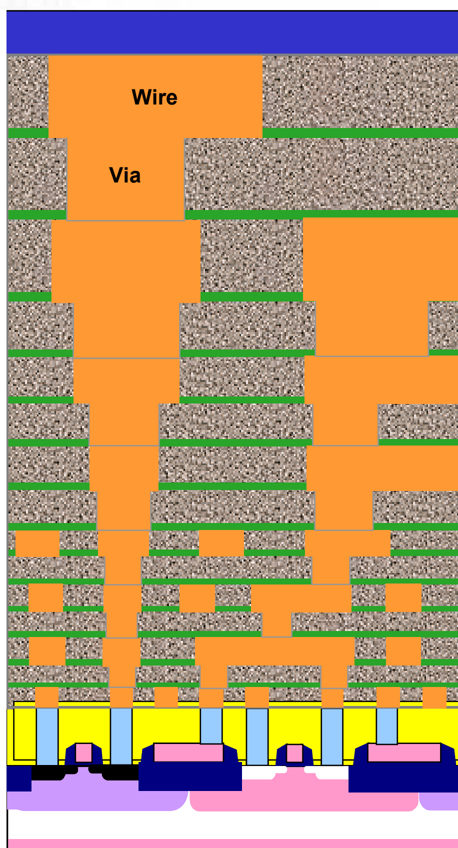
Interconnect Materials

Interconnects



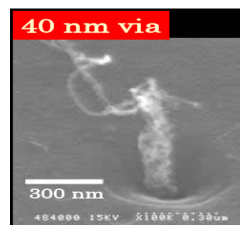
Ultra-thin Barrier Layers

- **Transition Nitride (ZrN, HfN, ZrGeN,...)**
- **Direct Plate (Ir, Os, Rh, ...)**
- **SAM**

Ultra low κ ILD

Novel Interconnects & Vias

- Carbon Nanotubes



Y. Awano, Fujitsu

-Graphene

-Single Crystal Metal Nanowires

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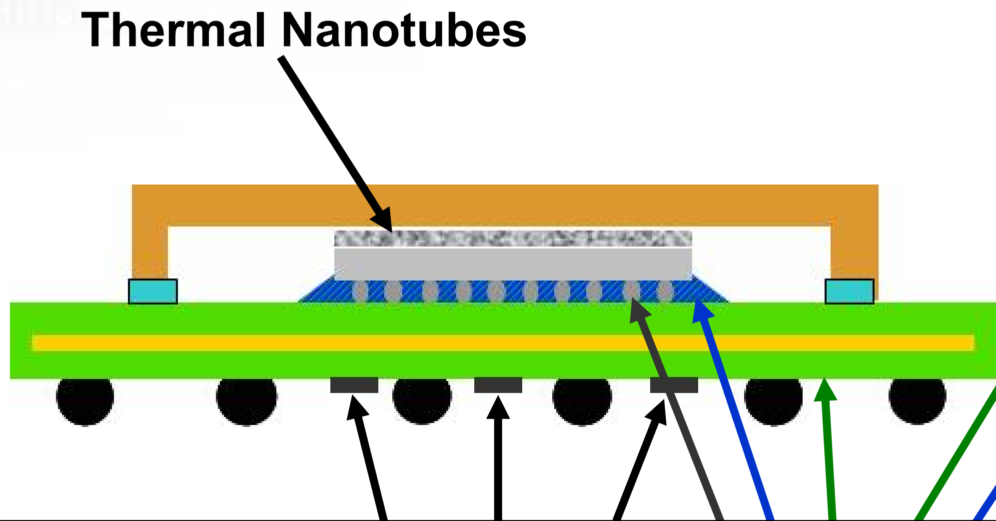
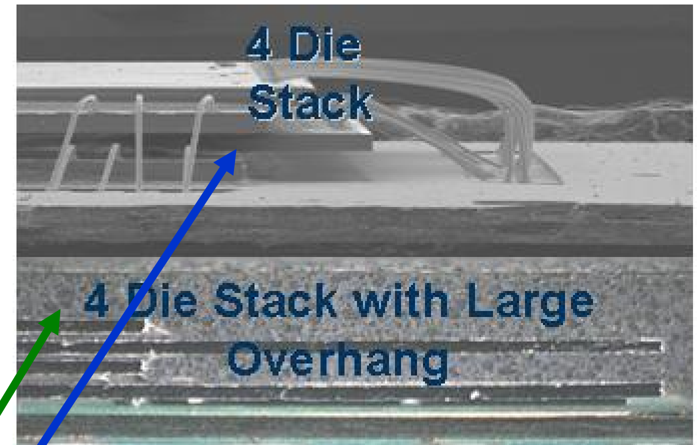
Emerging Packaging Applications





High Density Power Delivery Capacitors

- Dielectrics: High K
- Self Assembly
- Interconnects: Nanotubes or Nanowires

Package Thermo-Mechanical

- Substrate: Nanoparticles, Macromolecules
- Adhesives: Macromolecules, Nanoparticles
- Chip Interconnect: Nanoparticles
- Polymers: Nanoparticles & Macromolecules

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Hexagon of Assembly Material Requirements

Examples

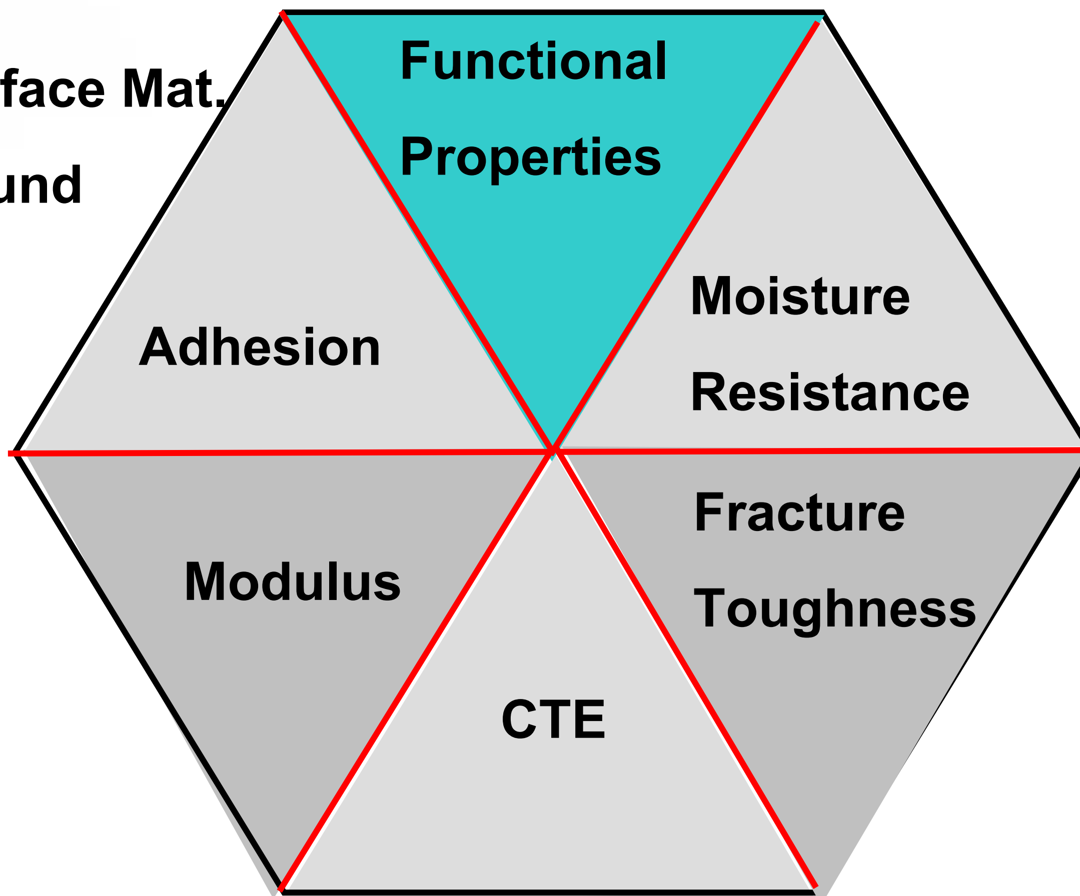
Thermal Interface Mat.

Mold Compound

Underfill

Adhesives

Epoxy



- Highly coupled Material Properties
- Apply novel materials to achieve optimal performance

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ESH Challenges

- Materials needed to overcome significant technical challenges
  - Few materials could meet requirements
  - Materials have known or uncharacterized EHS properties
  - Stimulate ESH research in uncharacterized materials
  - Encourage development of BKM for materials EHS in Research, Development & HVM
  - Efficient use of materials
  - Manufacturing in highly controlled environments

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Emerging Metrology and Modeling Needs

- **Metrology**
  - Chemical and structural imaging and dimensional accuracy at the nm scale
  - Low dimensional material properties (Mapping)
  - Nondestructive nanoscale embedded interface characterization
  - Simultaneous dynamic spin and electrical properties
  - nm scale characterization of vacancies and defects and effects on electronic properties
- **Modeling Materials and Interfaces**
  - Low dimensional material synthesis & properties
  - Spin material properties
  - Strongly correlated electron material properties
  - Anion & cation vacancy effect on electronic properties
  - Integrated models and metrology (de-convolution of nm scale metrology signals)
- **Metrology and modeling must be able characterize and predict performance and reliability**

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Summary

- ERM identifies and assesses materials as potential solutions for ITWG applications
- Significant challenges must be addressed for these materials to be viable for transfer to the ITWGs
- Complete 2009 ERM Chapter

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