

2006/7 ITRS

Emerging Research Materials

December 5, 2006

Michael Garner – Intel

Daniel Herr – SRC



2006 ERM Participants

Bob Allen	IBM	Louis Lome	IDA Cons.
Yuji Awano	Fujitsu	Francois Martin	LETI
Chuck Black	IBM	Chris Murray	IBM
Ageeth Bol	IBM	Dmitri Nikonov	Intel
George Bourianoff	Intel	Chris Ober	Cornell Univ.
Alex Bratkovski	HP	Mark Reed	Yale Univ.
John Carruthers	Port. St. Univ.	Dave Roberts	Air Products
U-In Chung	Samsung	Francis Ross	IBM
Hongjie Dai	Stanford Univ.	Sadasivan Shankar	Intel
Jean Dijon	LETI	Lars Samuelson	Lund University
Joe DeSimone	UNC	John Henry Scott	NIST
Satoshi Fujimura	TOK	Kaushal Singh	AMAT
Michael Garner	Intel, Co-Chair	Curt Richter	NIST
Emmanuel Giannelis	Cornell Univ.	Shinichi Tagaki	U of Tokyo
Joe Gordon	IBM	Koki Tamura	TOK
Jim Hannon	IBM	Emanuel Tutuc	IBM
Rudi Hendel	AMAT	Vijay Wakharkar	Intel
Dan Herr	SRC, Co-Chair	Kang Wang	UCLA
Jim Hutchby	SRC	Rainer Waser	Aachen U.
Ted Kamins	HP	C.P. Wong	Ga Tech. Univ.
		In Kyeong Yoo	Samsung
		Victor Zhirnov	SRC

Expect the Team to Grow Through 2007



Emerging Research Materials

- Update ERD Materials Section (2007)
- Develop ERM Chapter (2007)
 - Goal: Identify critical ERM technical and timing requirements
 - Consolidated Materials Research Requirements for:
 - University Researchers (Chemist, Materials Scientist, etc)
 - Chemical & Material Suppliers
 - Corporate Researchers



ERM Proposed Scope

- Cross Cutting Materials designed to address specific roadmap issues
- Carbon Nanotubes & Nanoparticles
- Macromolecules
- Directed Self Assembly
- Strongly Correlated Electron State Materials
- Hetero-structures & interfaces
- Spin Materials
- Environment Safety & Health

Monthly e-Workshops



ERM TWG Plan

- Identify ERM performance requirements with ITRS TWGs
- E-Workshops to Review Materials Status vs. Needs
- Identify Research Needs
 - Synthesis
 - Metrology
 - Modeling
 - ESH

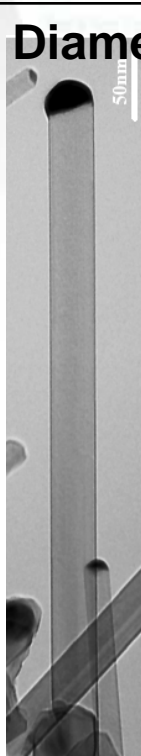


Emerging Research Materials Workshop Timetable

- *CNTs & Nanoparticles (September '06) Completed*
 - *Devices, Interconnect, Package, FEP, Litho*
- *Macromolecules (October, '06) Completed*
 - *Litho, FEP, Packages, Devices*
- *Strongly Correlated Electron State Materials (November)*
 - *ERD Completed*
- *Directed Self Assembly (December)*
 - *Litho, Interconnects, FEP, ERD*
- *Hetero-structures & Interfaces (January'07)*
 - *ERD, Interconnects, FEP, Package*
- *ESH (March'07)*
- *High Tc Magnetic Oxide Semiconductors (May '07)*



Control of Diameter

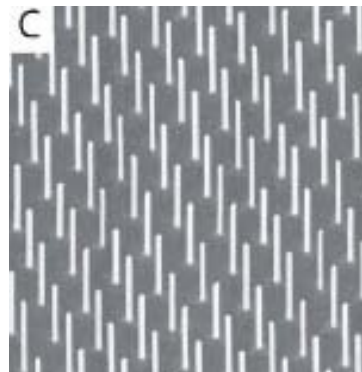


Must passivate sidewall to avoid side growth or catalyst Diffusion (F. Ross)

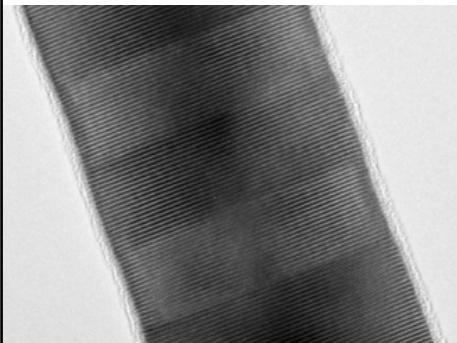
Nanowires

Location & Orientation Control

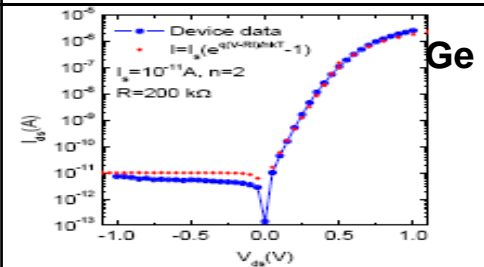
InAs Nanowires



Group IV & III-V
Grow in 111 Orientation
Catalyst determines location (L. Samuelson)



Atomically smooth Heterostructures (L. Samuelson)

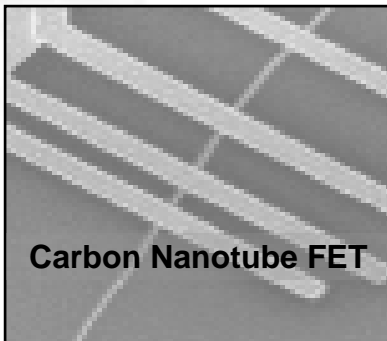


Nanowire doping is challenging and requires different mechanisms (E. Tutuc)

- Device Challenges: Control diameter, properties, location & orientation

Nanotubes

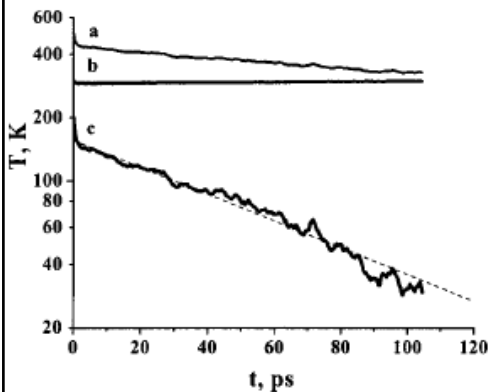
Devices



Carbon Nanotube FET

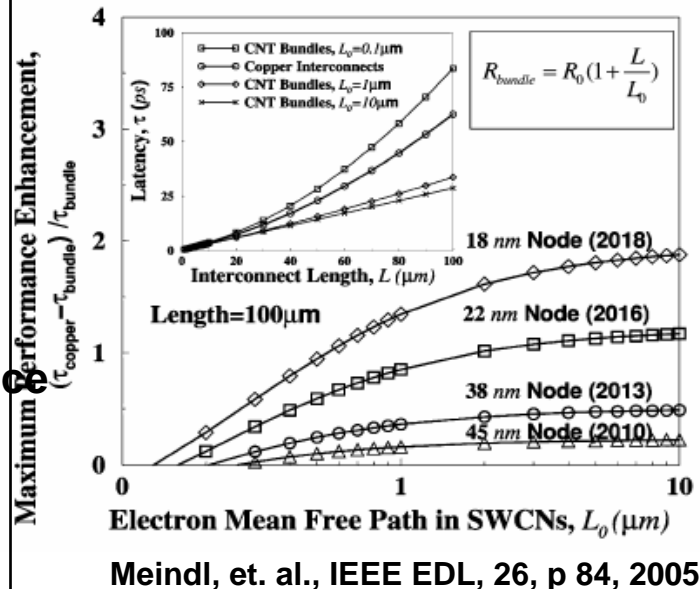
Source Intel

Thermal: CNT Interface Resistance
 $3.3 \times 10^{-8} \text{ Km}^2/\text{W}$



Shenogin et. al., JAP, p8136, 2004

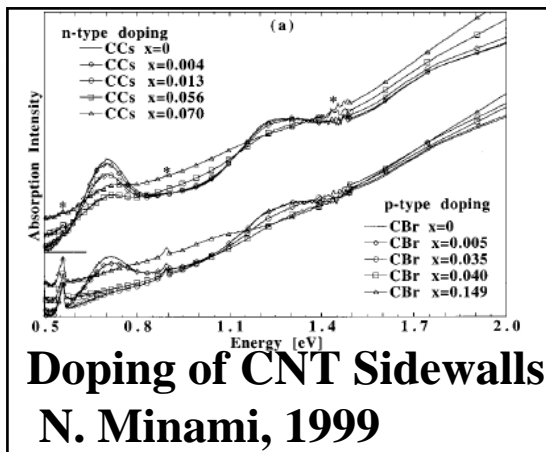
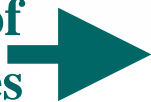
Interconnects



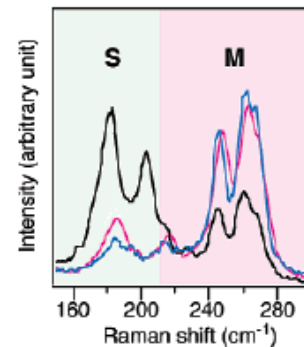
- Carbon nanotubes of interest for multiple applications

Carbon Nanotube Material Progress

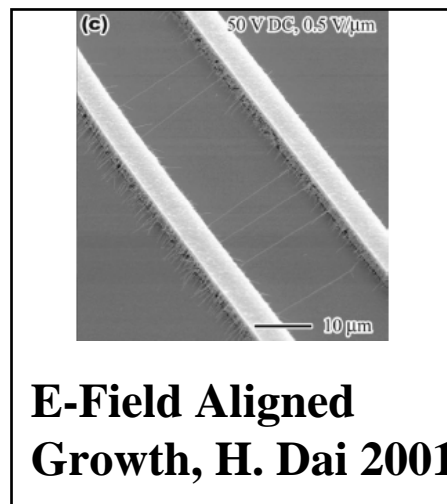
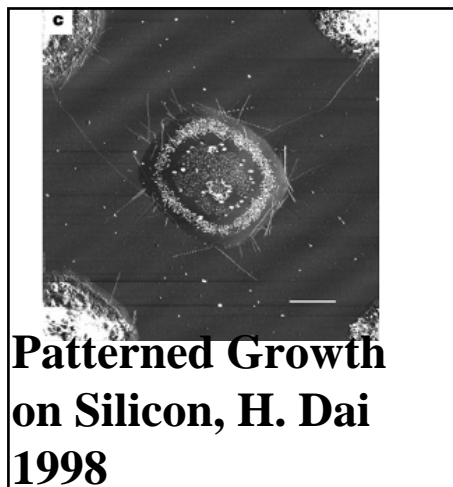
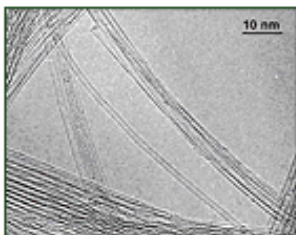
Control of
Properties



**Chemical Separation
Of Metallic and
semiconductor CNTs,**
N. Minami, 2005



Control location &
orientation



Electron microscope photograph of
Carbon Nanotubes

1991 Discovery

Material Characterization & Improvement

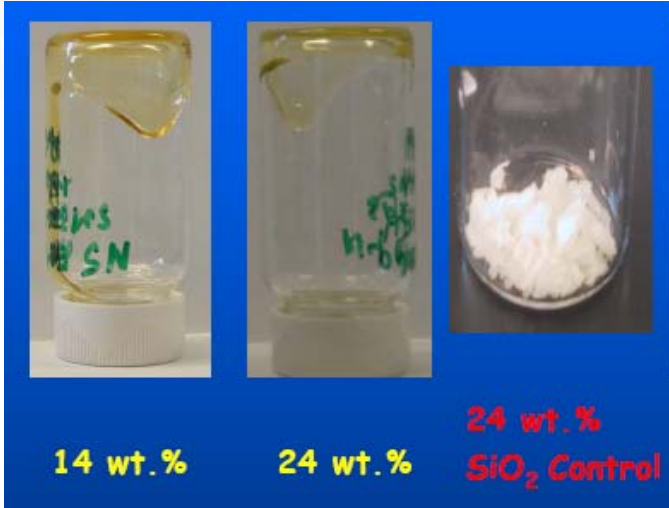
CNT's Discovered,
Iijima 1991

22nm Generation requires > 10⁹ transistors/cm²

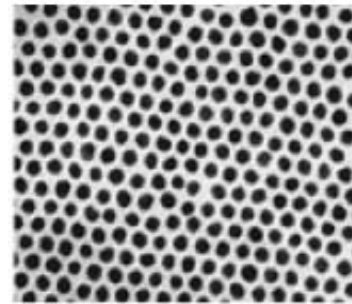


Nanoparticles

Nanoliquids (Nonsolvent)

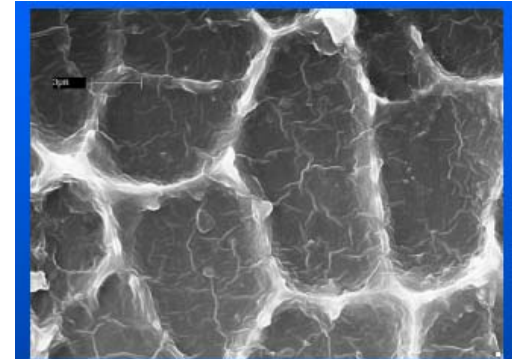


Higher refractive index,
but higher viscosity
(E. Giannelis)

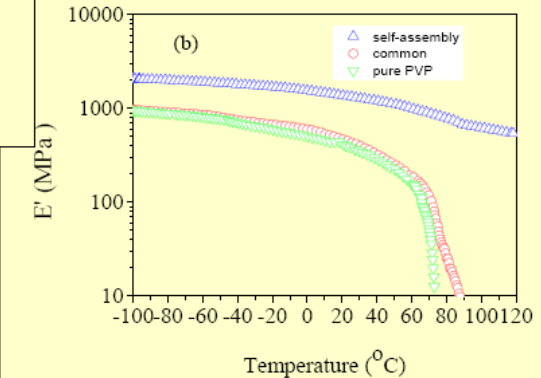


Co/Ni 9 nm
Liquid phase
Nanoparticles
Catalyst?
(C. Murray)

Nanocomposites



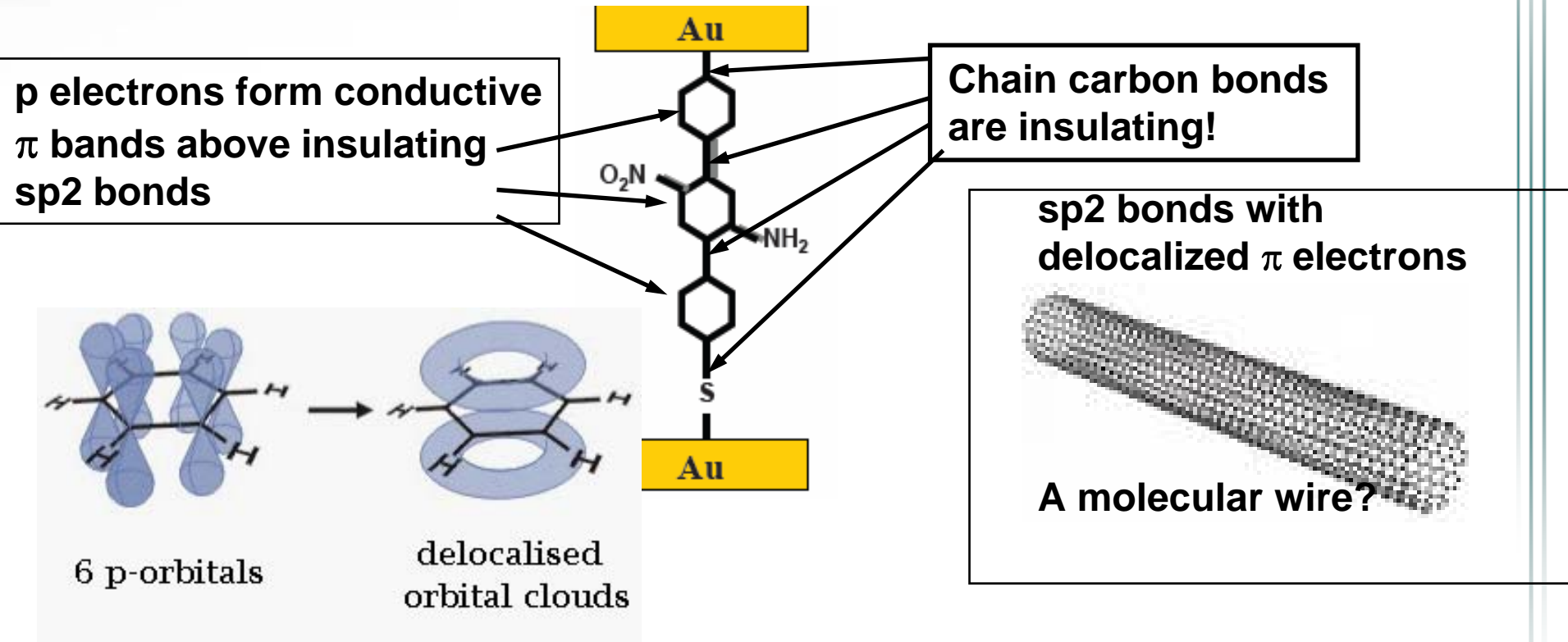
0.5 % CNT



Increase modulus & T_g
(E. Giannelis)

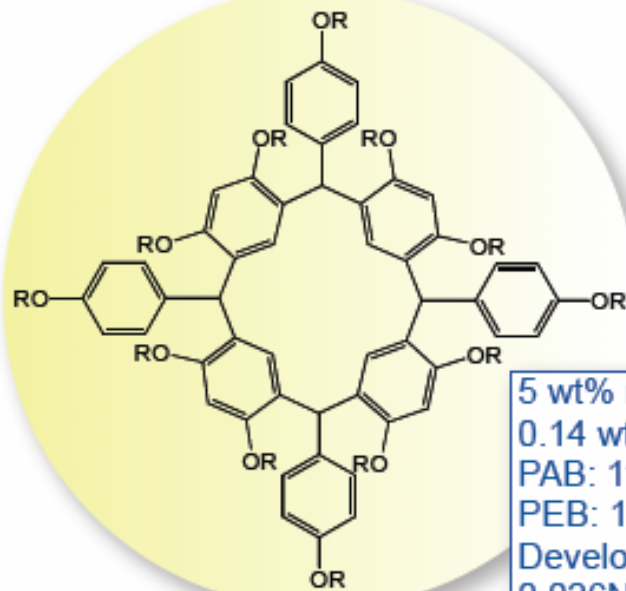
- Nanoparticle unique properties.

Macromolecules for Devices

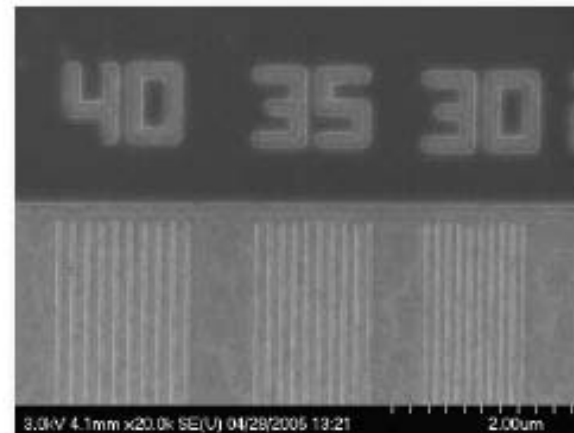


- Are chain bonds limiting molecular devices?

Macromolecules for Lithography



5 wt% non-PFOS PAG
0.14 wt% TOA
PAB: 115°C, 60s
PEB: 115°C, 60s
Development:
0.026N TMAH, 30s

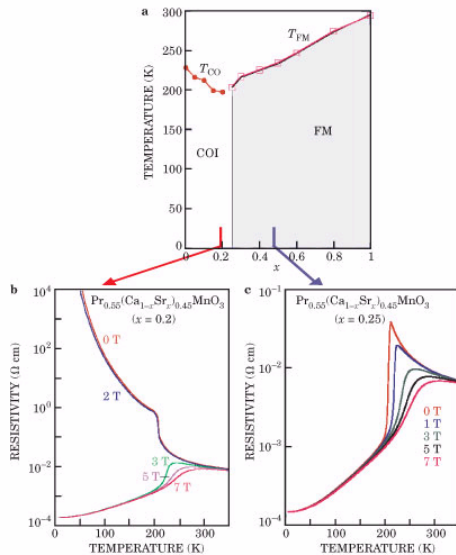


Positive Tone Molecular Glass C. Ober

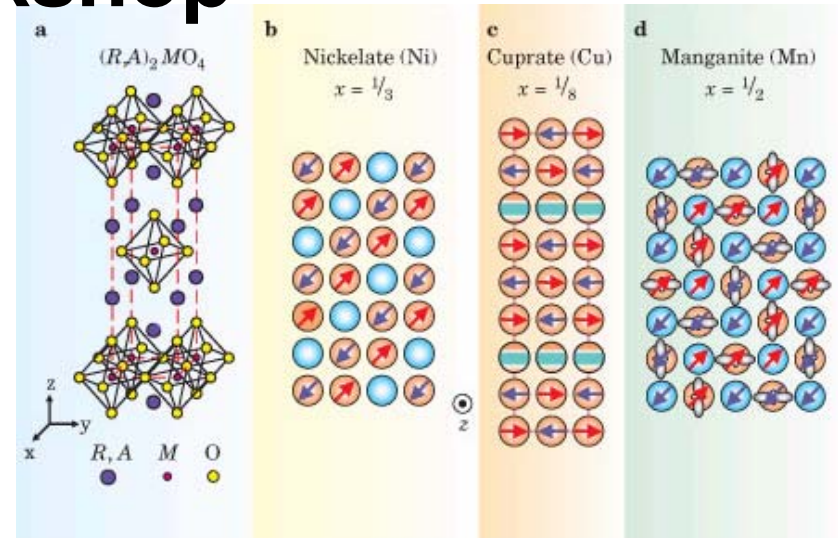
- Macromolecular design for future resist is critical!



Strongly Correlated Electron State Materials Workshop



Tokura



Tokura

- Materials exhibit complex phase relationships
 - Structure, Strain, Spin, Charge, Orbital Ordering
- Goal: Determine whether complex phases and coupled dynamic and static properties have any potential to enable alternate state logic devices

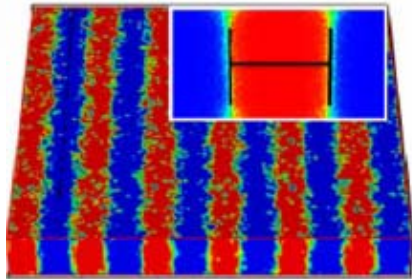
Can these materials enable new device functions?



Directed Self Assembled Materials

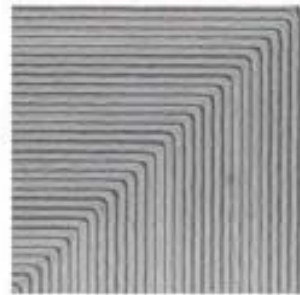
Low K ILD

Lithography

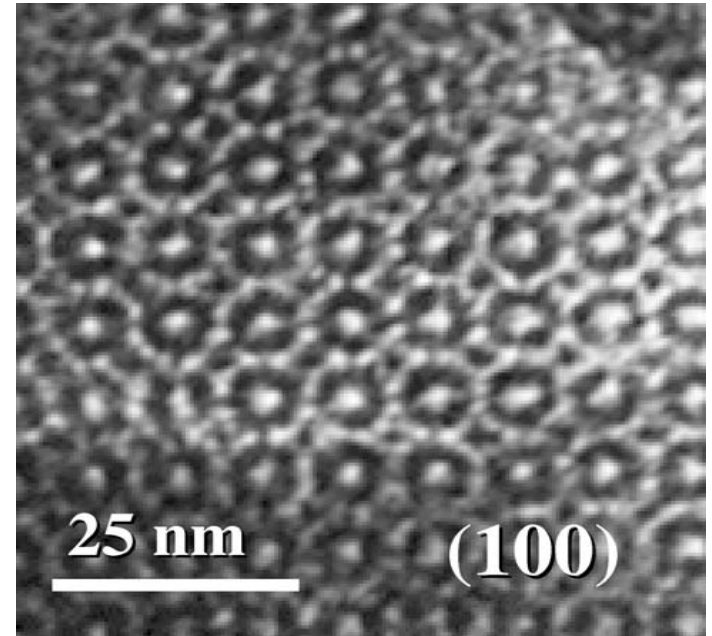


$W/L_g = 0.45$

90°



Di-block Copolymer self assembly on patterned
Molecular monolayer: Goal reduce LER
P. Nealey, U. Wisc.



Source: J. Brinker, UNM/Sandia National Labs

- Potential Application of Directed Self Assembly for Lithography and Interconnects

Summary 2007 Plans

- Complete ERM e-Workshops
- ERM Chapter 2007
 - Organize ERM Chapter
 - Scope Aligned with TWGs Needs
 - Establish Emerging Research Material Requirements
 - Review ERM Status vs. Needs



Back-up

