Data Storage - Hard Disk Drives vs. Semiconductors

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Hard disk drives (HDDs) lie at the base of the memory pyramid or hierarchy used in computer systems and computing devices due to the attributes of extremely high capacity (terabit), high data rate (GHz), nonvolatility, and reasonable access time (ms). In particular, the bit areal density growth of HDDs has often exceeded Moore's Law over the last 50 years resulting in a 100 million fold increase. Today the sizes of recorded magnetic bits in HDD's are significantly smaller than the stored bits of solid state memories. A survey of the various technologies used in HDDs reveals a nanotechnology "playground" for scientists and engineers that exists today. For example: 6 nm diameter magnetic grains covered by 3 nm of diamond-like carbon and 1 nm of specially crafted lubricant, sub-100 nm wide magnetic sensors and writers in the head, critical magnetic sensor layers down to less than 1 nm thick, airfoils than maintain a sub-10 nm gap between the head and disk while flying at 100 mph under a variety of environmental conditions, and mechanical actuators than can move the head to a desired position on the disk with nanometer precision in only a few milliseconds.

Today NAND flash and small Hard Disk Drives (HDDs) compete directly for use in portable devices such as music players, digital cameras and video players, and soon even in converged devices such as high-end cell phones. How will this battle play out in the future? Will ultra-small HDDs such as HitachiGST's "Mikey" drive maintain their capacity advantage over flash storage in the future? Can a future solid state technology ever compete with larger mainstream HDDs by making efficient use of the third dimension? In this talk I review the HDD technologies necessary to achieve greater than a Terabit of memory capacity in a sub-CF form factor. These technologies include perpendicular recording, tilted recording, thermally-assisted recording, and patterned media. Comparisons between the flash roadmaps and HDD roadmaps will be made.

Keywords:

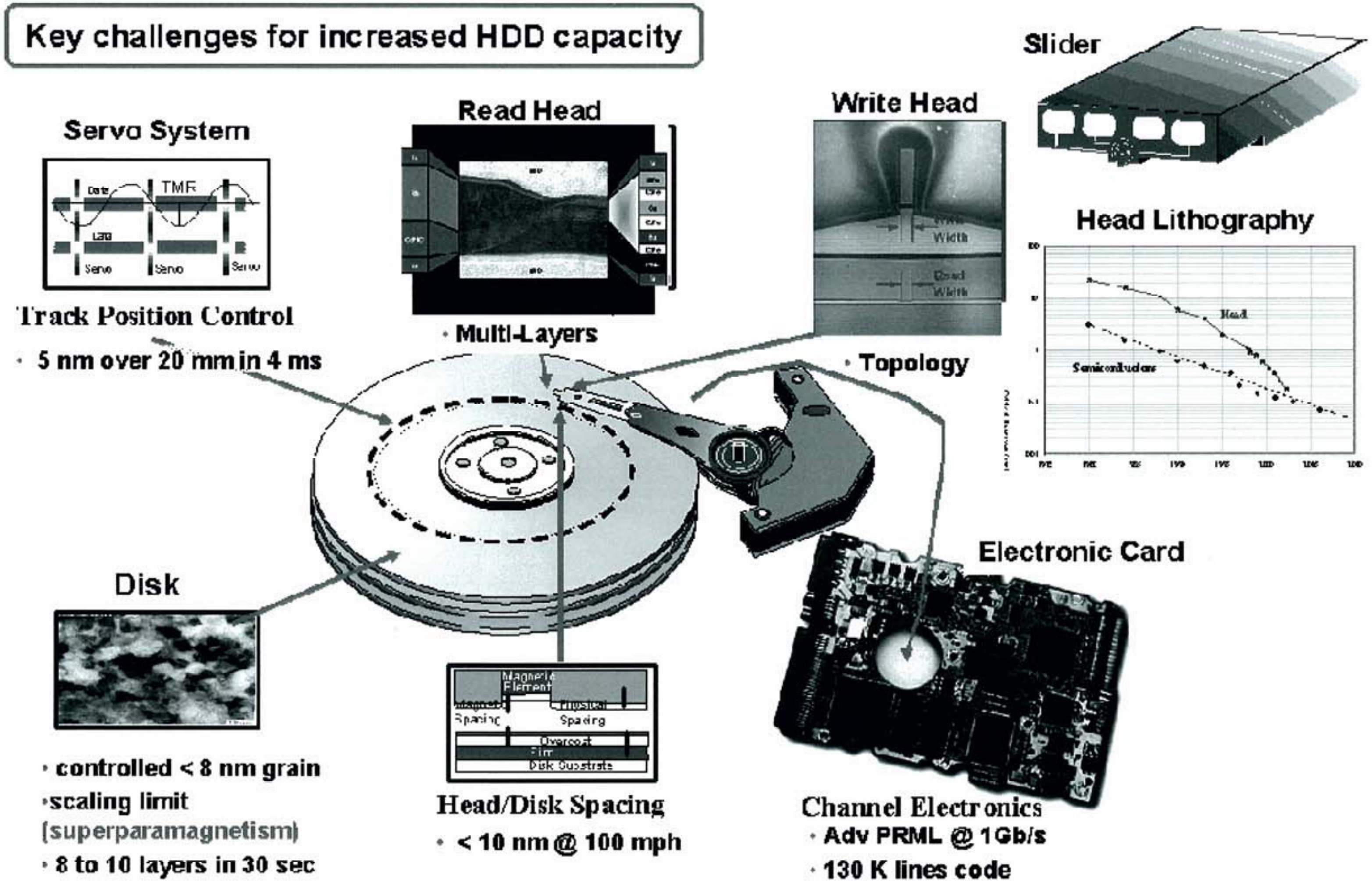
Superparamagnetic Effect: the tendency of very small magnetic particles to flip their orientation due to thermal activation. Limits the smallest magnetic grain size on the disk for a given magnetic anisotropy (or write field supplied by the head). Limits areal density since today each bit of information is represented by about 50 to 100 grains.

Longitudinal, Perpendicular and Tilted Recording: refers to the magnetic orientation of the disk recording layer's grains relative to the disk surface. Perpendicular recording is beginning to replace longitudinal recording due to the ability of the write head to apply higher fields on thicker, higher anisotropy media and therefore pack in more grains per unit area without superparamagnetism.

Thermally Assisted Recording: potential future recording technology which allows for the use of very high magnetic anisotropy recording material and very small grain size. Lowers the needed head field by locally heating the disk with a near-field optical source.

Patterned Media: uses lithography (such as imprint) to define coherent magnetic islands on the disk. Reduces the number of magnetic particles per bit from about 100 to only one.

Figure on next page: a graphic survey of some of the key ongoing challenges for increasing areal density in hard disk drives.


Key challenges for increased HDD capacity
Servo System
TMR
Servo
Servo
Servo
Track Position Control
• 5 nm over 20 mm in 4 ms
Read Head
• Multi-Layers
Write Head
Width
Width
• Topology
Slider
Head Lithography
Head
Semiconductors
Disk
• controlled < 8 nm grain
•scaling limit
(superparamagnetism)
• 8 to 10 layers in 30 sec
Magnetic Element
Spacing
Physical Spacing
Overcoat
Film
Disk Substrate
Head/Disk Spacing
• < 10 nm @ 100 mph
Electronic Card
Channel Electronics
• Adv PRML @ 1Gb/s
• 130 K lines code