Emerging Information Storage Technology

A Technologist Viewpoint

Gordon Hughes,

Associate Director, UCSD CMRR

Center for Magnetic Recording Research

gfhughes@ucsd.edu

858-534-5317

New Technologies are Old Stuff

- **50 years of rivalry for the $30B HDD market**
  - **Bubbles, holography, spin echo, hot electrons…**
- **Critical enablers: F, bit access & density**
- **F = semiconductor lithography capability**
  - **F = minimum chip feature size, now 95 => 65 nm**
  - **Magnetic HDD an exception, sidesteps F bit limit**
- **Technologies need density & bit access**
  - **Making a few small research bits is not useful**

Today's Competitor List

- **Magnetic Disk – 10^7X, over half a century**
  Moving target, doubles faster than Moore's Law
- **Flash - non volatile RAM**
- **MRAM – Magnetic non volatile RAM**
- **Millipede – IBM's MEMS probe arrays**
- **Rotating disk holography - InPhase**
- **Molecular storage - HP**
- **Many different MEMS memory cells**
  Ferromagnetic, ferroelectric
  quantum dots, mechanical switches

Old (but New) Storage Technology

- **PC Serial ATA drives in Enterprise Storage**
- **A new near-line disk hierarchy level: D2D2T**
  - **"Disk-to-Disk-to-Tape" using near-line RAID disk**
  - **No more overnight tape backup in 24x7 businesses**
  - **Offload tape backup as a background task**
- **Use big, cheap, slow Serial ATA drives**
  - **400 GB, 7.2krpm, mostly serial HDD storage, MAID**
- **Enterprise-class reliability is possible**
  - **But there are a few traps to avoid…**
  - **G. F. Hughes, "Reliability and Security of RAID Storage Systems and D2D Archives using SATA Disk Drives" ACM Trans. on Storage, Dec 2004**

Future Storage Technology "News Flashes":

- **Flash is taking the < 1" HDD market!**
  - **GByte flash chips today ⇒ 4 GB products**
  - **0.85-inch HDDs have similar few-GB capacity**
  - **But: is flash near its lithographic scaling limit?**
- **MRAM is not very dense chip storage!**
  - **Only 4-8 Mbit chips << 1,000 MByte flash chips**
- **IBM Millipede demo at CeBit only 40 kbits!**
- **InPhase persistent at holographic WORM!**

Storage Challenge is *Dense Bits & Access*

- **Successful storage technology needs computer bit *access* technology too**
- **Need to get as *near* to bits as they are *small***
- **True of HDD, DRAM, Flash, MRAM**

  HDD heads close to disk bits; chip access lines close
- **Holography struggles to be the exception**

  But the leader is using rotating disk access

F: Flash vs. HDD vs. MRAM vs. Probe

- **Bit density is set by semiconductor lithography**
  - **By the lithographic minimum feature size (line width)**
  - **F = 95 nm, going to F = 65 nm now**
- **Flash bit cell = $2F^2$**
  - **Flash chips may appear in HDDs, for Microsoft's "instant on" O/S**
- **Flash capacity now 1 GByte chips for $70 (Toshiba)**
  - **6/60 MB/s Read/Write, F=70 nm**
- **MRAM bit cell = $20F^2$**
  - **Toshiba, NEC magnetic tunnel junction moving to 6-$8F^2$**
  - **Issues are power, yield, cost, device margins over wafer**
- **HDD bit cell = $0.15F^2$ = (1.2FxF/8) = 13X denser than flash**
  - **Only the *track* density is limited by minimum litho F (head width)**
  - **The linear bit density is set by magnetic recording design**
    - **Bit length set by film thicknesses (≈1nm), fly height (15 nm), magnetics**
    - **All are much smaller than F**

Companies Active in MRAM

- **Cypress Semiconductor, San Jose**

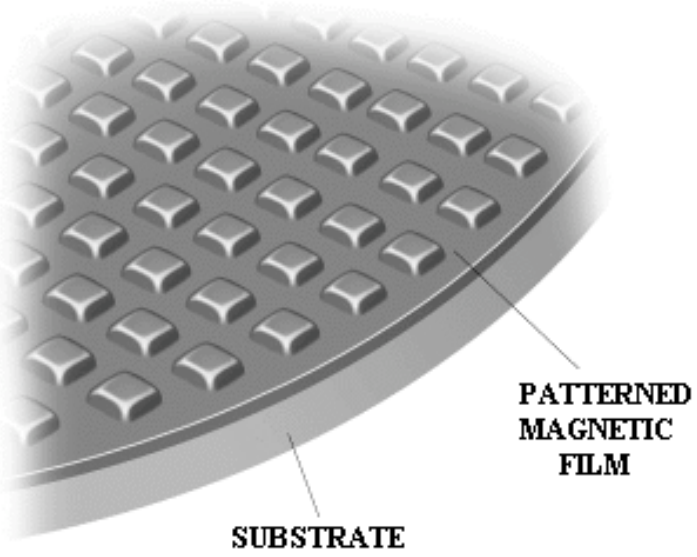
  Expects $2 million MRAM sales this year.
- **Current chips 4-8 Mbits << 8 Gbit flash**
- **Commercial MRAM: IBM, Infineon, Freescale, NEC, Toshiba, Samsung, Sony, Taiwan Semi, Hewlett-Packard, Philips**
- **Military MRAM: Honeywell, Motorola**
- **Patents: Motorola, Non Volatile Electronics**

HP's Molecular Storage

- **Molecular electronics Architecture**
- **Programmable crossbar circuit arrays,**
  Two-terminal bit latch devices
- **Goal is < 10 nanometer size bits**
- **Access problem not addressed:**
  HP experimental line widths are 5–20 μm,
  active bit latch junction areas 5–200 μm^2
  This is not high density storage

HDD Patterned Magnetic Media

- **Today's HDD recording**
  May limit at ≈150 Gbits/in^2
- **Patterned media**
  May go to 1 Tbit/in^2
  (24 nm patterning means F=12nm)
- **Flash is patterned bit example**
- **First products: patterned tracks**
  Side step bit litho limits
  Preserve 13X flash density



(Scientific American, May 2000)

The IBM 'Millipede'

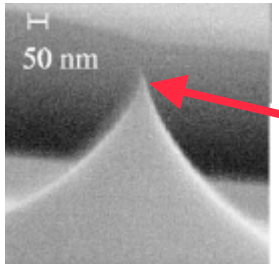
- **Thermomechanical write/read process**
- **Must have HDD capacity, above flash**
- **Research demos, Mostly single probe**
- **641 Gbit/in^2, 20 nm bits, 40 nm bit pitch**

  400 *user* Gb/in^2 from (1,7, 2/3) modulation code
- **Data Access problem:**

  Need 20 nm pitch multi probe *arrays*

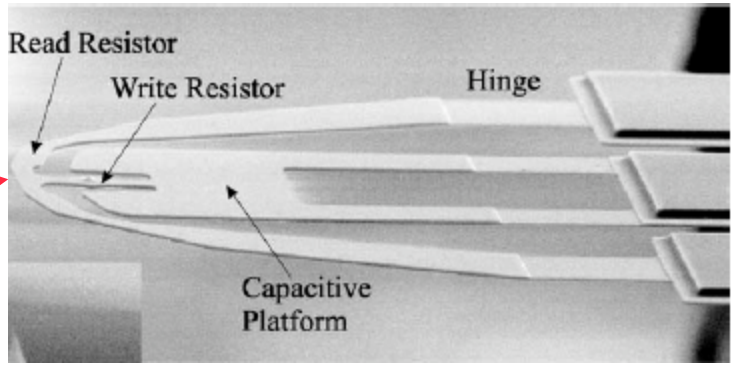
  But millipede single probe heater is 5 x 2 μm

Array Heads need Nanosize Structures



20 nm
bit probe

Micron
probe
heater



H. Pozidis et al, Demonstration of Thermomechanical Recording at 641 Gbit/in2,
IEEE Trans Mag, 40, 4, July 2004

- **Same problem with hard drive *array* heads**
  100 nm pole tips with 5 um head structures,
- **Makes high density array heads impractical**
- **HDDs use one high speed channel per surface**

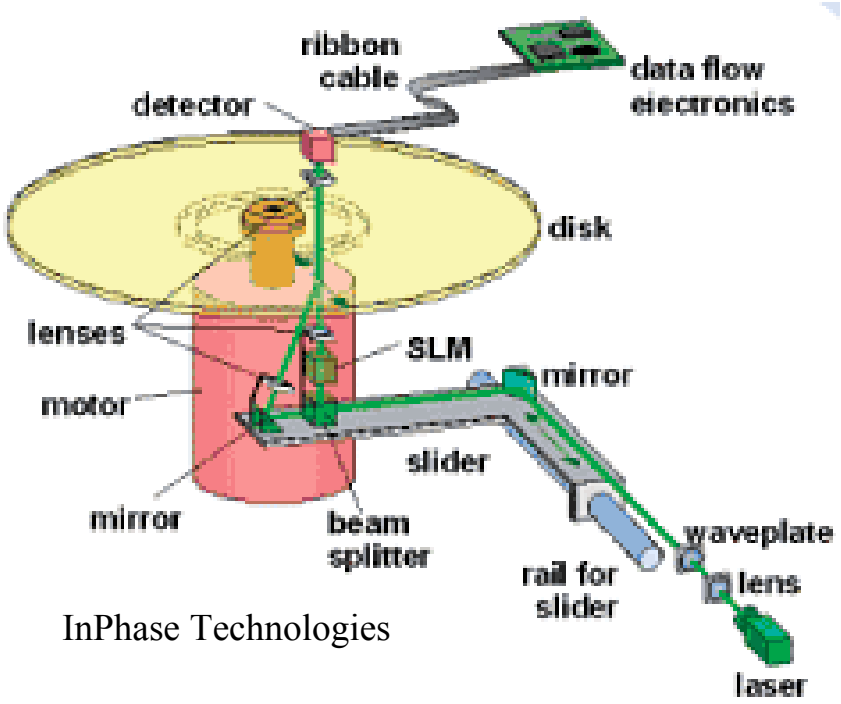
IBM exhibits Millipede prototype at CeBit

- 6.4x6.4 mm demo chips for SD Flash card
- Intended to compete with Flash
- 4096 silicon tips create 10 nm pits

  Potentially 1,200 Gbit device?
- Millipede "tracks" only 100 nm long

  ∴ Demo capacity only tens of kbits

Holographic Storage



InPhase Technologies

Holographic Data Storage

The wave of the future

…always has been

…always will be

-Anonymous HDD skeptic

InPhase Technologies Holographic Drive

- Bell Labs Research work, spun off in Longmont CO
- Several decades of work – may succeed
- A rotating WORM disk, like optical CD/DVD
- Suited for fast serial access, like CD/DVD-R
- Prototype 200 GB per 130 mm disk, 20 MB/sec
- 12 MB of data each 407 nm blue laser disk spot

  High fly head (mm), like optical disks
- InPhase currently selling media & test equipment
- Partners: **Hitachi-Maxcell, Imation, ALPS**

More Holographic Companies

- **Collosal Storage Corp**
  - **Atomic Holographic's Nanostorage Drive**
  - **Entangled Particle Holographic NanoStorage**
- **Opticom ASA**
  - **Bacteriorhodopsin organic protein molecules**
  - **PC-card format polymer memory**
- **Other holographic WORM disk efforts:**
  - **Aprilis, Holoplex, HGST, Optilink, Holostor, Matteris**

Conclusions

- **Use HDDs for 100's of GB**

  Fastest writing, 100X lower cost, no bit wear
- **Flash for <4 GB, moving up fast**

  No moving parts, compact, plug & play
- **Patterned media has serious F problem**
- **Is there a 4-8 Mbit for MRAM?**
- **Millipede & Molecular not close**

  Both in early research stage