Disruptive Technologies

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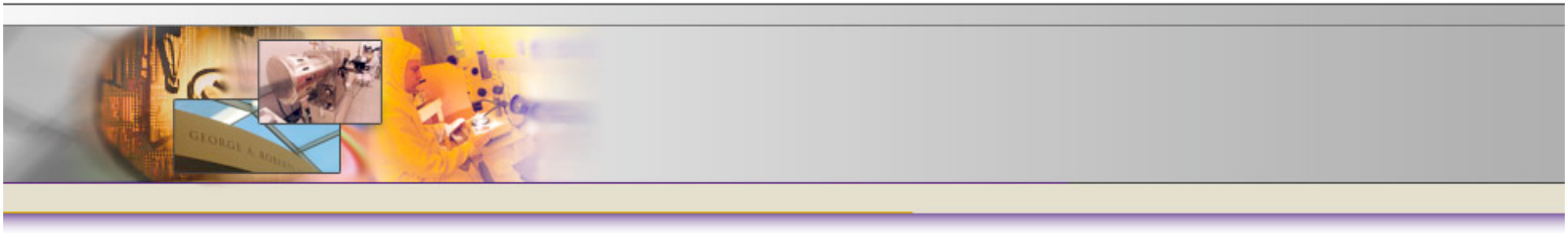

DSSC

The Data Storage Systems Center

Electrical & Computer ENGINEERING

September 25, 2008

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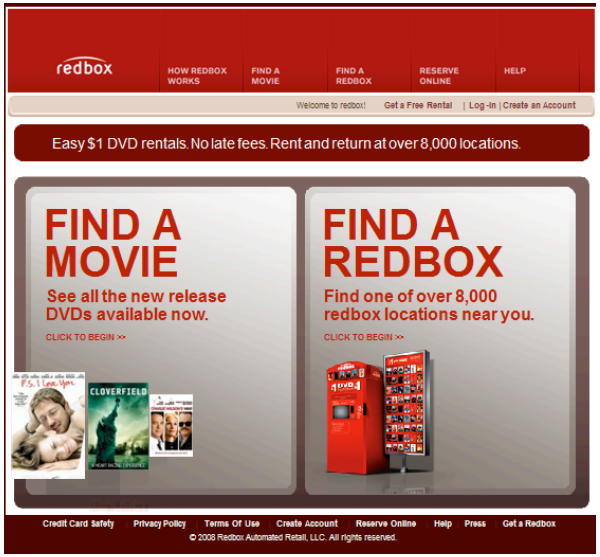
Importance of Storage

Storage is becoming more important

- *Not just "the place you keep your information".*
- *Huge data sets are becoming the object with which one computes – replacing traditional models in some applications*
- *Larger and larger data bases will become increasingly important and valuable*
- *Asymmetries exist in the upload (creation)/download (distribution) of these data sets.*
- *Examples: Machine translation, system control, object identification*

- *"Disruption" in the use pattern?*

Everything will be downloaded…



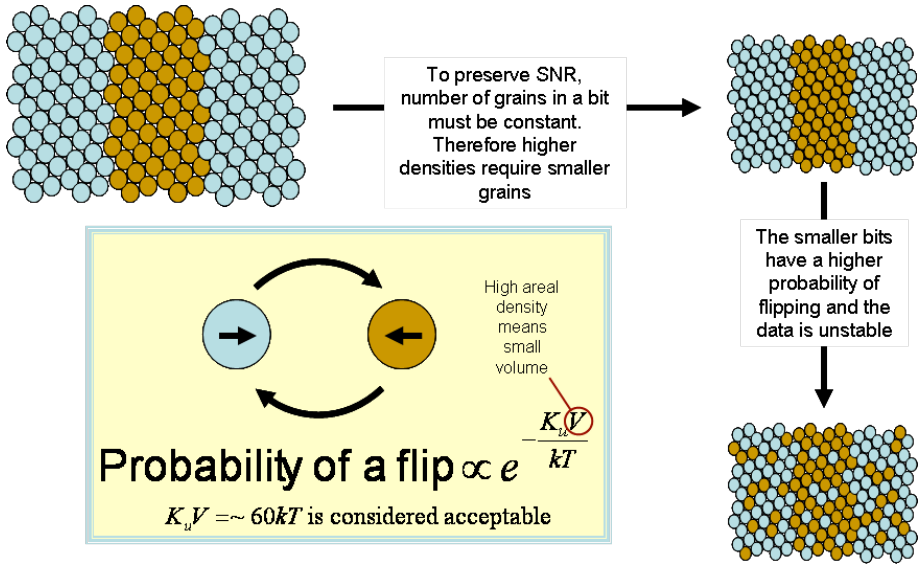
Maybe Not

- *NETFLIX:*
  - *100,000 titles and 55x10⁶ DVDs*
  - *Ships 1.9 million DVD a day, on average*
  - *Data rate of about 1 Tbit/sec 24/7*
  - *Cost to the consumer $5/month 2 titles/month ($2.50/DVD) (http://www.netflix.com/MediaCenter?id=5379&hnjr=8#facts)*
- *Redbox*
  - *$1 /DVD*
- *Energy to transmit 1 kbit about the same as energy to compute about 1 MegaOp*

Hard Disk Drives

The Problem (Superparamagnetic Limit)*

- *SNR requires fixed number of grains*
- *Fixed number of grains requires smaller grains for higher density*
- *Small grains must employ higher stability (K_u) materials*
- *Higher stability materials cannot be written with head fields*
- *Implies need for energy assist (HAMR, MAMR) to increase density*



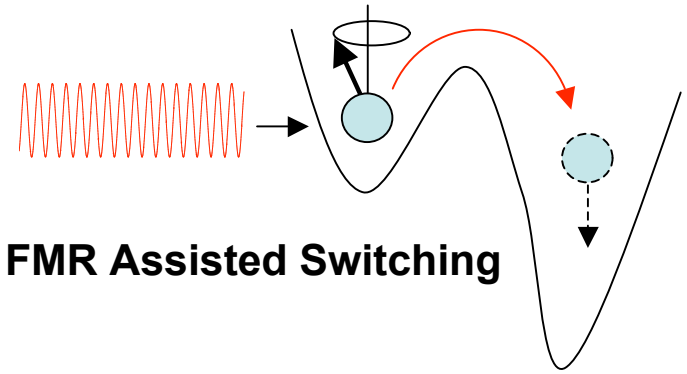
- **Bit Patterned media**
  - *Could allow for one grain per bit*

* "Thermal Stability of Recorded Information at High Densities", S.H. Charap, P.-L. Lu, Y. He, *IEEE Trans. Mag* **33**, 978(1997).

μ-Wave Assisted Mag-Recording

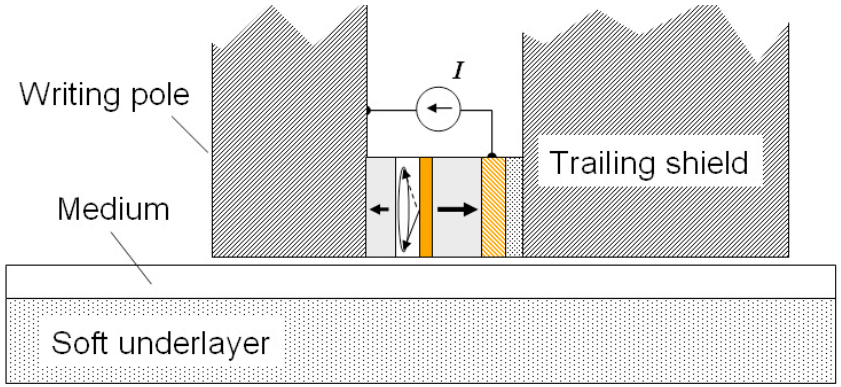
Towards 10 Tbits/in² Area Density

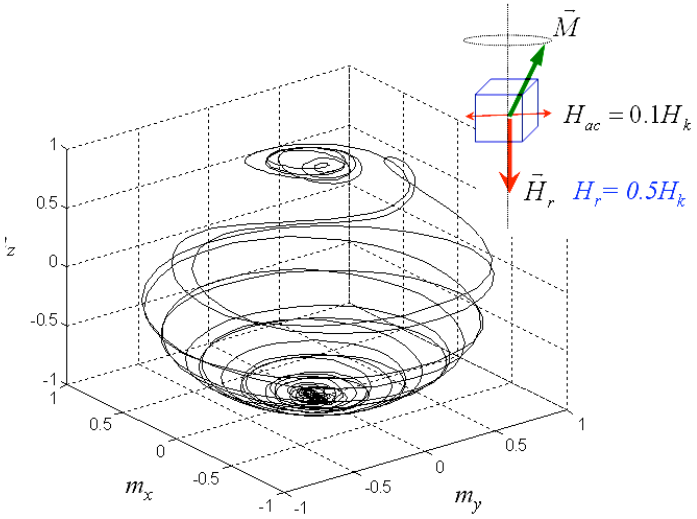
Jimmy Zhu, ABB Professor of Engineering



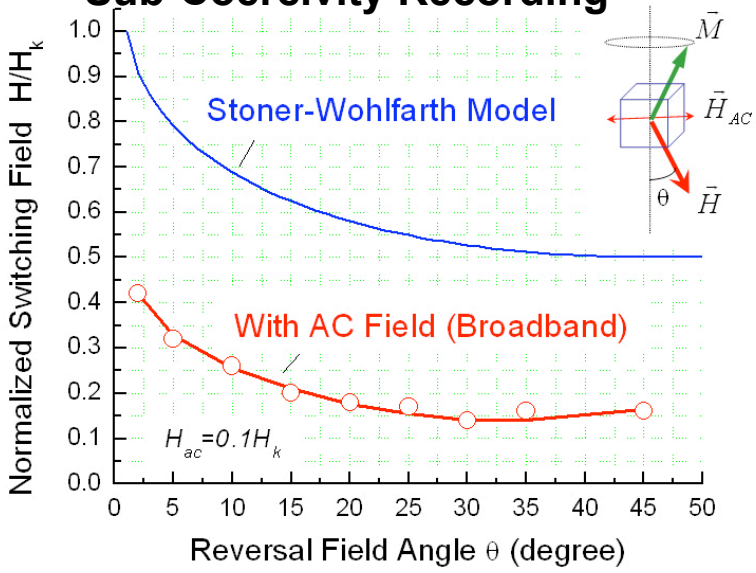
FMR Assisted Switching

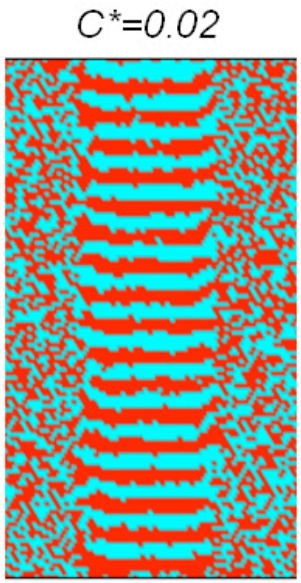
Spin Torque AC Field Generator





Sub-Coercivity Recording

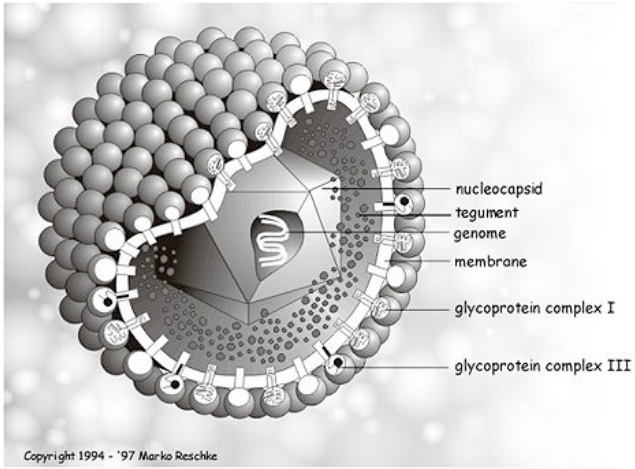




What might be possible…

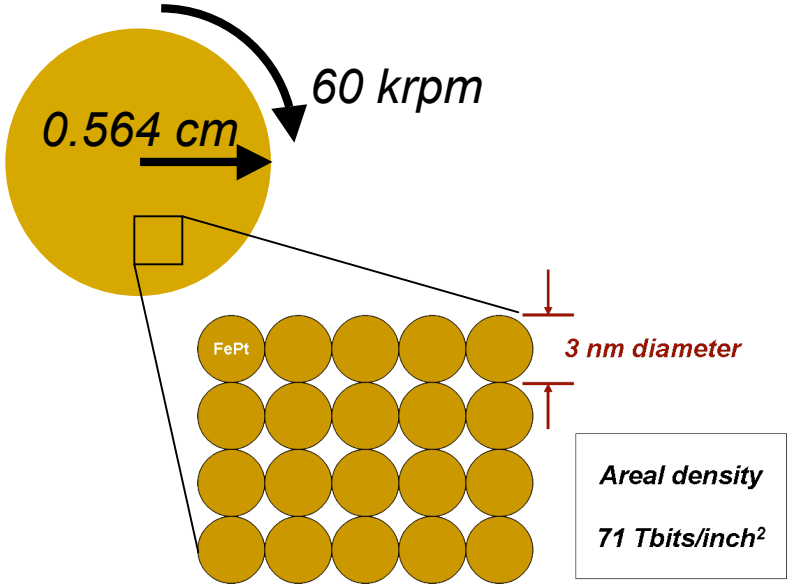
VIRUS

- *Human Cytomegalovirus: 200,000 base pairs*
- *Nucleocapsid ~ 100 nm diameter*
- *Information storage density $3x10^{16}$ bits/inch^2*
- *about 10^5X today's state-of-the-art*



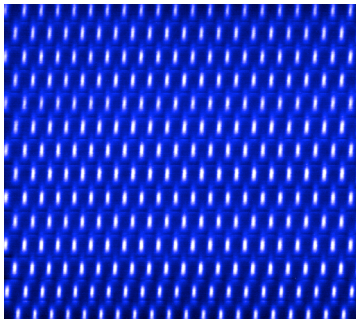
DISK

- *Limit capacity to 1 Terabyte (8 Terabits)*
  - *Area of 0.16 inch^2 (1 cm^2 media)*
- *For 1 msec latency*
  - *1 kHz vibration or 60,000 rpm*
  - *10 GBits/sec data rate*

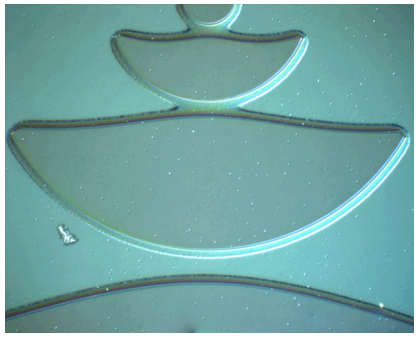


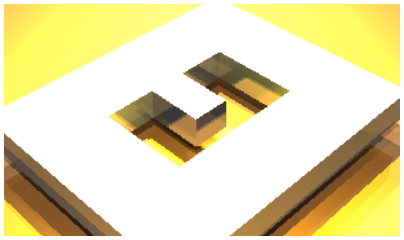
Optical Storage

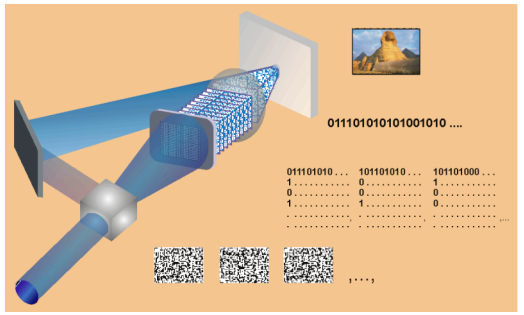
- ***Removable Media***
- ***Inexpensive fast replication***
- ***Inexpensive substrate***



- ***Near field***
  - *Near field optical transducers*
  - *Servo fly heights*
- ***Volumetric (bit wise)***
  - *Micro holographic*
  - *Two photon*
- ***Holographic***





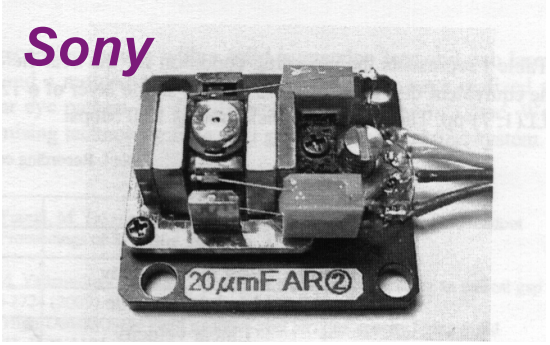


4th Generation Optical

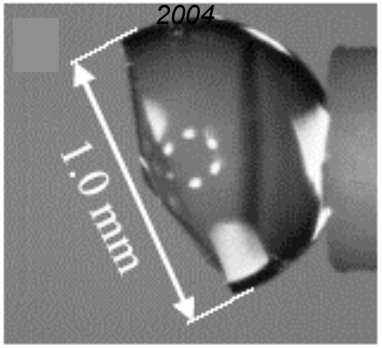
Near field optical technology

- *Motivation for 4th generation optical not yet clear*
- *Sony and Philips actuated SIL, CMU Actuated laser diode*
- *Decreased interest (e.g. Philips)*
  - *DVD and BD expected to dominate market for next decade*
  - *"volumetric" storage improving (bit wise, holographic, microholograms)*

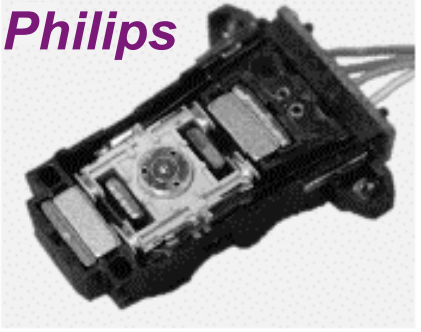
Sony



T. Ishimoto et al., Proc. of SPIE Vol. 5380, p. 233, 2004



Philips



F. Zijp et al., Proc. of SPIE Vol. 5380, p. 209, 2004

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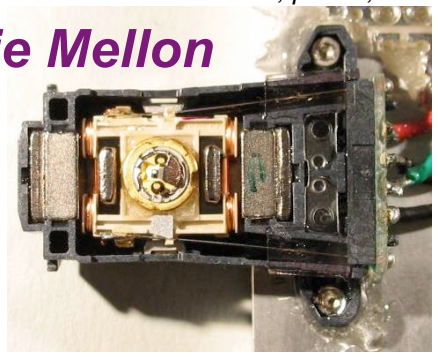


P. Herget et al., JJAP Vol. 45, p. 1193, 2006

Solid State Memory

Many Candidates

- *Flash, MRAM, PCRAM, FeRAM*
- *All must to meet requirements of reliability, fast access, endurance, low-cost archival, capacity (http://www.research.ibm.com/journal/rd/524/burr.html)*
- *Innovation on many fronts*
  - *Materials*
  - *Design*
  - *Architecture*

parameter	specification
Access time	50-1,000 ns
Data rate	100 MB/s
Endurance (cycles)	10^9-10^{12}
Hard error rate (bits/terabyte)	10^{-4}
Mean time between failures	2 million hours
Data retention	10 years
On power	100 mW
Standby power	1 mW
Cost	<< $5/GB
Annual compound growth rate	35%

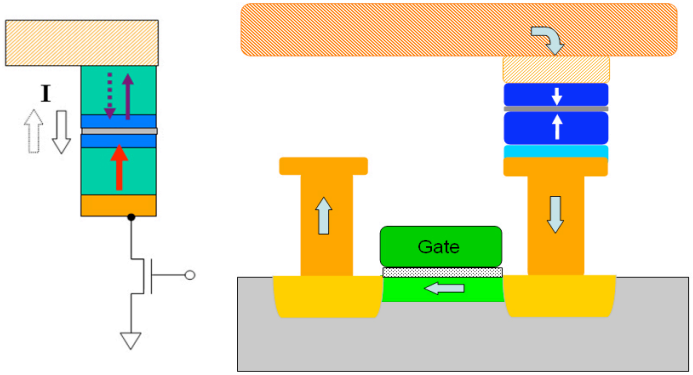
*to compete with HDD

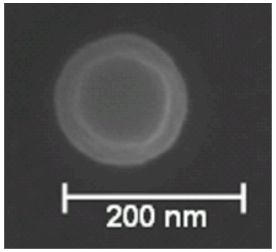
STT Perpendicular MRAM

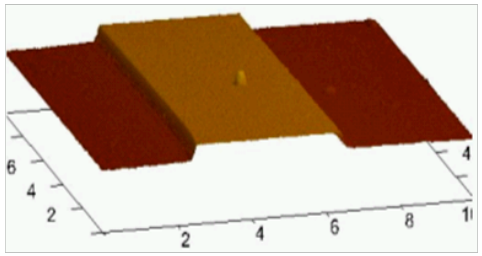
Enable Scalability to 10 Gbits/device

Jimmy Zhu, ABB Professor of Engineering

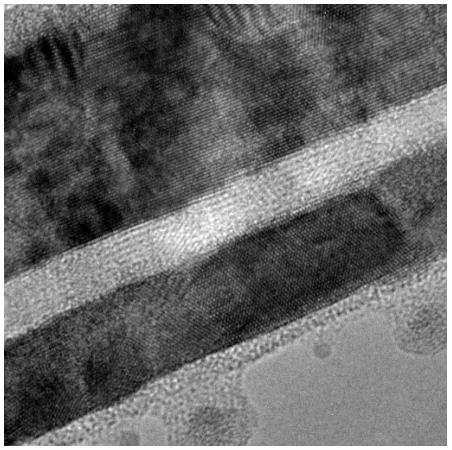
Spin Torque Transfer PMRAM



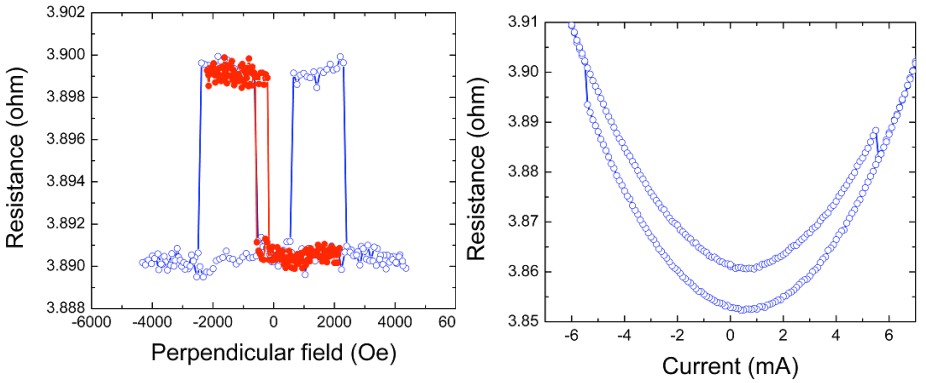




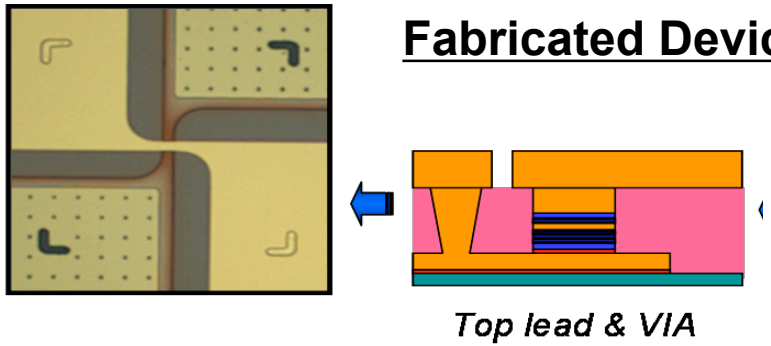
Fabricated Perpendicular MTJ



Field & current driven switching

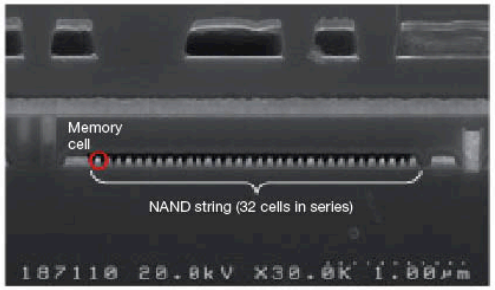


Fabricated Device



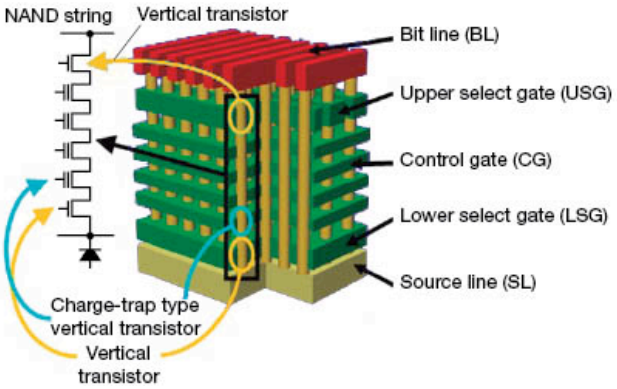
Top lead & VIA

Flash

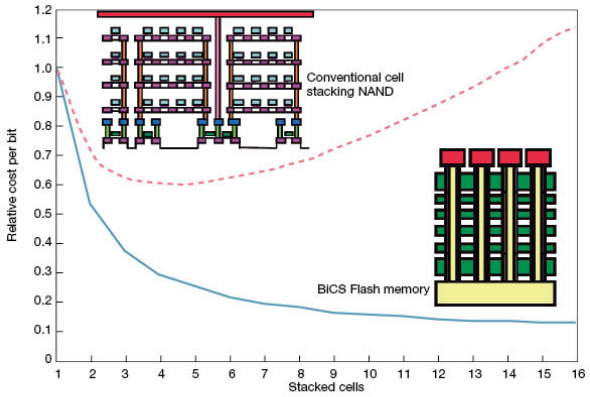


Capacity Continues to Grow

- *Cross-sectional photograph of 38 nm generation NAND Flash memory (Samsung Electronics).*

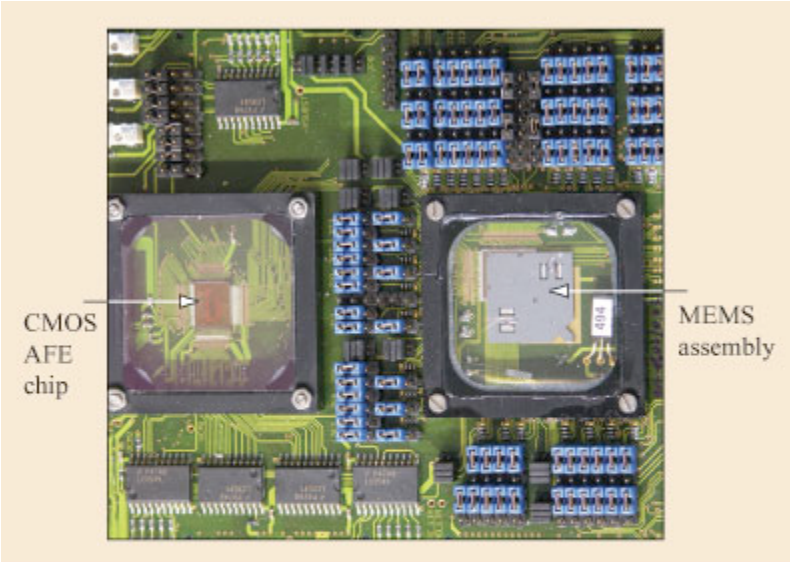


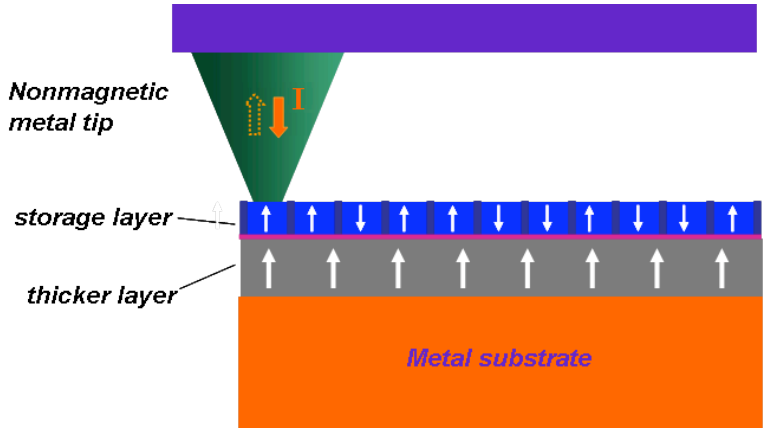
- *Structure of Bit-Cost Scalable (BiCS) Flash memory announced by Toshiba. (2007 Symposium on VLSI Technology/Circuits International Conference on Semiconductor Technology, Kyoto, Japan).*



- *Existing stacking technologies show a rise in cost with an increase in layers above ~5-6 while BiCS offers a steady cost reduction as the number of layers increases (Toshiba) (http://techon.nikkeibp.co.jp/article/HONSHI/20070831/138584/)*

Probe Storage





Probe Storage

- *1 Tb/in^2 possible with probe-based storage.*
- *Small-scale prototype demonstrating all basic functions demonstrated.*
- *840 Gb/in^2 (http://www.research.ibm.com/journal/rd/524/pantazi.html)*

Spintronics

- *Example; probe-based recording scheme utilizing spin transfer effect.*
- *Electrons travel from the polarization layer to the tip, the spin transfer torque will switch the magnetization of the storage layer underneath the tip to the magnetization direction of the polarization layer.*
- *If the current direction is reversed, an opposite magnetic bit is created.*

Summary

- *Storage is becoming more and more important*
- *Huge data sets are becoming the object with which one computes*
- *Systems that allow for search, model building, context understanding, and manipulation of large quantities of stored information will become increasingly important.*
- *Much of this will likely have to be accomplished locally*
- *New technology can enable this "disruption" in the use pattern by providing large capacity local storage as well as at storage centers*