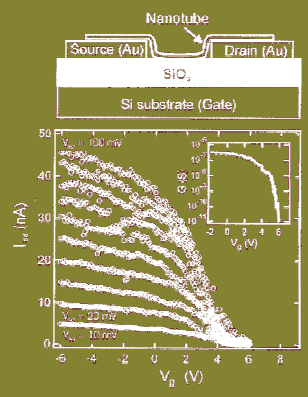
Nanotube FET



[Shea, H.R.; Martel, R.; Hertel, T.; Schmidt, T.; Avouris, Ph. Microelectronic Engineering **46**, 101-4 (1999)]

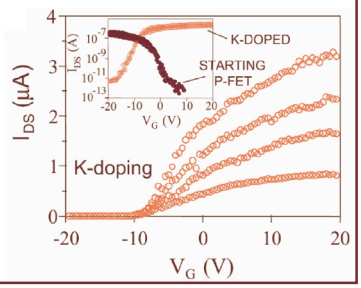
© 2001 D.W. Greve

Carbon Nanotube Inter- and Intramolecular Logic Gates

NANO LETTERS
xxxx
Vol. 0, No. 0
A–D

V. Derycke, R. Martel, J. Appenzeller, and Ph. Avouris*

IBM Research Division, T. J. Watson Research Center, Yorktown Heights, New York 10598

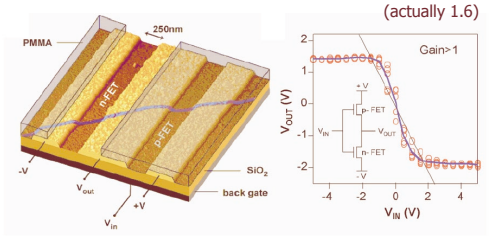


Carbon Nanotube Inter- and Intramolecular Logic Gates

NANO LETTERS
xxxx
Vol. 0, No. 0
A–D

V. Derycke, R. Martel, J. Appenzeller, and Ph. Avouris*

IBM Research Division, T. J. Watson Research Center, Yorktown Heights, New York 10598



(actually 1.6)

© 2001 D.W. Greve

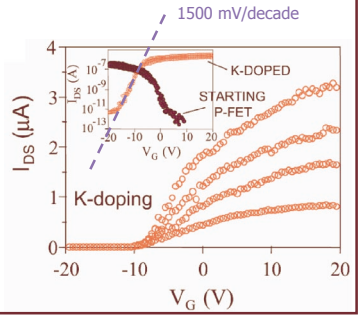
Carbon Nanotube Inter- and Intramolecular Logic Gates

NANO LETTERS
xxxx
Vol. 0, No. 0
A–D

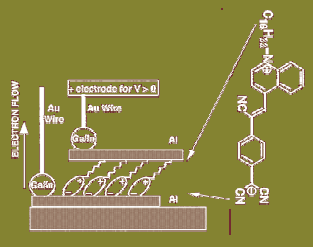
V. Derycke, R. Martel, J. Appenzeller, and Ph. Avouris*

IBM Research Division, T. J. Watson Research Center, Yorktown Heights, New York 10598

1500 mV/decade

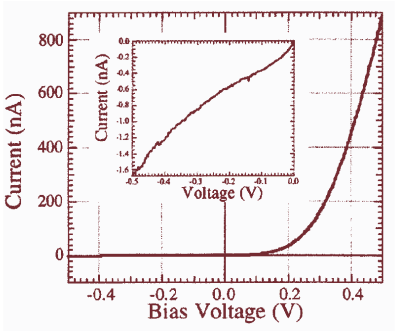


A molecular diode



[J.C. Ellenborgen and J. C. Love, Proc. IEEE **88**, 386 (2000)]

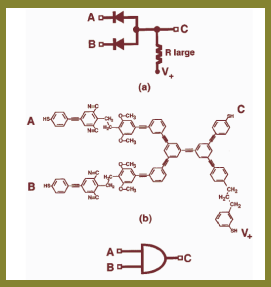
© 2001 D.W. Greve



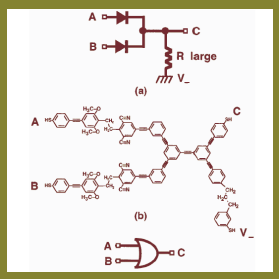
[from J.C. Ellenborgen and J. C. Love, Proc. IEEE **88**, 386 (2000)]

© 2001 D.W. Greve

AND



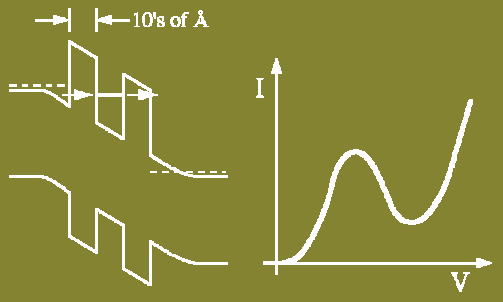
OR



[M. Reed, cited in J.C. Ellenborgen and J. C. Love, Proc. IEEE **88**, 386 (2000)]

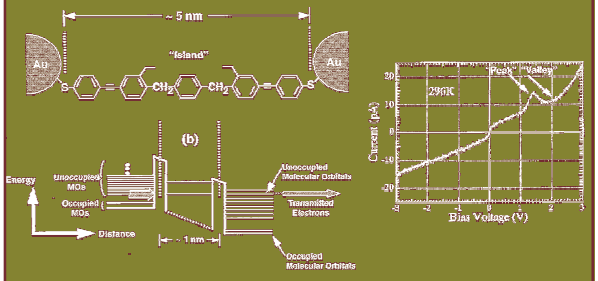
© 2001 D.W. Greve

Resonant tunneling



© 2001 D.W. Greve

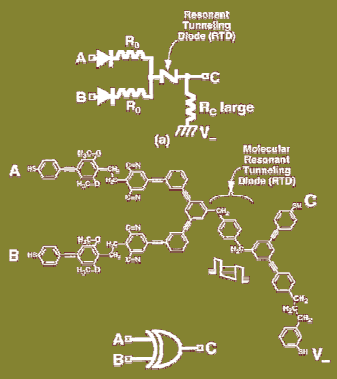
A molecular RTD



[M. Reed, cited in J.C. Ellenborgen and J. C. Love, Proc. IEEE **88**, 386 (2000)]

© 2001 D.W. Greve

XOR gate



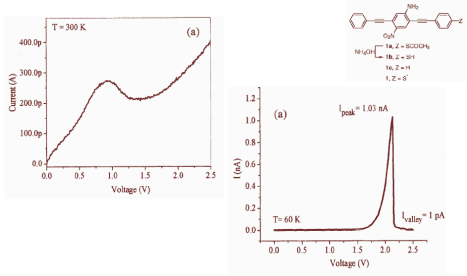
[.C. Ellenborgen and J. C. Love, Proc. IEEE **88**, 386 (2000)]

© 2001 D.W. Greve

APPLIED PHYSICS LETTERS VOLUME 77, NUMBER 8 21 AUGUST 2000

Room-temperature negative differential resistance in nanoscale molecular junctions

J. Chen, W. Wang, and M. A. Reed
Departments of Electrical Engineering, Applied Physics, and Physics, Yale University, P.O. Box 208284, New Haven, Connecticut 06520
A. M. Rawlett, D. W. Price, and J. M. Tour
Department of Chemistry and Center for Nanoscale Science and Technology, Rice University, MS 222, 6100 Main Street, Houston, Texas 77005



© 2001 D.W. Greve

"Consider this," he writes. "There are [a billion trillion] water molecules in just one drop of water." That's hundreds of times the sum total of all the transistors in every computer ever made, he reckons. If just a fraction of the molecules in a speck of matter could be made to act as electronic switches, able to control the electrical currents that are the basic language of computers, present-day computers with their paltry billions of transistors could quickly become obsolete. So would today's giant and expensive chip fabrication plants: A molecular computer might build itself in a set of chemical steps.

The chemistry of computing

Computers made of molecule-size parts could build themselves

U.S.NEWS & WORLD REPORT, MAY 1, 2000

A supercomputer shrunk to a speck?

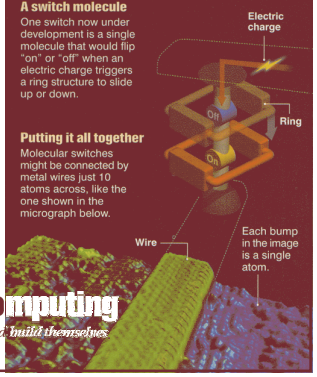
Future computers could be made of switches and wires no bigger than single molecules.

A switch molecule

One switch now under development is a single molecule that would flip "on" or "off" when an electric charge triggers a ring structure to slide up or down.

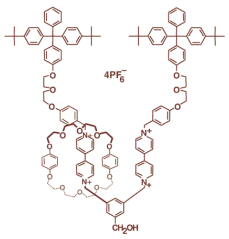
Putting it all together

Molecular switches might be connected by metal wires just 10 atoms across, like the one shown in the micrograph below.



Electronically Configurable Molecular-Based Logic Gates

C. P. Collier, E. W. Wong, M. Belohradský, F. M. Raymo, J. F. Stoddart, P. J. Kuekes, R. S. Williams, and J. R. Heath, Science 1999 July 16; 285: 391-394.

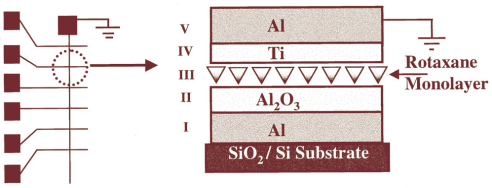


rotaxane

© 2001 D.W. Greve

Electronically Configurable Molecular-Based Logic Gates

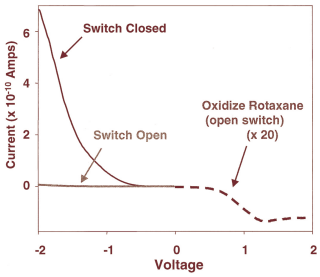
C. P. Collier, E. W. Wong, M. Belohradský, F. M. Raymo, J. F. Stoddart, P. J. Kuekes, R. S. Williams, and J. R. Heath, Science 1999 July 16; 285: 391-394.



© 2001 D.W. Greve

Electronically Configurable Molecular-Based Logic Gates

C. P. Collier, E. W. Wong, M. Belohradský, F. M. Raymo, J. F. Stoddart, P. J. Kuekes, R. S. Williams, and J. R. Heath, Science 1999 July 16; 285: 391-394.

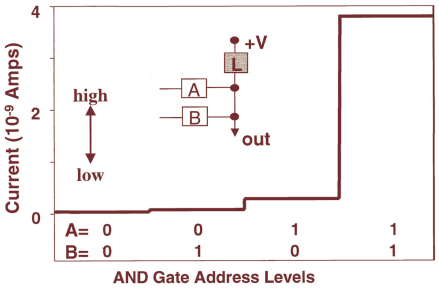


ON/OFF = 60-80

© 2001 D.W. Greve

Electronically Configurable Molecular-Based Logic Gates

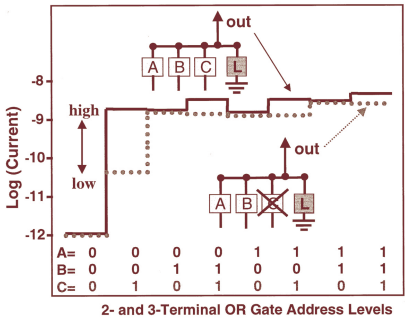
C. P. Collier, E. W. Wong, M. Belohradský, F. M. Raymo, J. F. Stoddart, P. J. Kuekes, R. S. Williams, and J. R. Heath, Science 1999 July 16; 285: 391-394.



© 2001 D.W. Greve

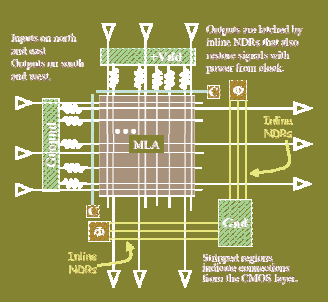
Electronically Configurable Molecular-Based Logic Gates

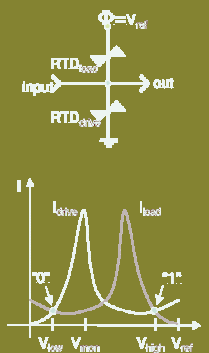
C. P. Collier, E. W. Wong, M. Belohradský, F. M. Raymo, J. F. Stoddart, P. J. Kuekes, R. S. Williams, and J. R. Heath, Science 1999 July 16; 285: 391-394.



© 2001 D.W. Greve

Architectural concept

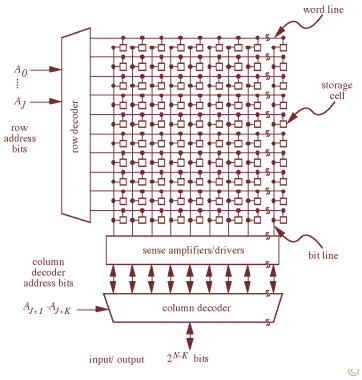




[S.C. Goldstein and D. Rosewater, CMU]

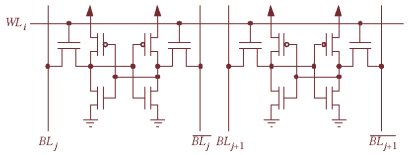
© 2001 D.W. Greve

Array structures-memory



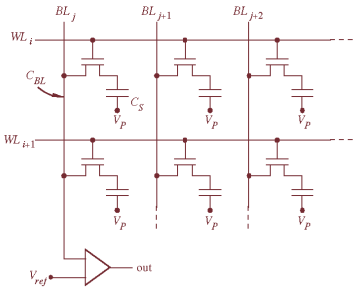
© 2001 D.W. Greve

Array structures-SRAM



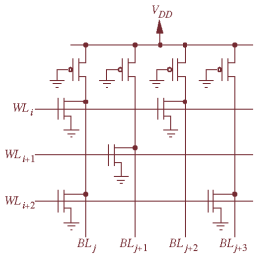
© 2001 D.W. Greve

Array structures-DRAM



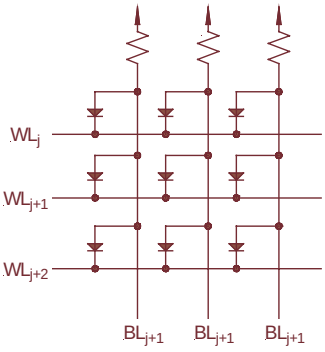
© 2001 D.W. Greve

Array structures-ROM (MOS)



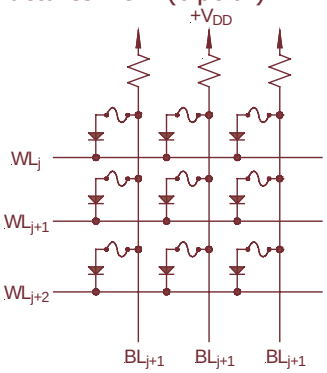
© 2001 D.W. Greve

Array structures-ROM (bipolar)



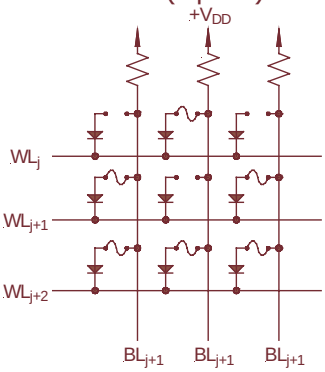
© 2001 D.W. Greve

Array structures-ROM (bipolar)



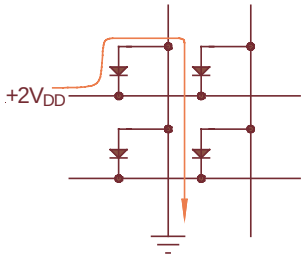
© 2001 D.W. Greve

Array structures-ROM (bipolar)



© 2001 D.W. Greve

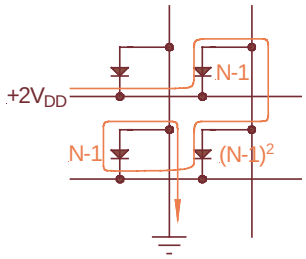
Sneak paths-writing



Assume programmable diode is written with twice read voltage in reverse direction

© 2001 D.W. Greve

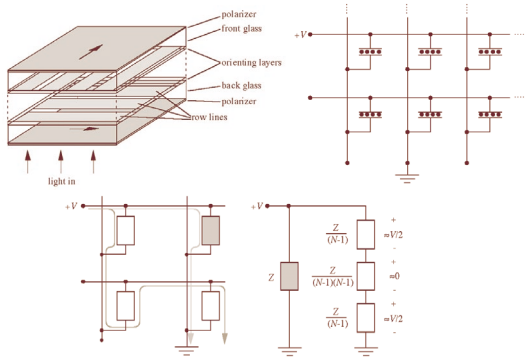
Other diodes during writing



Worst case- N-1 junctions are written with half writing voltage N-1 (?) times

© 2001 D.W. Greve

Passive matrix LCD display



© 2001 D.W. Greve

Summary/conclusions/cautions

- many devices/architectures under study
- nanodevices have a long way to go
- many practical problems which cannot be ignored

© 2001 D.W. Greve