The Transition to Perpendicular Magnetic Recording

Hitachi Global Storage Technologies

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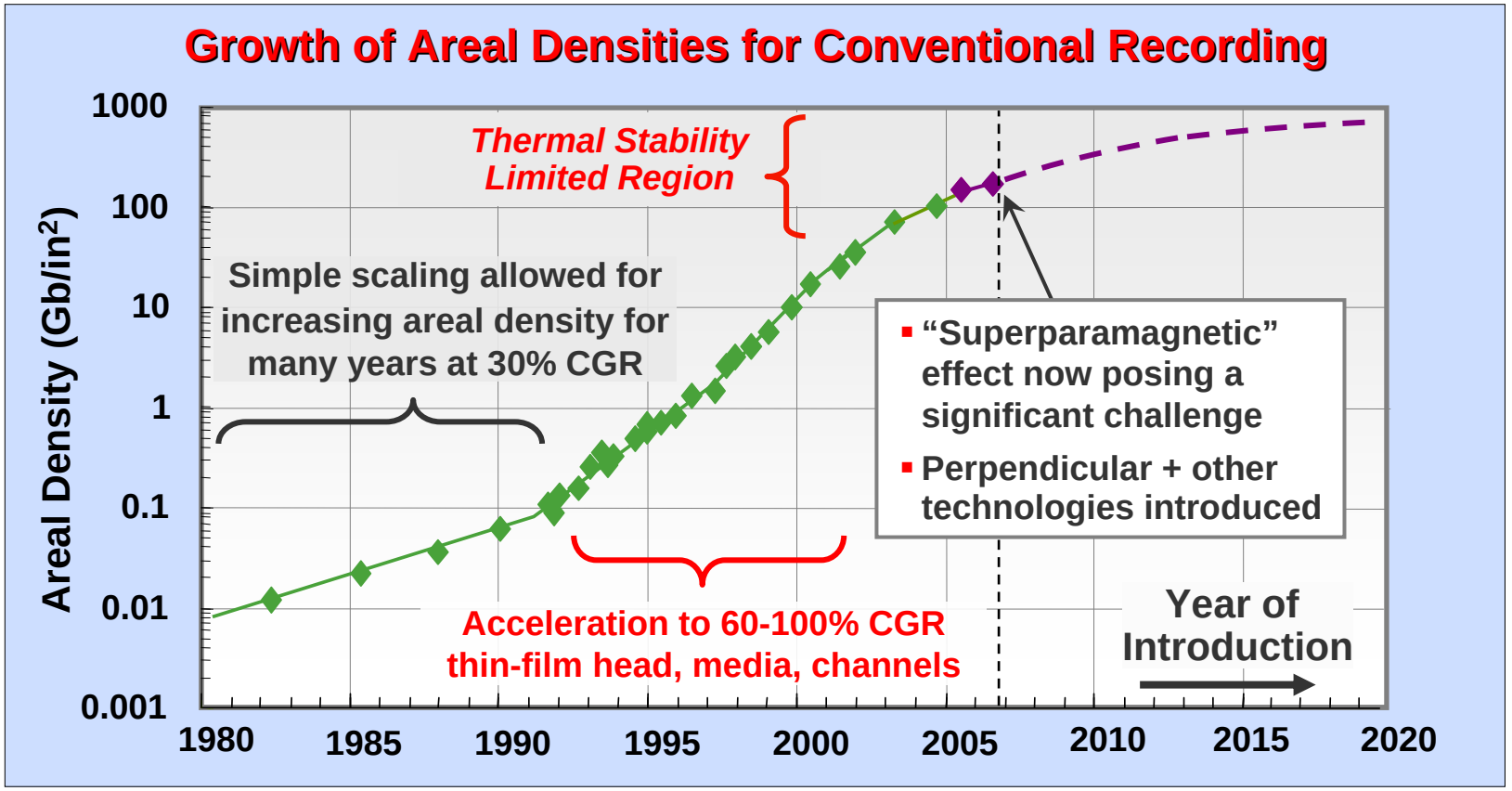
Why Perpendicular Magnetic Recording (PMR)?

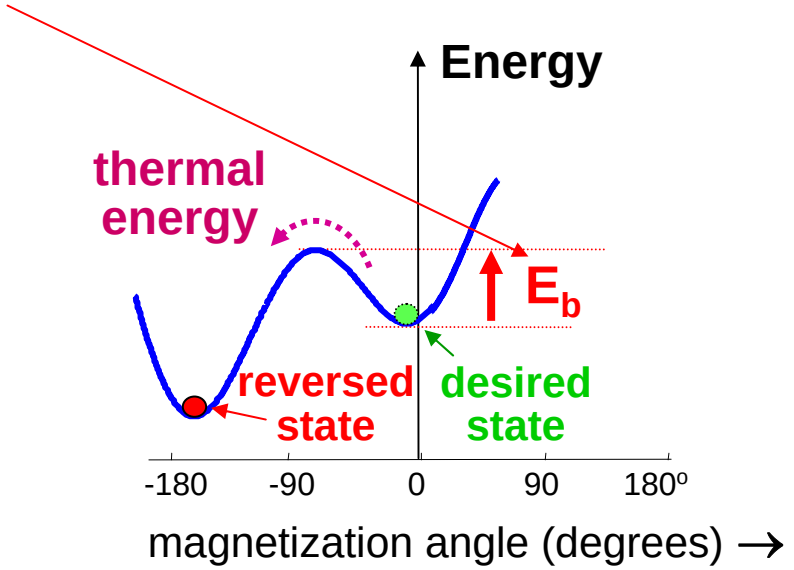
- In early years simple scaling allowed for increase in areal density at 30% CGR
- Past decade MR, GMR head & thin film media, growth accelerated to 60-100% CGR
- Now “Superparamagnetic” effect poses a significant challenge requiring new technologies
- PMR is the first step to allow areal density ~1Tbit/in2 in spite of “superparamagnetic” effect



Thermal Stability *(Superparamagnetic Effect)*

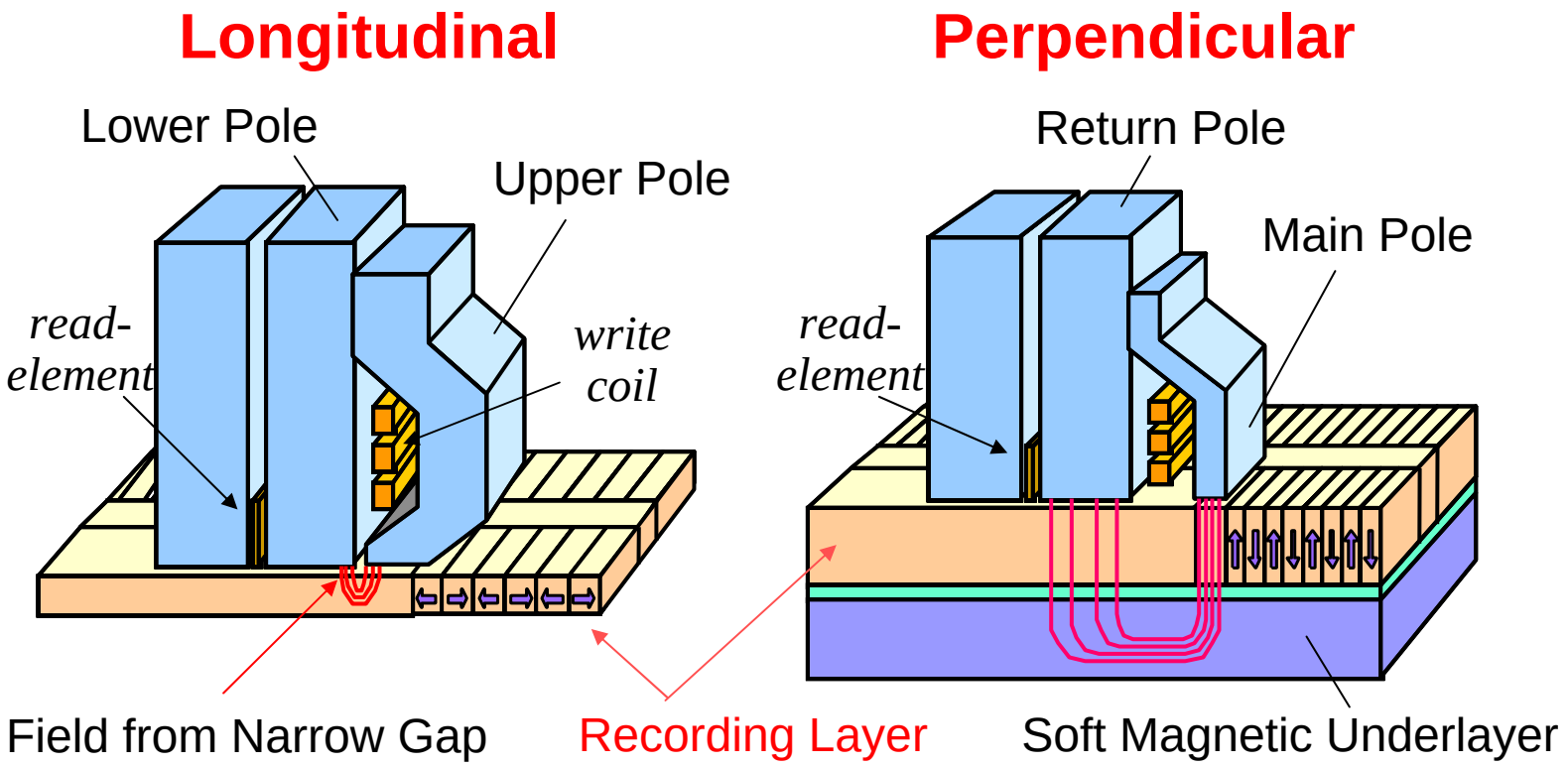
- Recording medium is made up of many very-small magnetic grains
- Bits are written onto these grains. About 100 grains for each bit
- For high areal-densities, the bits and the grains themselves have to be very small → it takes only very small energy to flip them!
- If grains are too small they spontaneously reverse magnetization just from thermal energy at room temperature!

Energy Barrier = Magnetization x Switching-field x Grain Volume



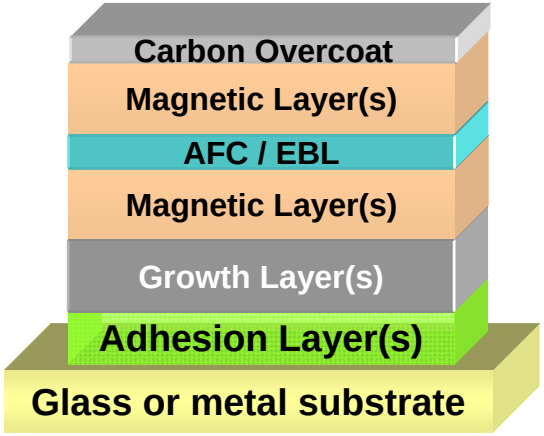
Longitudinal (LMR) vs Perpendicular Magnetic Recording (PMR)

- In PMR recording part of the head structure must be built into the disk!
  - Magnetically soft disk under layer placed immediately under hard recording layer completes the magnetic path
  - Only the strong field concentrated under main pole writes onto medium
    (the diffuse 'return field' under return pole is too weak to affect medium)
- Perpendicular recording uses higher coercivity material. This is possible as the head's write field penetrates the medium more efficiently in the perpendicular geometry

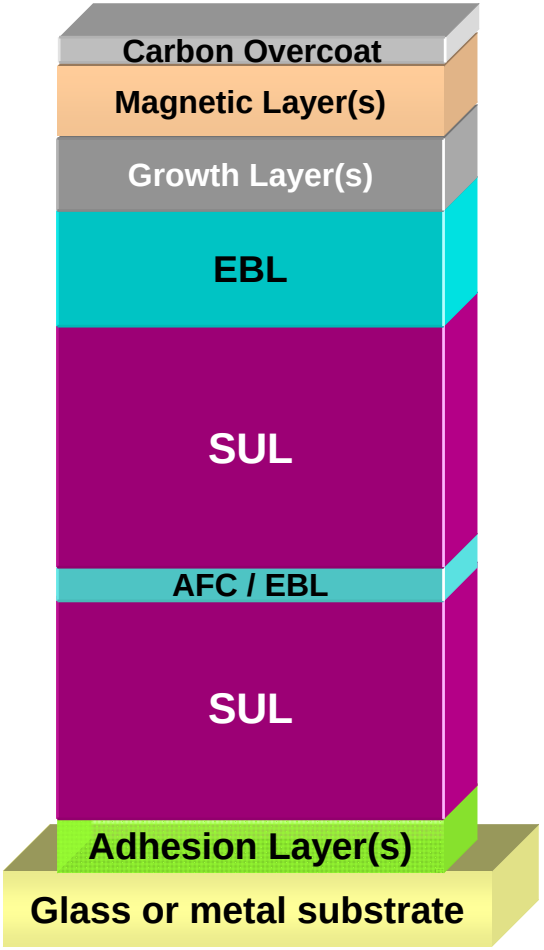


LMR vs. PMR Media

- In PMR design, media structure has become more complex
- More and thicker layers for PMR suggest more complicated tooling
- Corrosion can be a concern
- No texture is required
- Glass and AlMg more similar



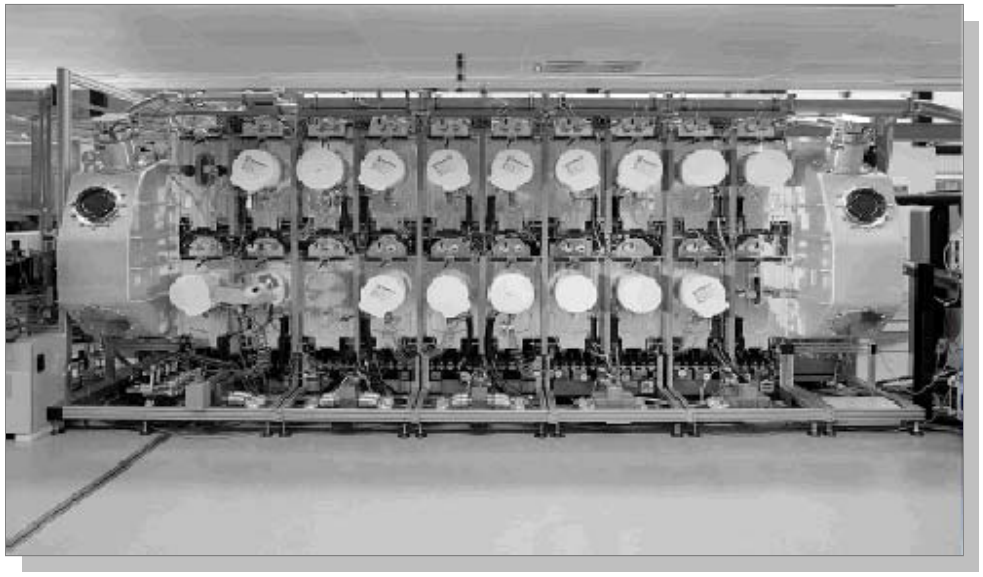
LMR



PMR

PMR Sputter Toolset Utilization

The Intevac 200 Lean Tool



The Oerlikon Race track

Mike Russak

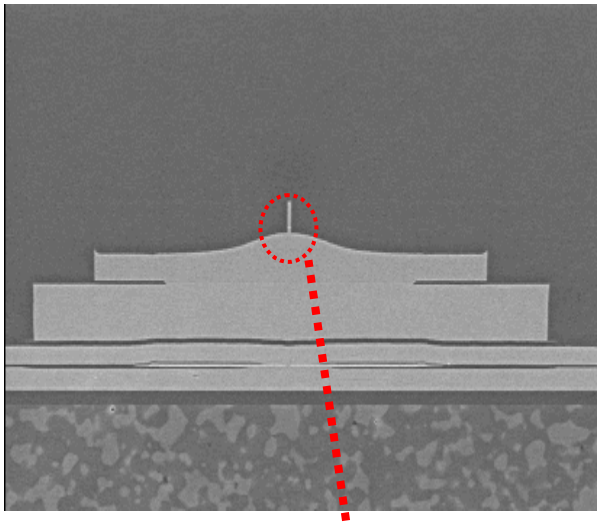
PMR Media Status

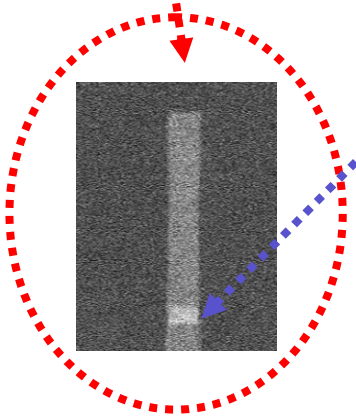
- Technology hurdles in PMR recording systems are no longer show stoppers.
- The HDD industry is in the LMR to PMR transition.
- PMR based HDDs are in the marketplace
- First generation PMR media designs are completed.
  - About 150 Gb/square inch
- Focus is moving to manufacturability and sputter toolset utilization.
  - Major non-technical issue is cost management of PMR media production
    - Yield congruence with LMR
    - Tool throughput for PMR
    - Tool utilization for PMR
- Head-media interface reliability is the major area of technical focus.

KOMAG

Head

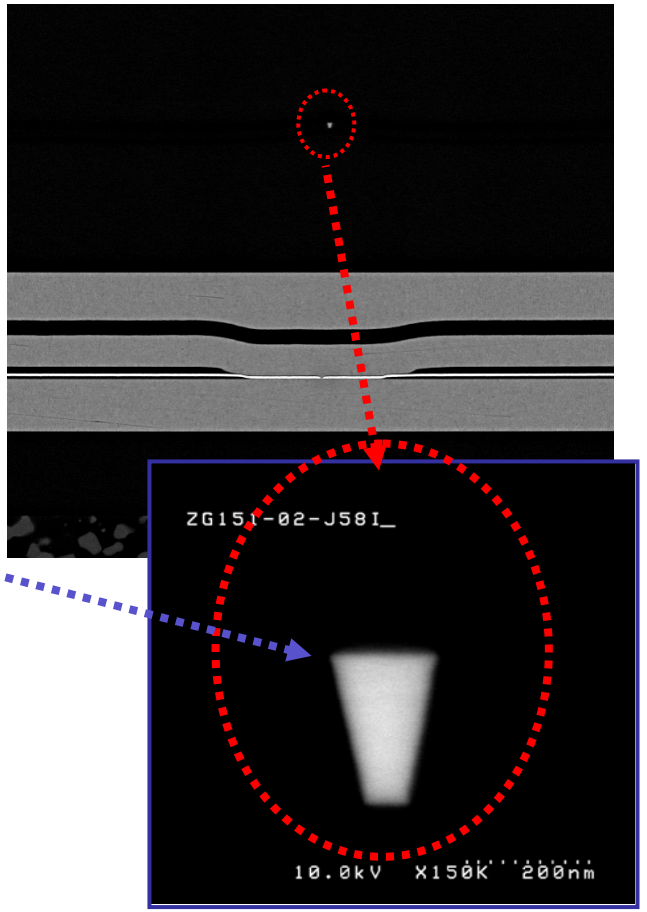
- Head design has become more complex going to PMR
- PMR has introduced more steps and tighter tolerances





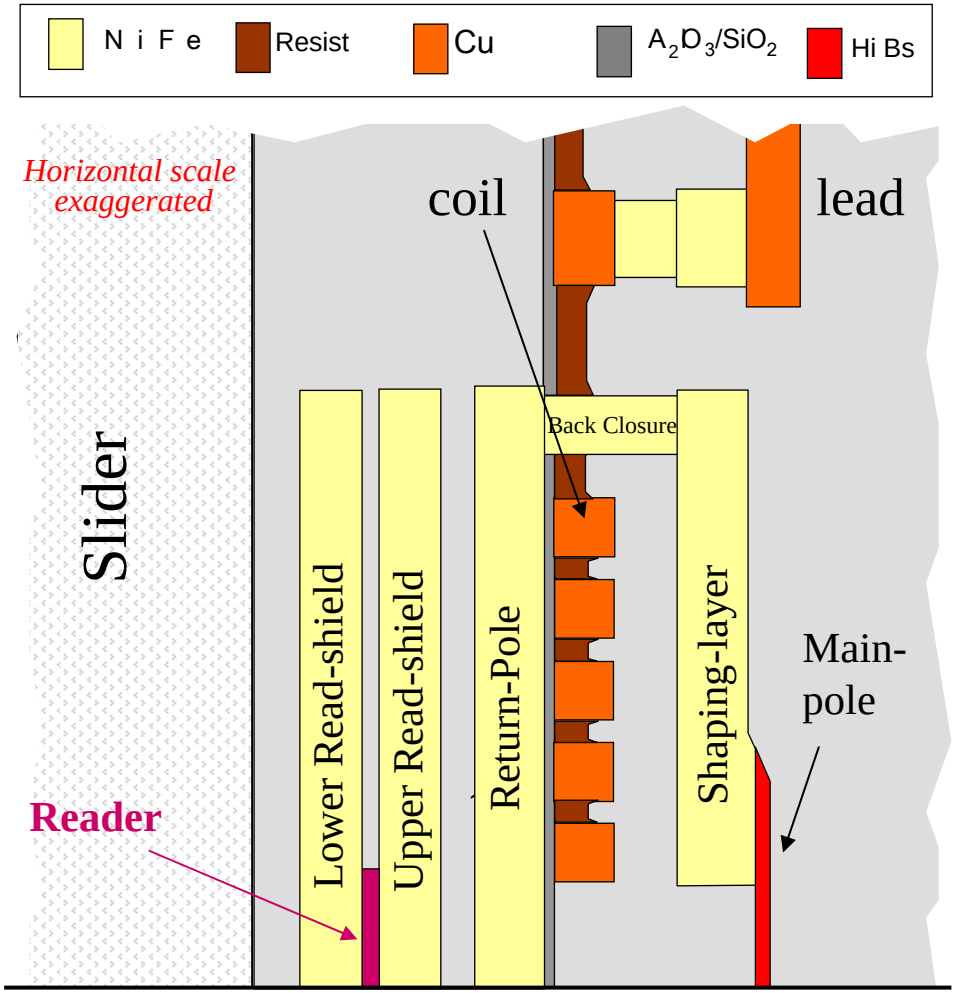
Conventional Structure

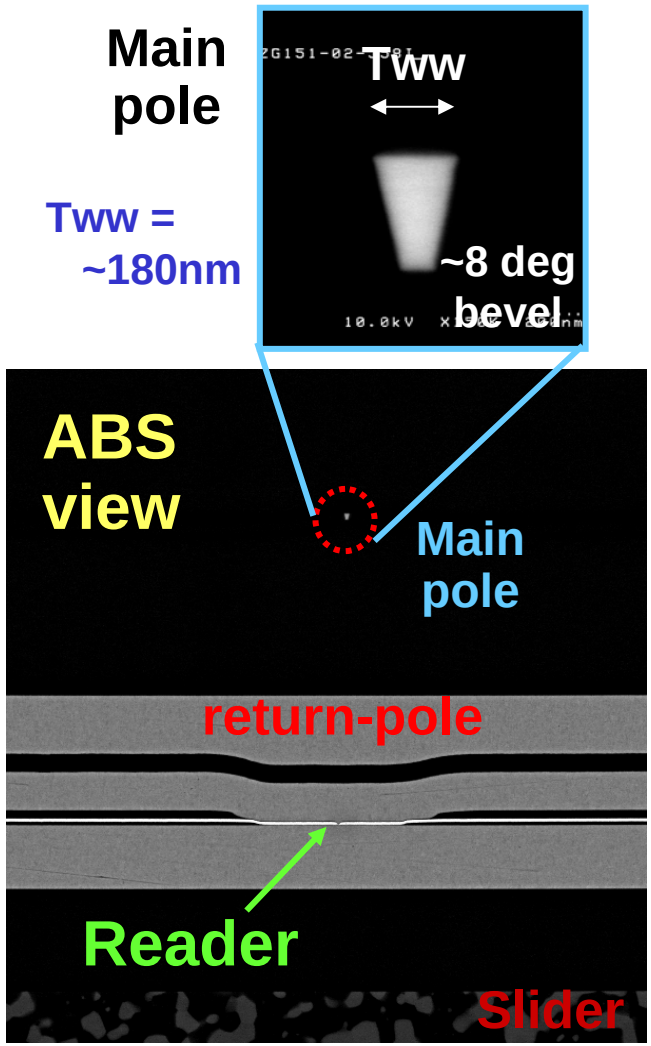
writing occurs at trailing-edge



Conventional Trapezoidal Structure
(Field gradient:80-100 Oe/nm)

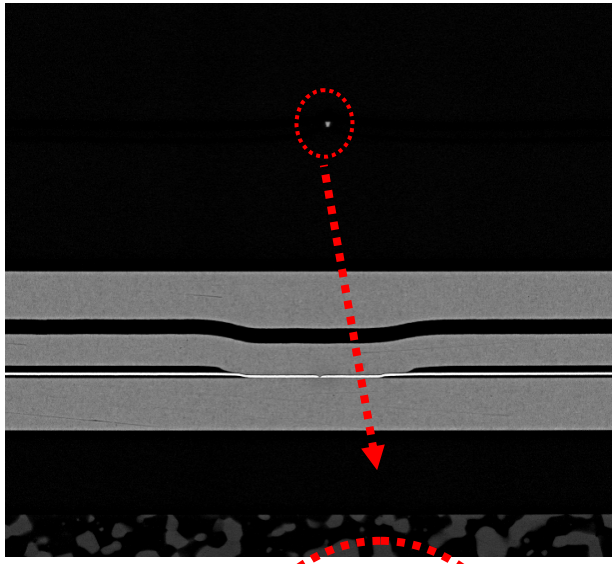
Head Structure

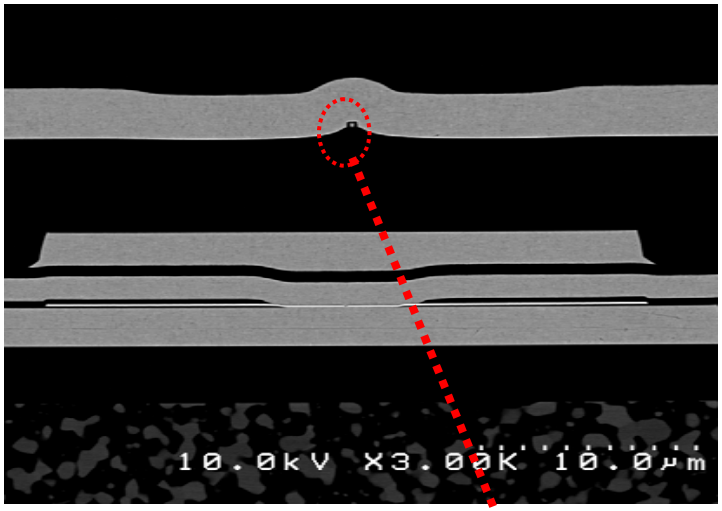




"1st Generation Technology"

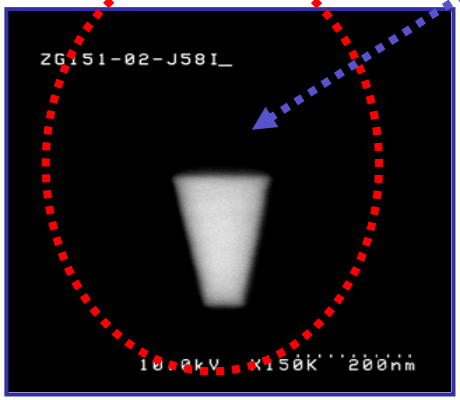
Evolution of Perpendicular Recording Heads



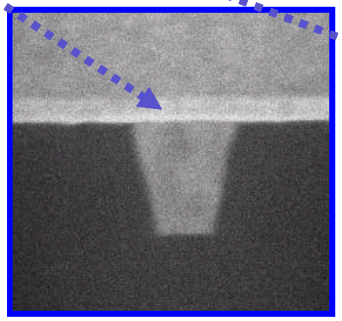


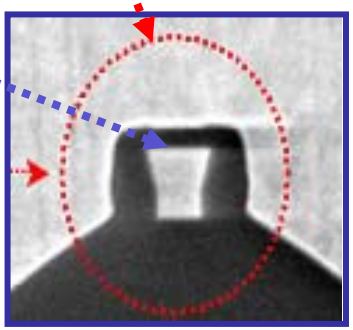
writing occurs at trailing-edge

Main pole



Conventional Trapezoidal Structure





New Trailing & Side-Shield Structure

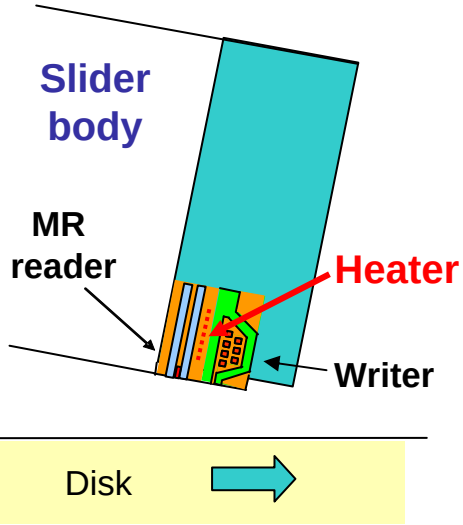
(Higher Field gradient)

→ sharper transitions!

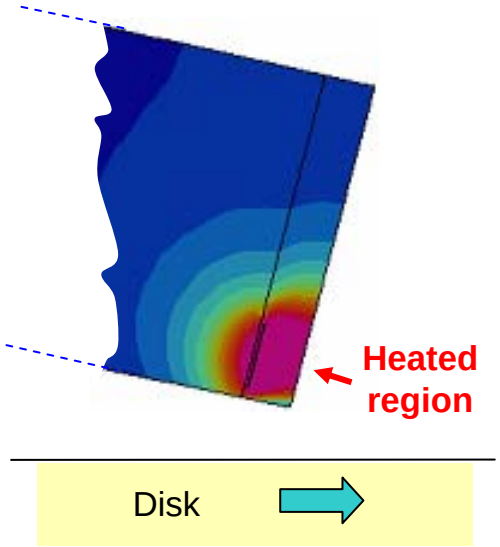
Thermal Fly-height Control (TFC)

- Magnetic Spacing remains one of strongest levers for areal density
  - Control flying height with small thermal actuator (heater) built into head
  - Can absorb fly-height tolerances, brings head to lowest safe flying height
  - Readily compensates head protrusion due to writing, temp. change, etc.
  - Better reliability since low duty cycle (only active during read or write)

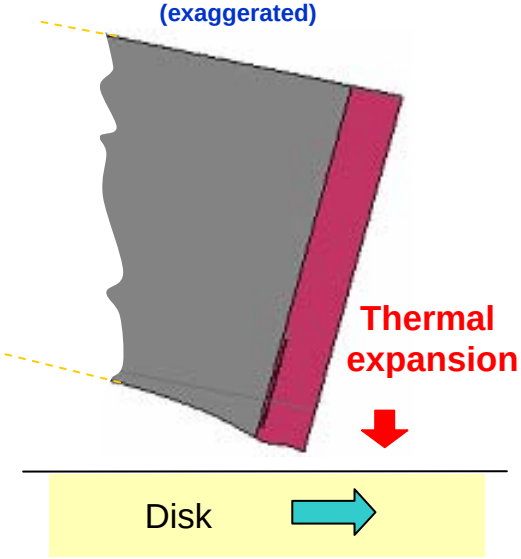
Heating element integrated with R/W head
(not to scale)



Temperature rise around R/W elements

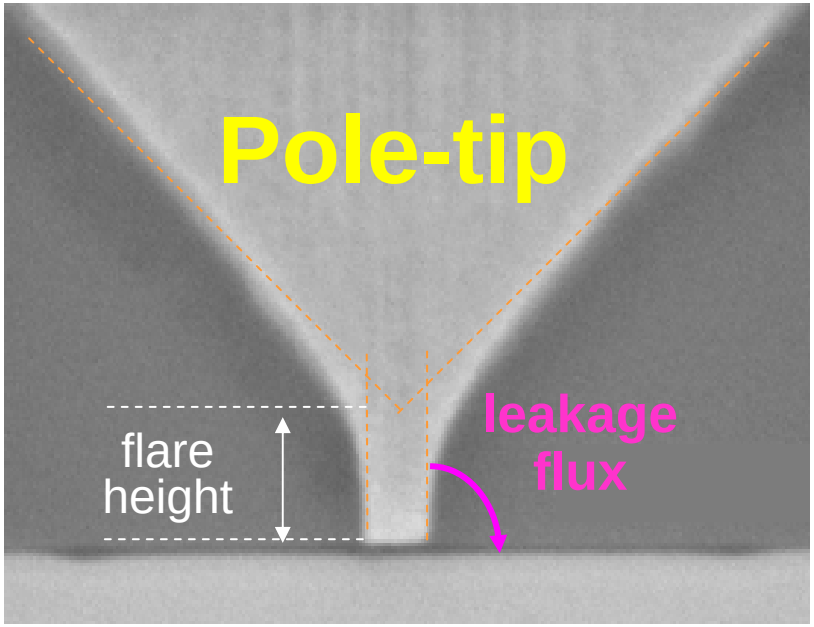


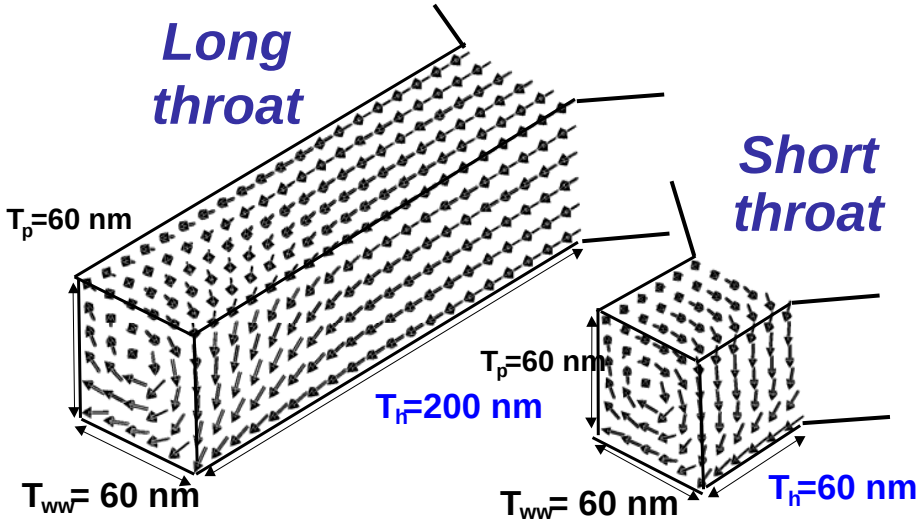
Slider deformation & flying height change
(exaggerated)



Pole-tip Erasure (Head Remanence)

- Flare-height control is critical in balancing Adjacent Track Erasure (ATE), write-capability, & pole-tip remanence!





H_{max} = 2975 Oe

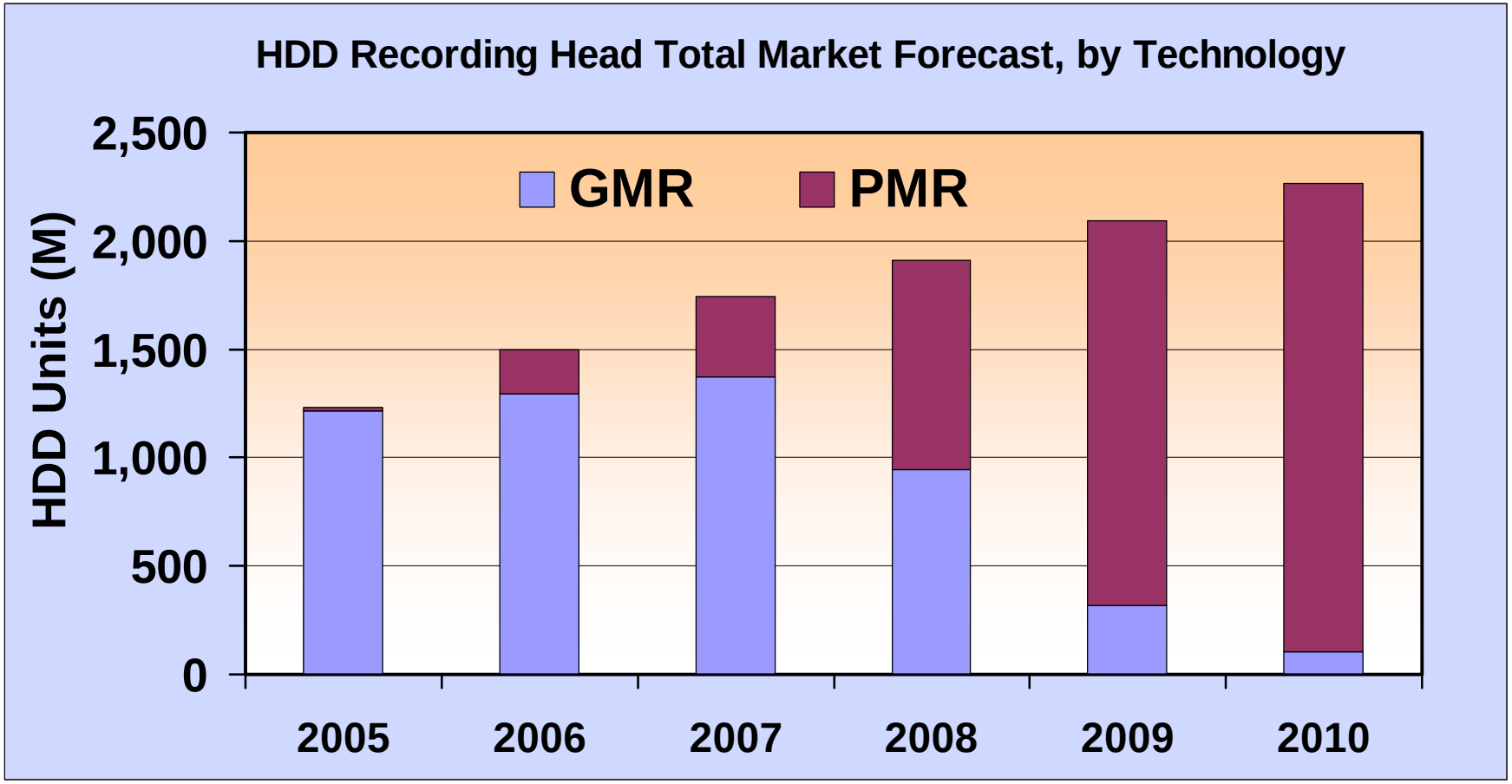
H_{max} = 1703 Oe

Maximum Remanent Field

Takano, Wood, PMRC 2004

HDD Head market forecast

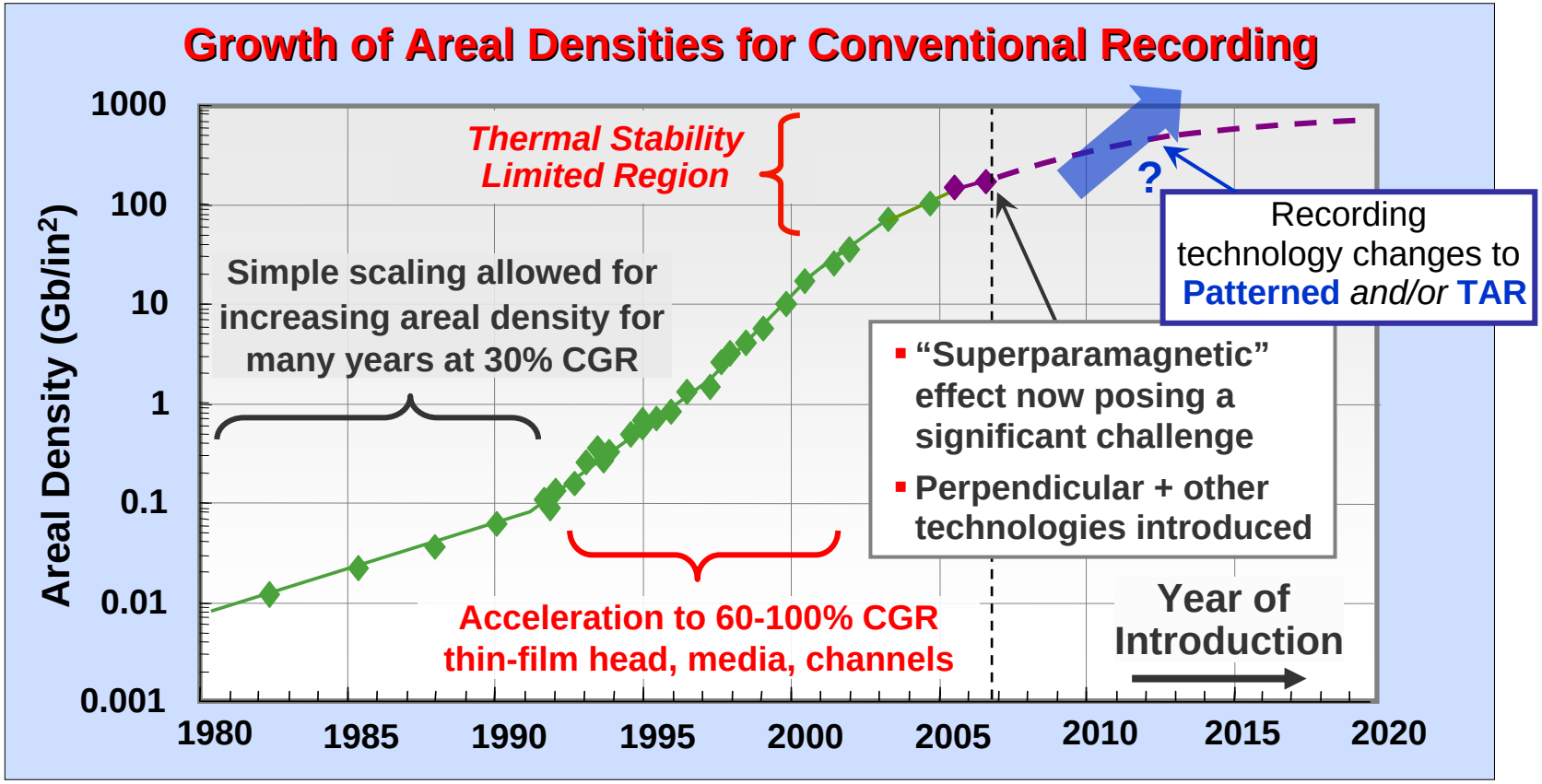
- Major HDD manufacturers are already shipping products in PMR today
- By 2009-2010, it is forecasted that most of HDD drives will be PMR



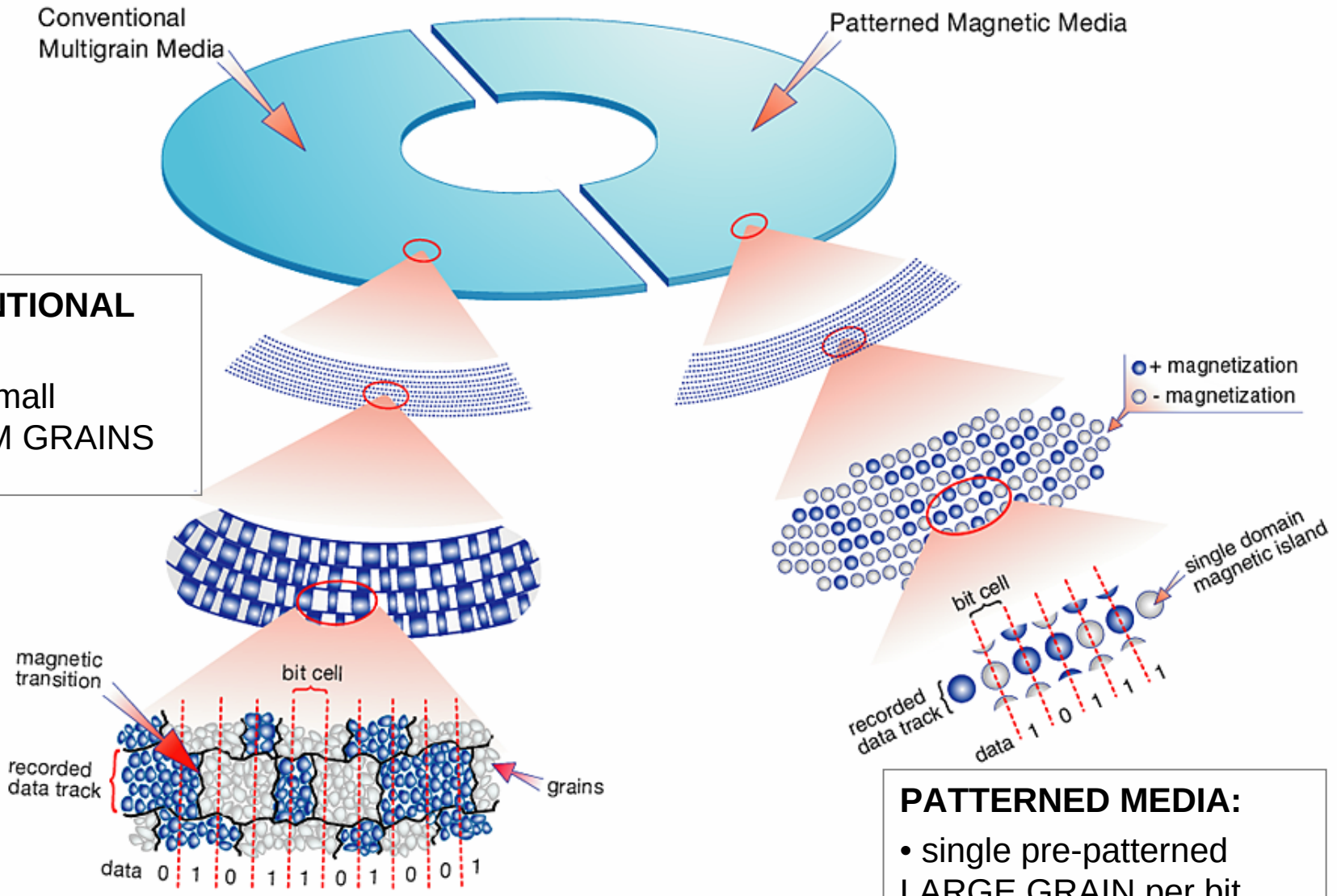
Source of data : Trend Focus

Beyond PMR- New Technologies

- Considerable opportunity for further advances in technology:
  - Enhanced media, reduced head geometries, side-shields, reduced magnetic spacing, reduced bit aspect ratio, etc.



Conventional vs. Patterned Media



CONVENTIONAL MEDIA:

- many small RANDOM GRAINS per bit

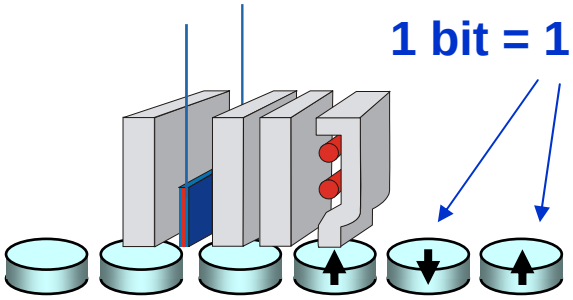
PATTERNED MEDIA:

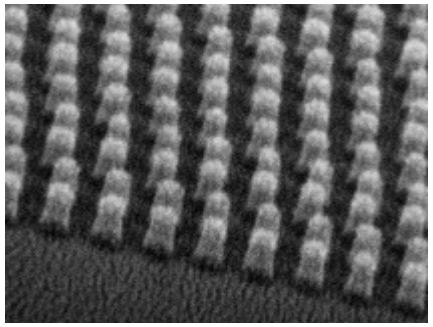
- single pre-patterned LARGE GRAIN per bit

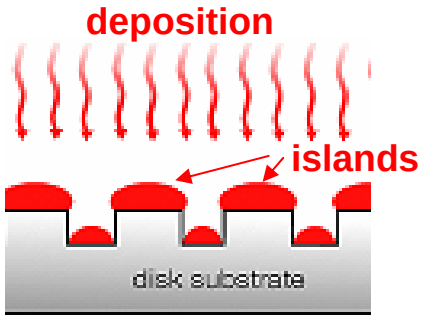
Patterned Media

- In patterned media the feature resolution can be ~20 nm
- Most viable approach is nano-imprint lithography
- Major changes are required in drive architecture
  - Bit aspect ratio ~1:1 (1:3 or 1:4 better for head design and servo design)
  - Bit locations determined by pattern on disk: write synchronization
  - HDI on non-homogenous surface

Patterned Media (1 large grain per bit)





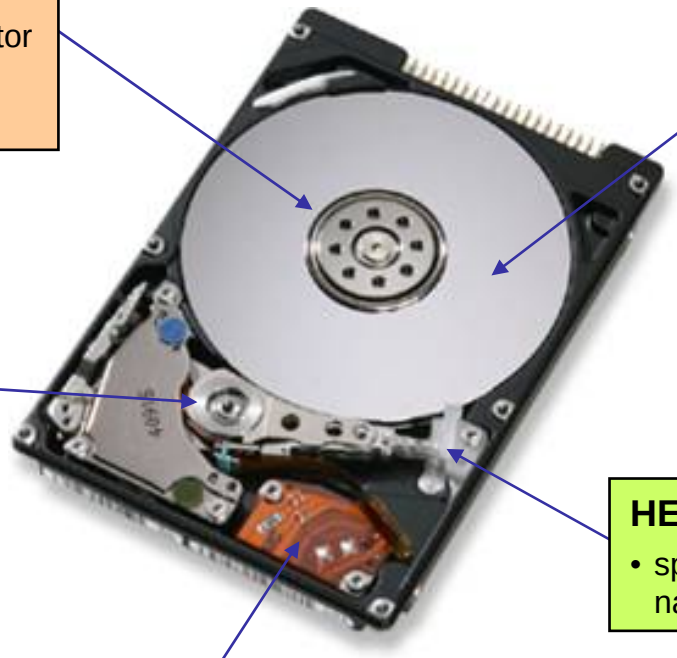


Patterned Media Drive of the Future

- More than just a new type of media…

SPINDLE MOTOR
- ultrasmooth, low cogging motor and driver
- minimize write phase error

MEDIA
- nanoimprinted and etched substrate
- discrete magnetic islands
- planarized



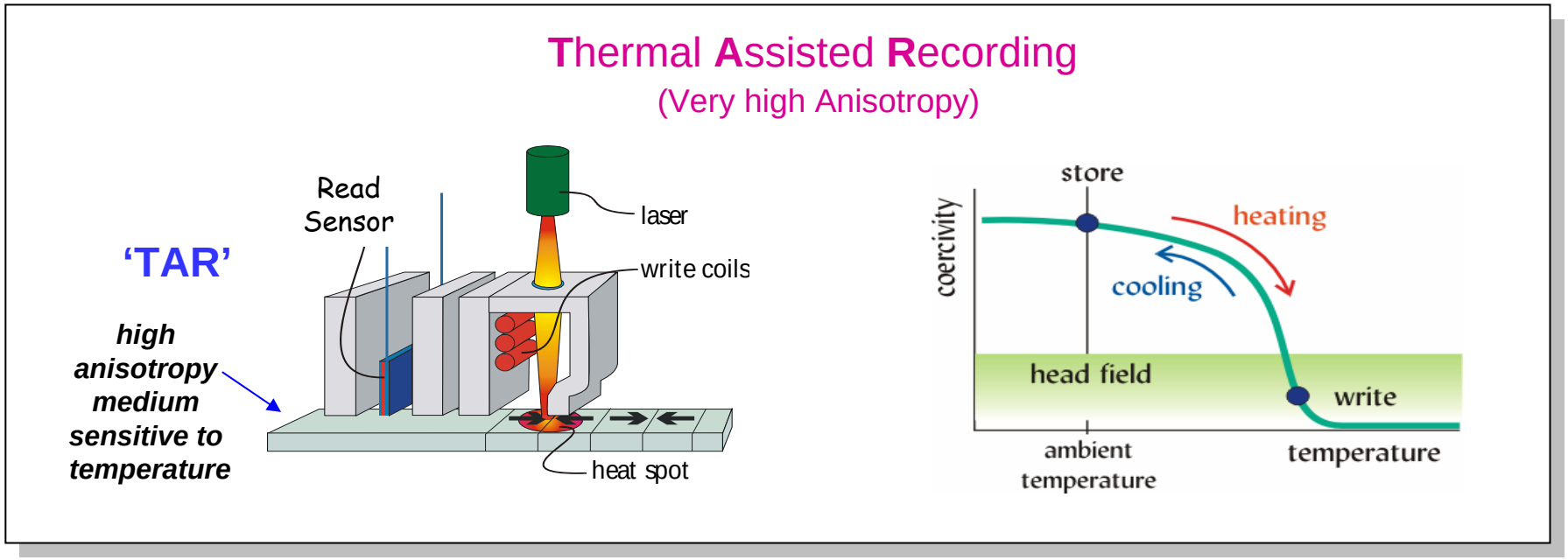
TRACKING SERVO
- very narrow tracks
- pre-patterned servo features
- dual-stage actuator (microactuator)

HEAD
- special structures for very narrow tracks

DATA CHANNEL
- write synchronization
- modified data detection

Thermal Assisted Recording (TAR)

- Employ temperature dependence of media coercivity to meet simultaneous demands of
  - Low coercivity for writing
  - High coercivity for stable long term storage
- Requires small spot heating source with <10 ns response time aligned to write head
- Need to integrate optics into magnetic head recording
- Combination of TAR and patterned media could extend areal density beyond 10 Tb/in^2



Summary

- "Superparamagnetic" effect now posing a significant challenge in extending magnetic recoding
- "Superparamagnetic" effect require new technologies, particularly perpendicular magnetic recording
- Initial production of Perpendicular Magnetic Recording has been successful
  - Reliability
  - Volume ramp
  - Yields
- Perpendicular Magnetic Recoding can reach approximately 1 Terabit/in^2
  - Substantial engineering improvements will be required to approach 1 Terabit/in^2

    (magnetic spacing, interlayer thickness, side-shielding for reader & writer, read sensitivity, track-following, powerful detector & error correction, better format efficiency, long data blocks, pattern media, TAR, etc.)

Thank you

HITACHI

Inspire the Next