Metrology Challenges for Quality Control in the Data Storage Industry

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APMP 2016 Mid-year Meeting Technical Session

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WORLD-SCALE MANUFACTURING

Source: EDB

ELECTRONICS:

- 60% contributed by semiconductor sector
- 14 Si wafer fabs including world's top 3
- 20 semiconductor assembly and testing operations; 3 of top 6
- 15 of the world top 25 fabless semiconductor companies
- World's top 3 HDD companies; >40% of world disk media

- Home to **14** silicon wafer fabrication plants, **20** semi-conductor assembly & test centre
- More than **30** global medical technology firms, investing in more than **50** plants
- **70%** of global market share for jack-up rigs & conversion of Floating Production Storage Offloading units

BIOMEDICAL:

- World 's 4th best healthcare infrastructure
- 30 top medical technology companies; Regional headquarter to world top 10 medical technology companies
- > 30 world leading biomedical companies

TRANSPORT ENGINEERING:

- NO. 1 center in Asia for aerospace maintenance, repair and overhaul
- Largest Asia Pacific Location for Oil and Gas; one of world top 3 export refinery center.
- Busiest bunkering port in the world – 43M tonnes and US$29b
- 70% global market share of jack-up rigs of deep sea oil exploration

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OUTLINE

1. Hard-disk drive and global supply chain
2. Role of accurate measurement for quality control for manufacturing and innovation
3. Metrology challenges in HDD component manufacturing and design

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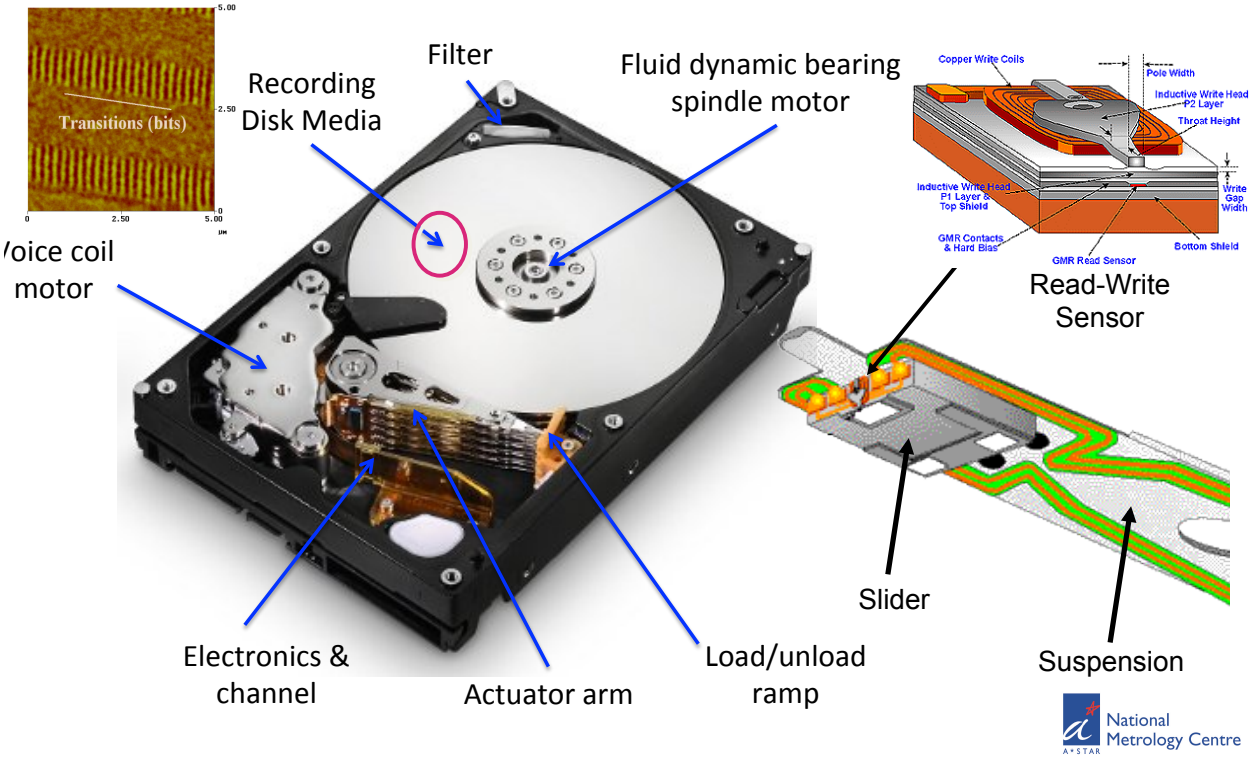
KEY COMPONENTS OF A HARD-DISK DRIVE



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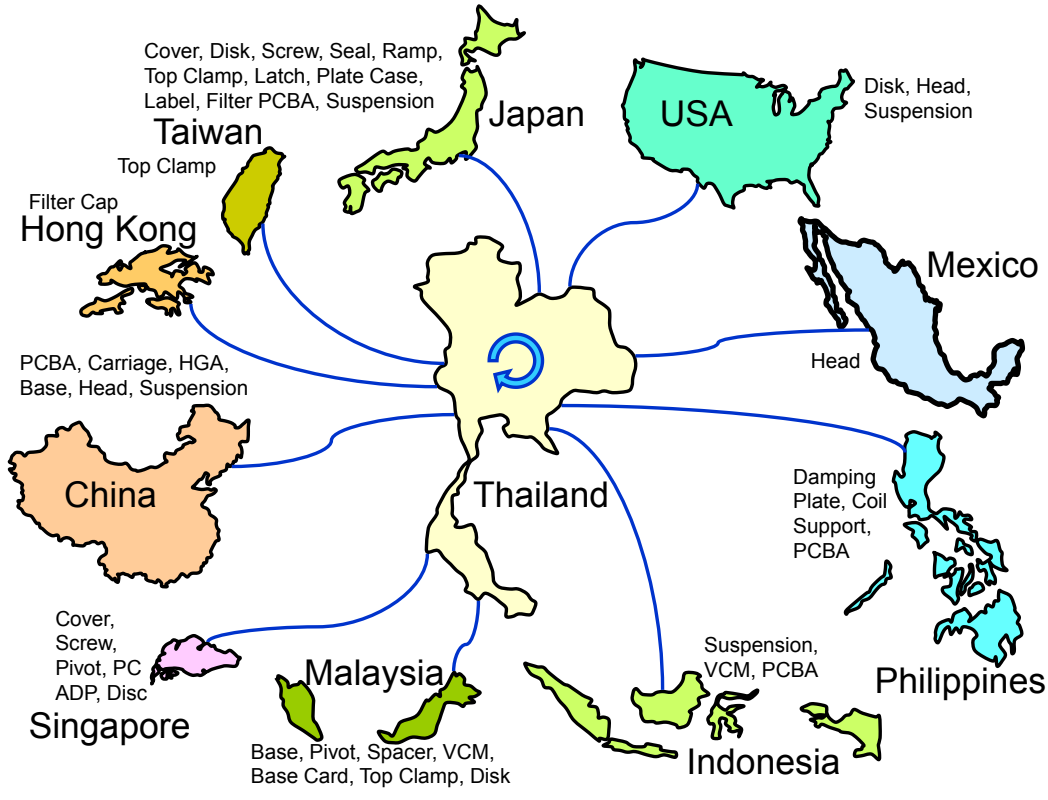
Hard Disk Drive Supply Chain in Thailand



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ROLE OF ACCURATE MEASUREMENT

HDD Manufacturing involves

- Complex manufacturing and integration processes
- Complex process flow
- Integration of components from global supply chain

1. MANUFACTURING PROCESS & PRODUCT QUALITY CONTROL

High quality, reliable and safe products & manufacturing efficiency and productivity (yield) requires

- accurate, repeatable, reproducible and comparable measurement for
  - process control,
  - testing and
  - characterization

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ROLE OF ACCURATE MEASUREMENT

2. NEW TECHNOLOGY & INNOVATION FOR HIGH CAPACITY STORAGE

New measurements and often more accurate, expanded range measurement need to support:

- New processes
- New function/performance
- Design for performance and quality

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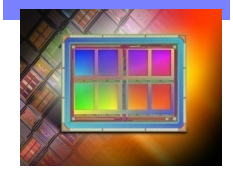
Data Storage Research @A*STAR

>15 Years

Magnetic Technology	Optical Materials & Systems	Network Storage Systems	Non-volatile Memory	Emerging Alternatives
				Probe Storage CNT RAM R-RAM DMS Spintronics Quantum Storage/ Computing
EHDR HDD Technology	Super-RENS	Enterprise Petabyte Green Storage CE Storage	PC-RAM STT-MRAM	

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METROLOGY CHALLENGES FOR HIGH DENSITY MAGNETIC RECORDING DISK MEDIA

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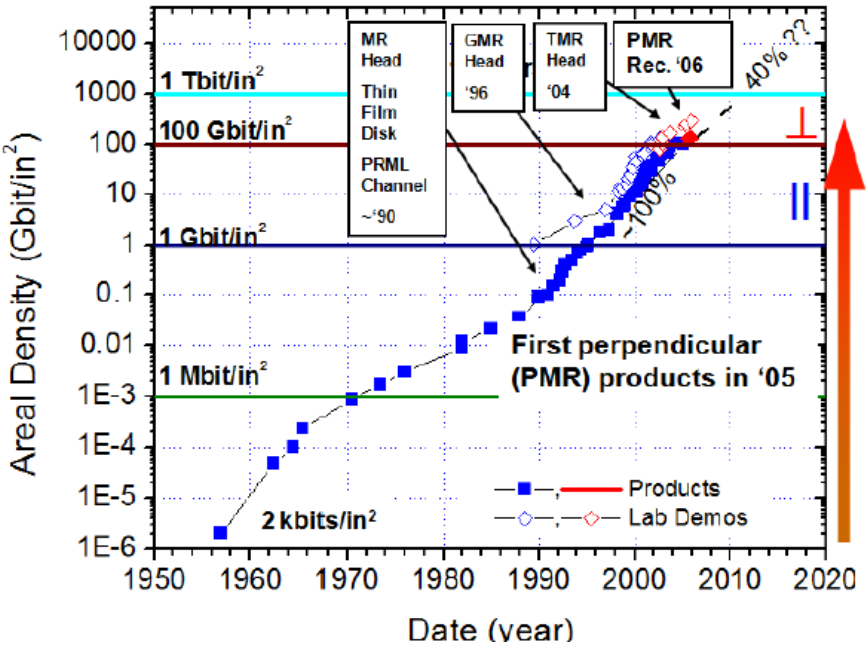
HDD Industry Roadmap: Areal Density Growth

Commercial product
720 Gbits/in², 500 GB/2.5" Platter

Demonstration
~1 Tbits/in²

Research frontier
1.5-10 Tbits/in²



Technology Options:
- Longitudinal
- Perpendicular
- Heat Assist
- Patterned Media

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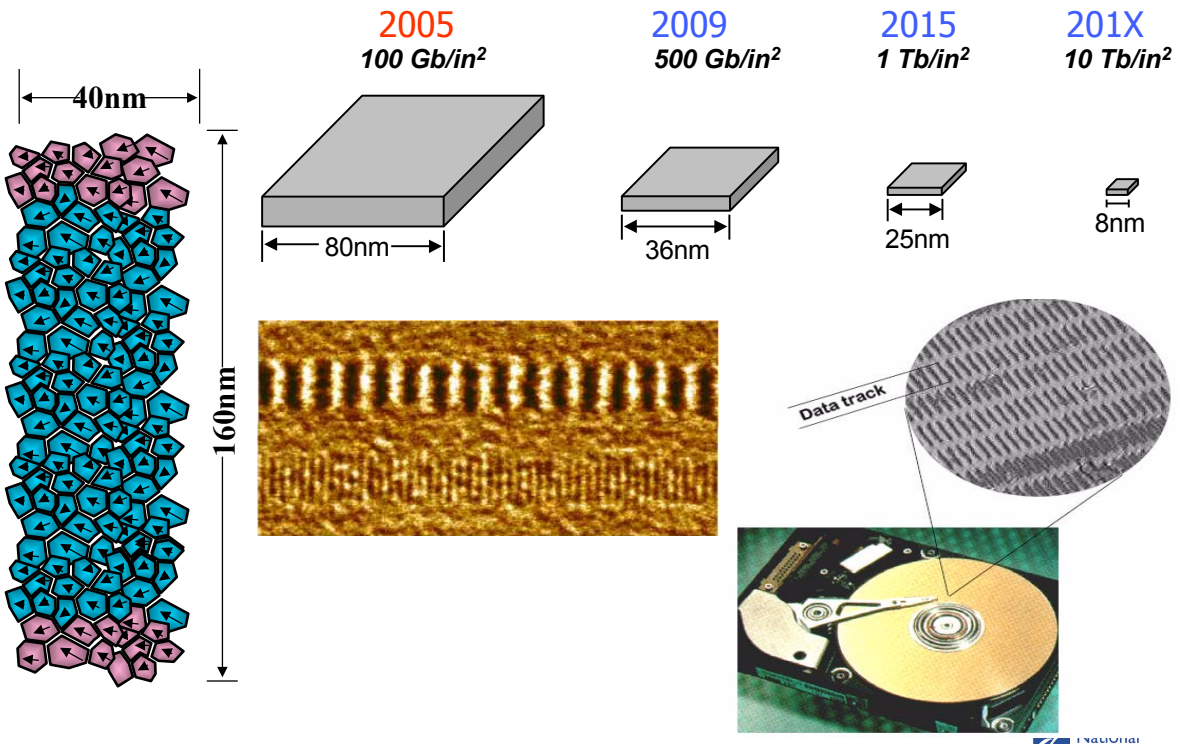
BIT SIZE SCALING



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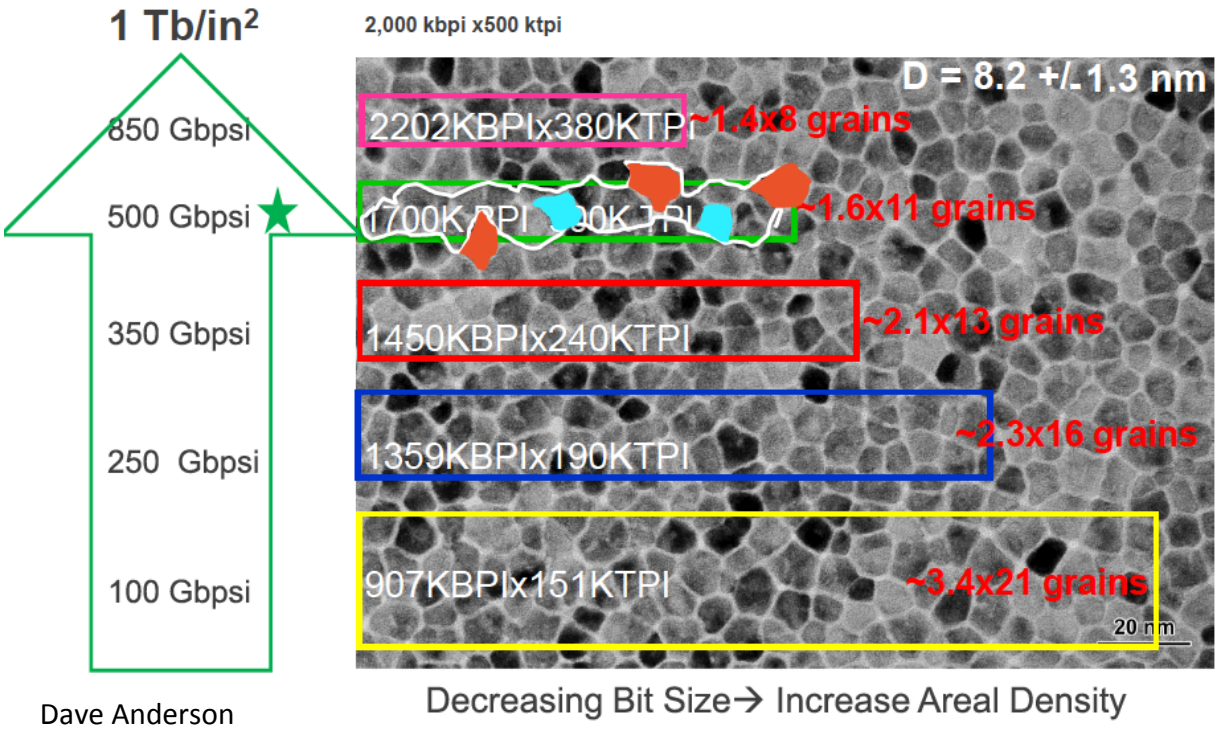
Recording Bit Scaling

Areal Density ≡ TPI * BPI (Tracks Per Inch X Bits Per Inch)

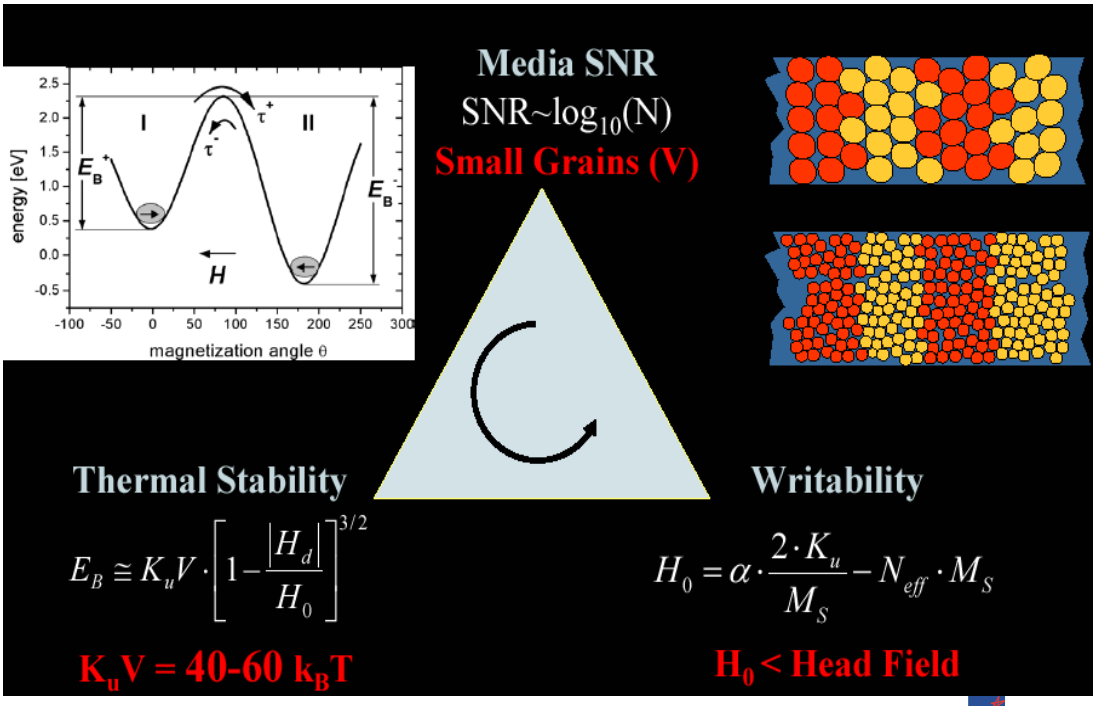


Decreasing Bit Size→ Increase Areal Density

Dave Anderson
Seagate

6

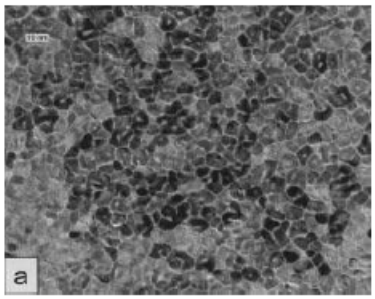
Fundamental Issues in Magnetic Recording: the trilemma



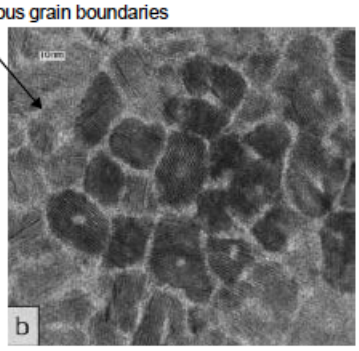
METROLOGY CHALLENGES

Measurement of grain size, grain size distribution, grain boundary

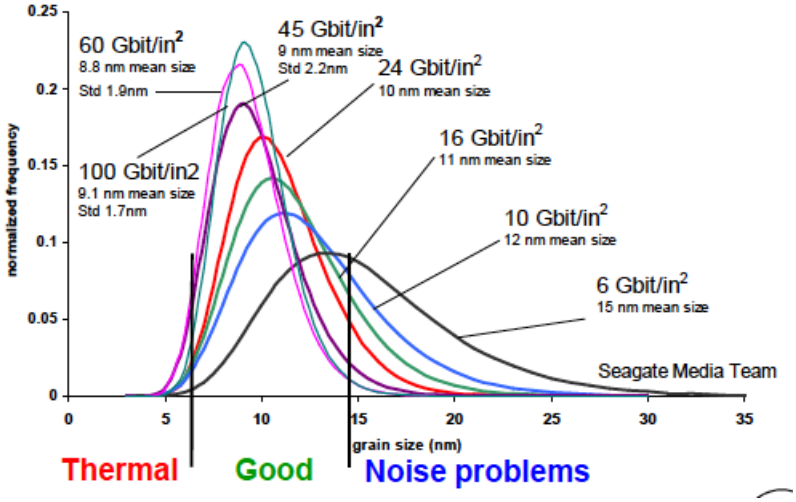
CoCrPtB - 35 Gbit/in² medium



norphous grain boundaries



- Smaller grains, better isolation
- But…
  - Thermal activation of small grains
  - Increased jitter from large grains



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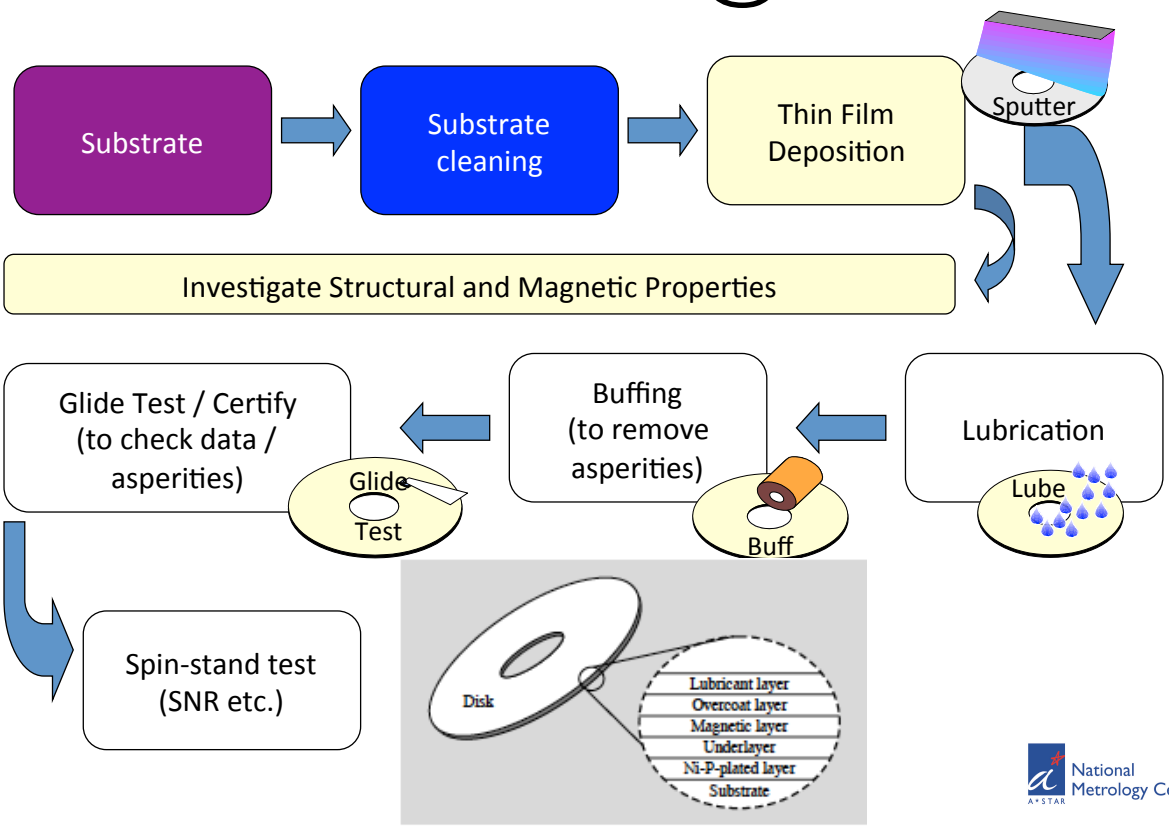
Media Process Flow @ A*STAR



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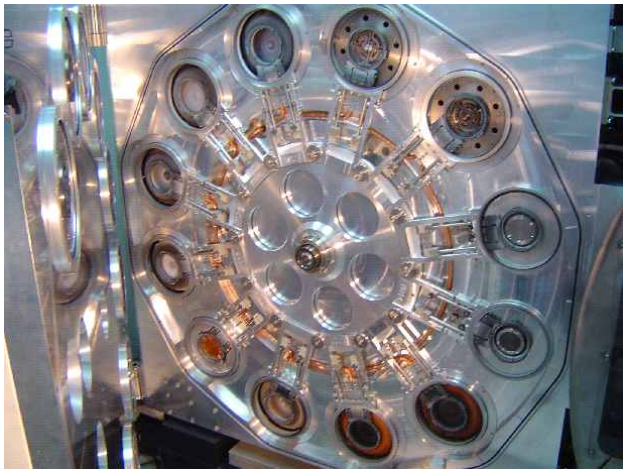
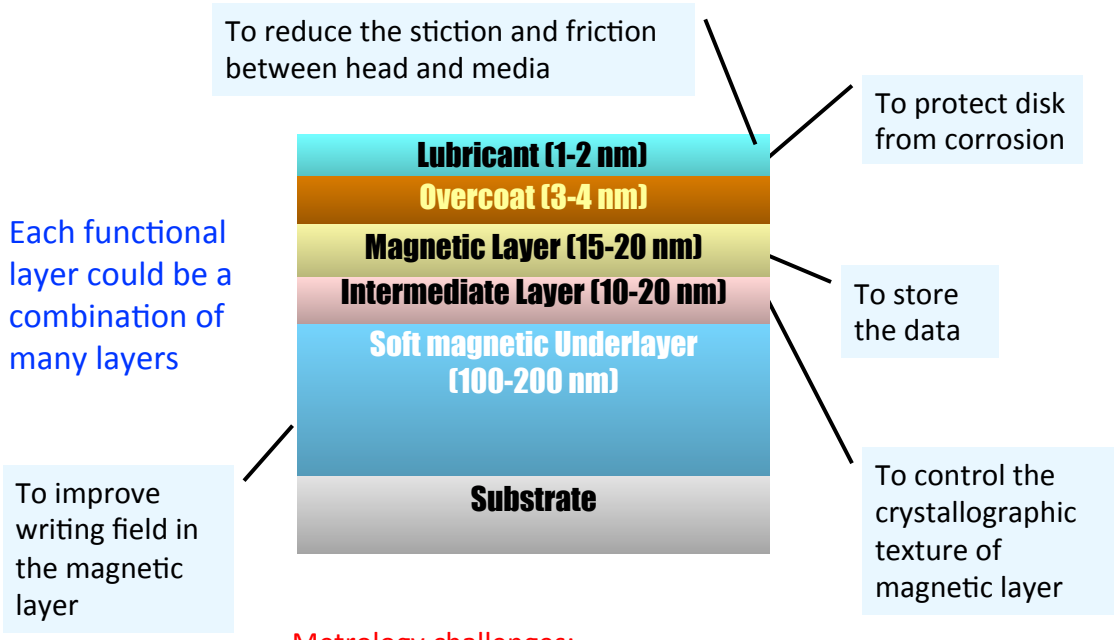
M12 sputtering tool @ A*STAR

- Manufacturing tool:
  - 450 disks per hour
  - 10 processing stations
  - 7 targets x 2 sides
  - Substrates move from one location to the other location
  - Future HDD sputtering tools will be more complex.



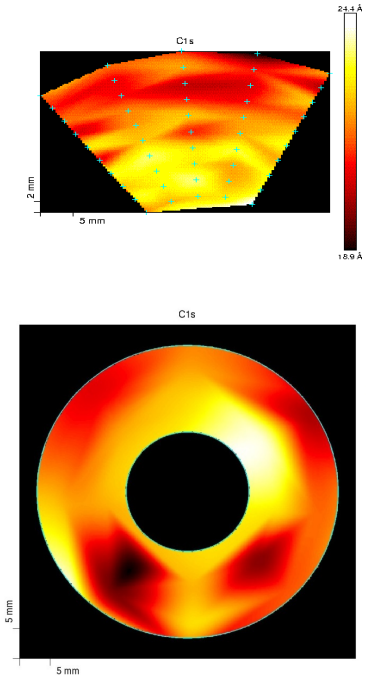
PERPENDICULAR RECORDIND MEDIA



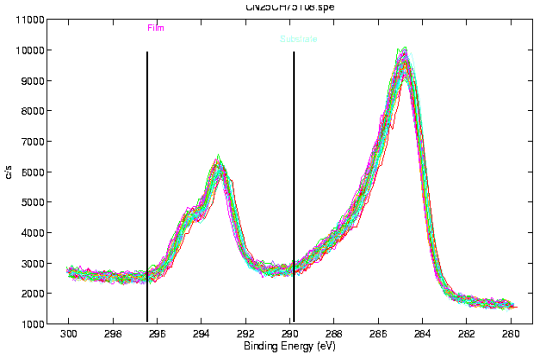
Metrology challenges:

- Thin film multilayer measurement
- Surface roughness
- High speed measurement/mapping

ULTRATHIN LUBRICANT THICKNESS MEASUREMENT AND MAPPING



•*the fluorocarbon and graphitic peak areas selected from the C1s narrow scan*



•*Lube thickness can be calculated by analyzing areas under the C-F and C-C peaks.*

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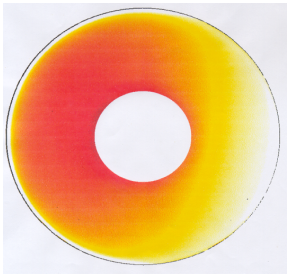
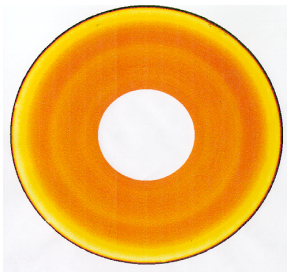
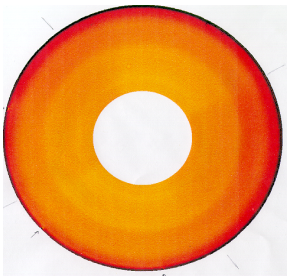
SRA Maps - Carbon Thickness Uniformity







S-polar reflectivity map

P-polar reflectivity map

Single layer carbon (in-line sputterer)

- Once around thickness variation

Dual-layer carbon (static sputterer)

- Circular symmetry in thickness non-uniformity
- OD have different optical properties than MD
- It is due to effective carbon composition difference

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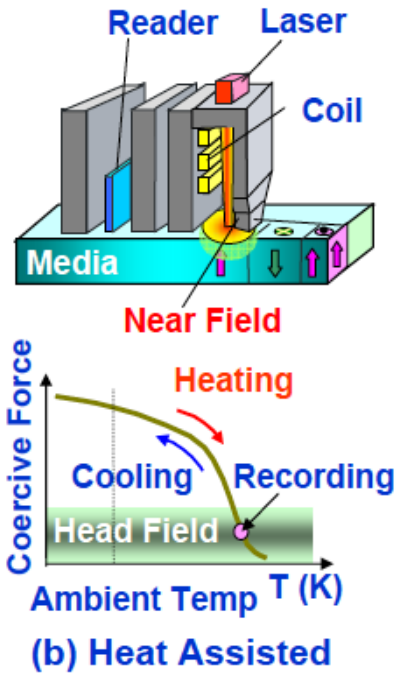
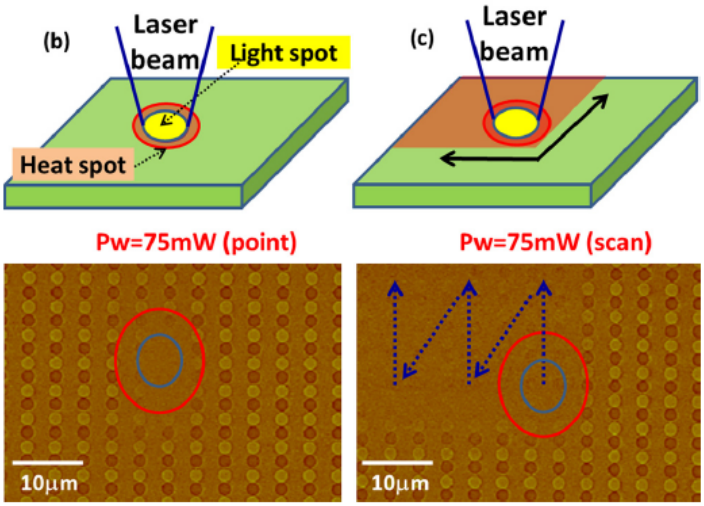
ENERGY ASSISTED WRITING TO THERMALLY STABLE AND HARD TO WRITE MEDIA



Metrology challenges:

- Laser power measurement
- Laser spot profile measurement
- Temperature measurement
- Thermal physical properties of the media layers and thermal transport



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METROLOGY CHALLENGES FOR HEAD MAGNETIC SPACING SCALING

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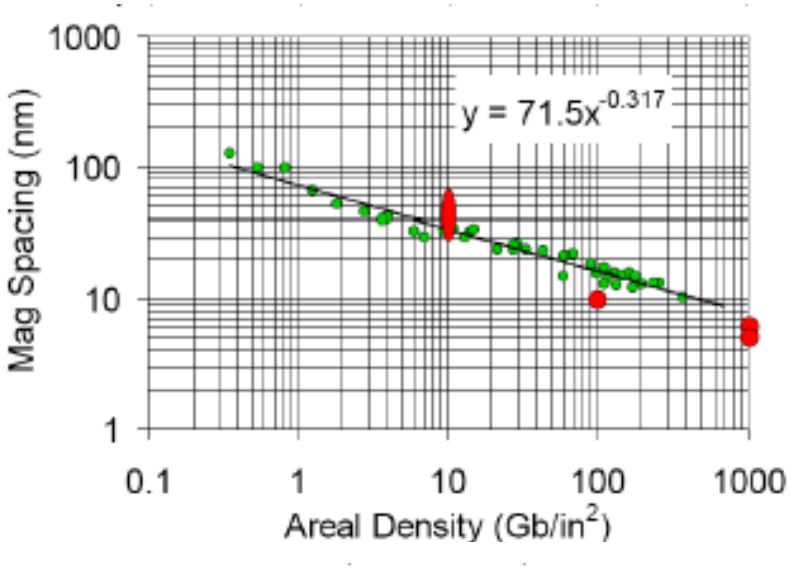
HEAD MAGNETIC SPACING (HMS)



AD (Gbpsi)	1,000	2,000	10,000
HMS (nm)	8.0	6.4	3.9
BAR	3.9	3.3	2.1

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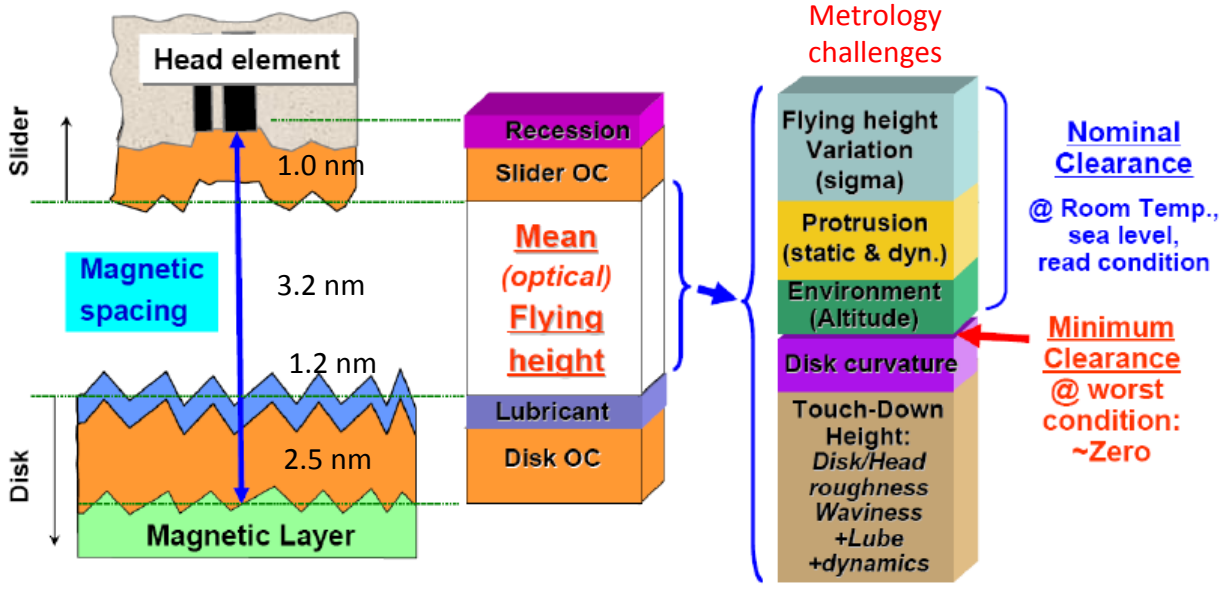
HEAD MAGNETIC SPACING BUDGET

HDI at Ultra Low Flying Height for better SNR

- For 70 Gbits/in2 Areal Density magnetic spacing ~ 18 nm
- For 1 Tbits/in2 Areal Density magnetic spacing < 7 nm



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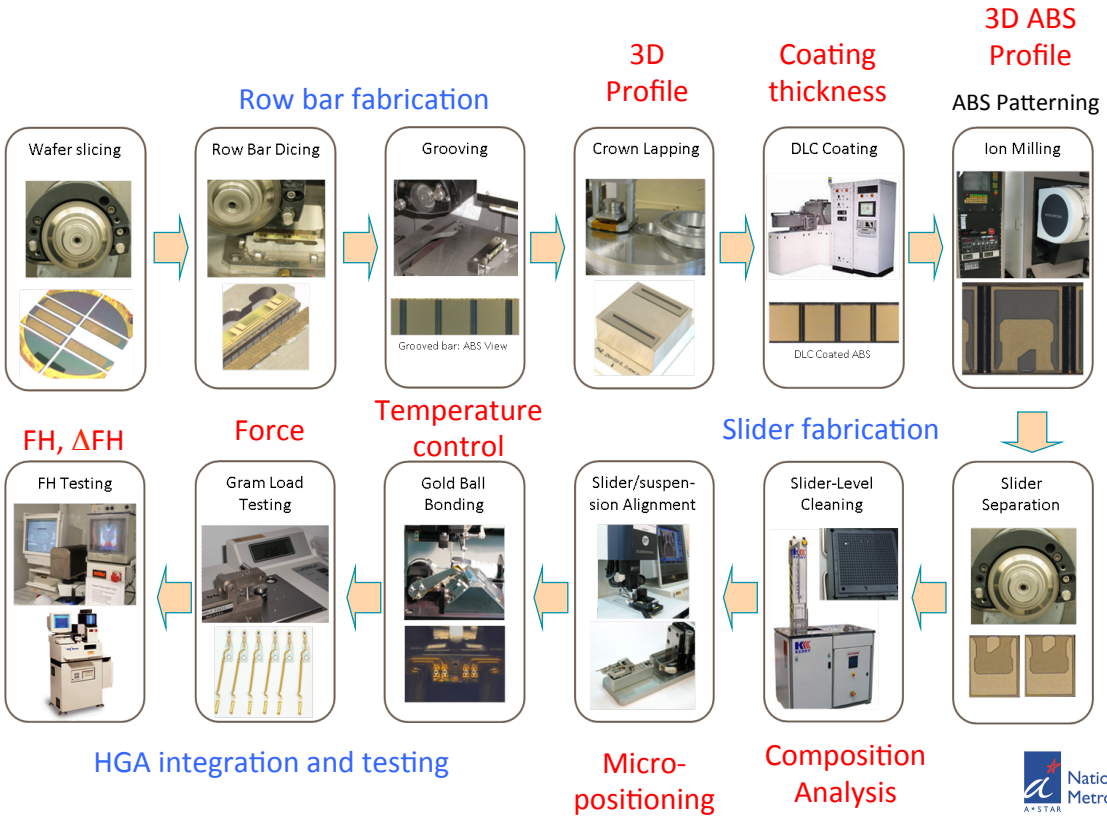
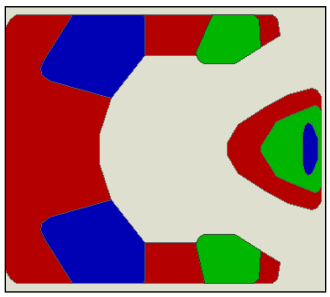
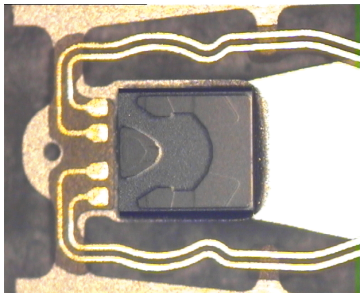
Slider Prototyping @ A*STAR



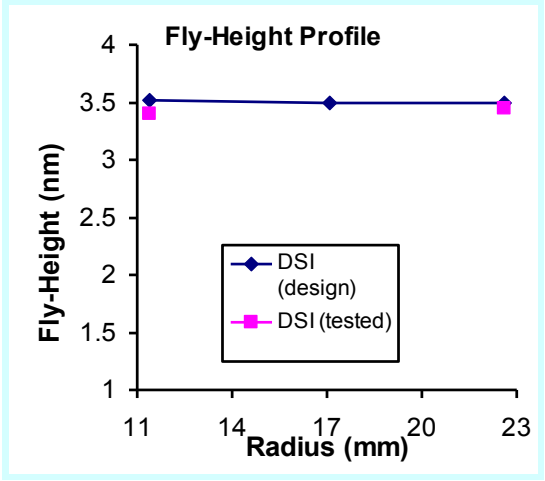
EXTREMELY LOW FLYING SLIDERS





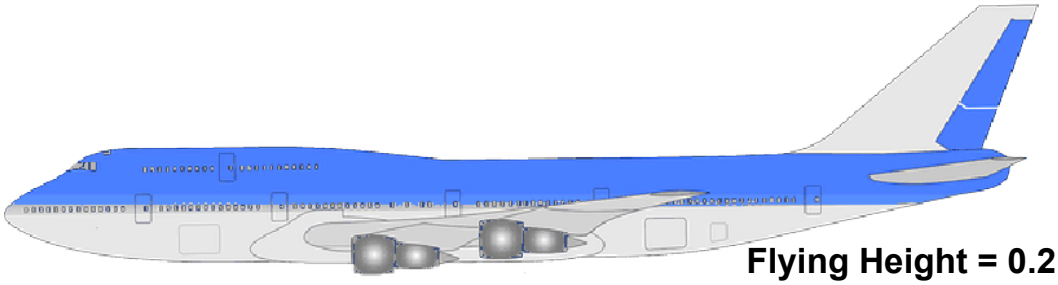
Metrology challenges

- Dynamic FH
- FH Modulation
- ABS 3D profile



Information Storage Industry Consortium Tested

How low is 3.5 nm?



Flying Height = 0.21 mm

MAGNETIC DISK

Flying a Slider (1.25 mm *1.0 mm *0.3mm), at ***3.5 nm***

is comparable to

Flying a Boeing 747 (70.6 m * 64.4 m *19.4m) at ***0.21 mm !!!***

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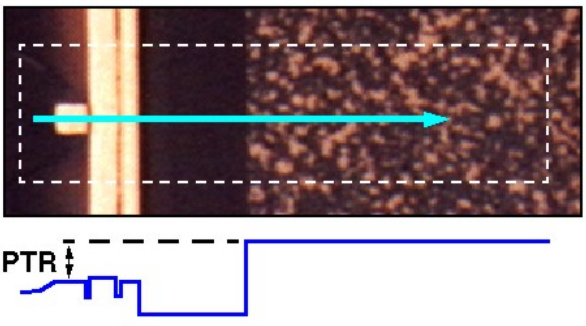
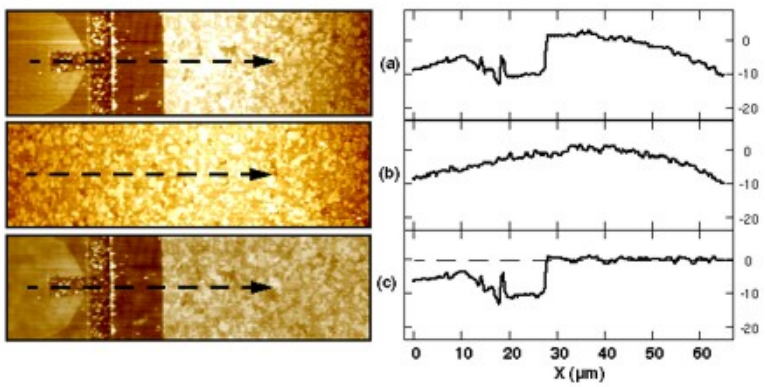
Pole Tip Recession Measurements by AFM





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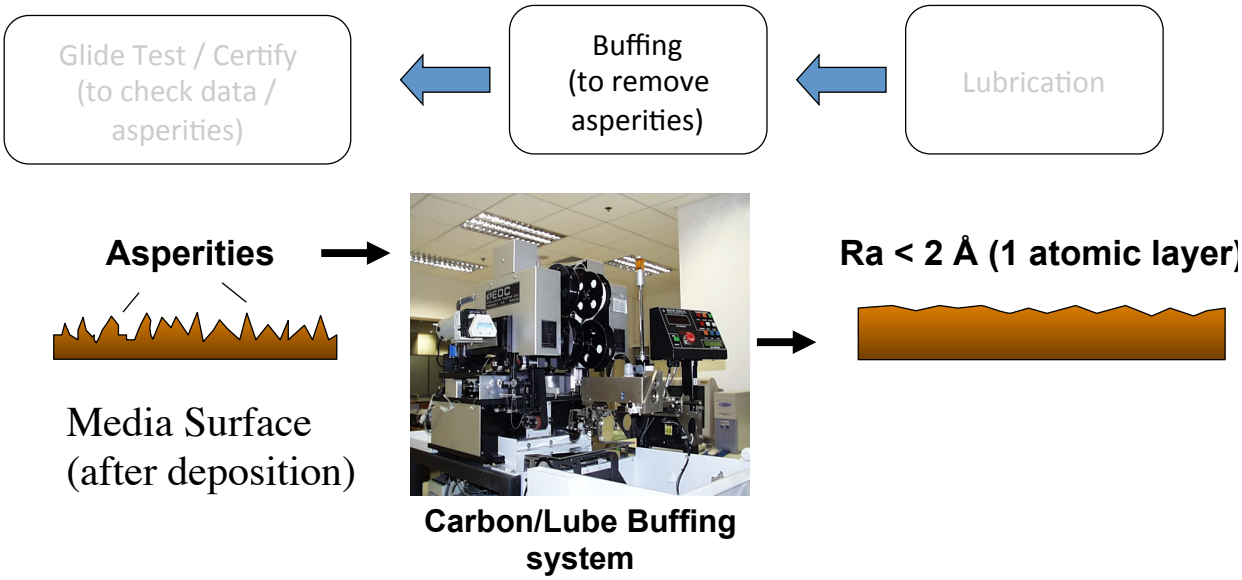
Buffing



Measurement challenges:

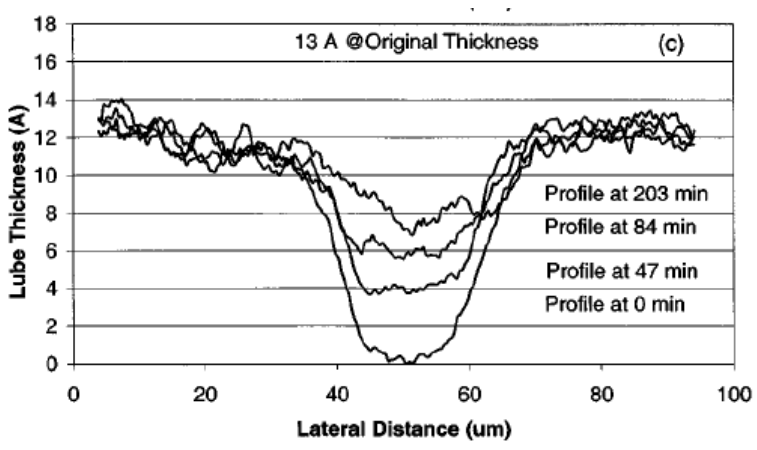
- Ultrasmooth disk and non-contact surface texture measurement

LUBRICANT THICKNESS AND MOBILITY

IEEE TRANSACTIONS ON MAGNETICS, VOL. 37, NO. 4, JULY 2001 1833

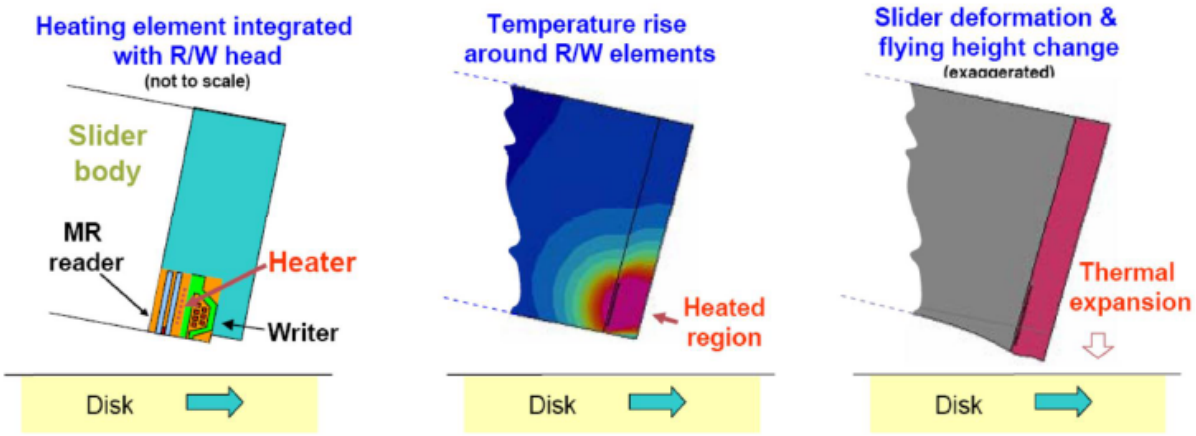
Mobility of Z-Dol Lubricant Thin Film on Carbon Overcoat Surface

Lei Zhu, *Member, IEEE* and Tom Liew, *Member, IEEE*



TFC (Thermal Flying-height Control) - *recent introduction ~2005*

- **Magnetic Spacing is one of strongest levers for areal density**
- **→ Control flying height with small thermal actuator (heater) built into head**
- **Only active during read or write → better reliability**
- **Compensates head protrusion (deformation) due to writing, temperature change, etc.**
- **Absorbs fly-height differences between heads, brings each head to lowest possible safe flying height.**



Measurement challenges: (a) thermal properties
(b) Surface protrusion/thermal expansion

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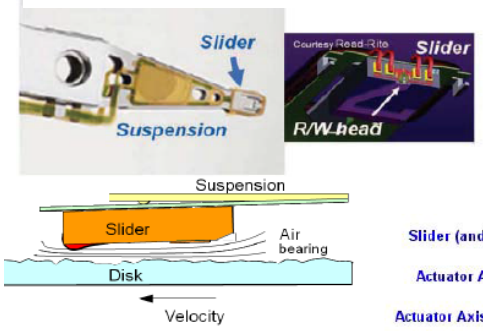
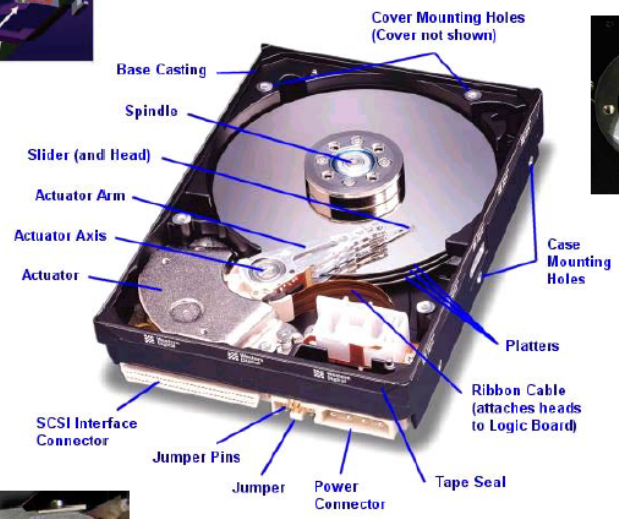
RF & EMI/EMC MEASUREMENT





Spindle

Actuator

unintentional generation, propagation and reception of electromagnetic energy with reference to the unwanted effects that such energy may induce

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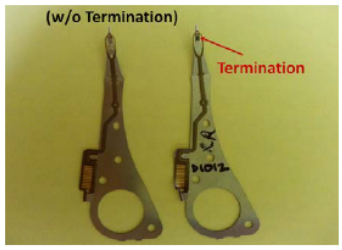
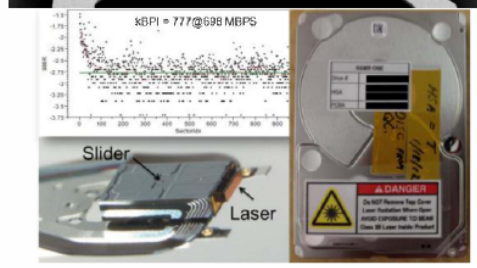
RF & EMI/EMC MEASUREMENT

Example
- 8 Leads





Examples
-Integrated HAMR drive

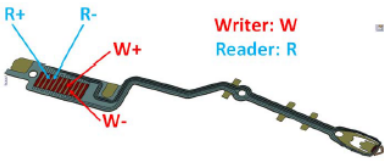


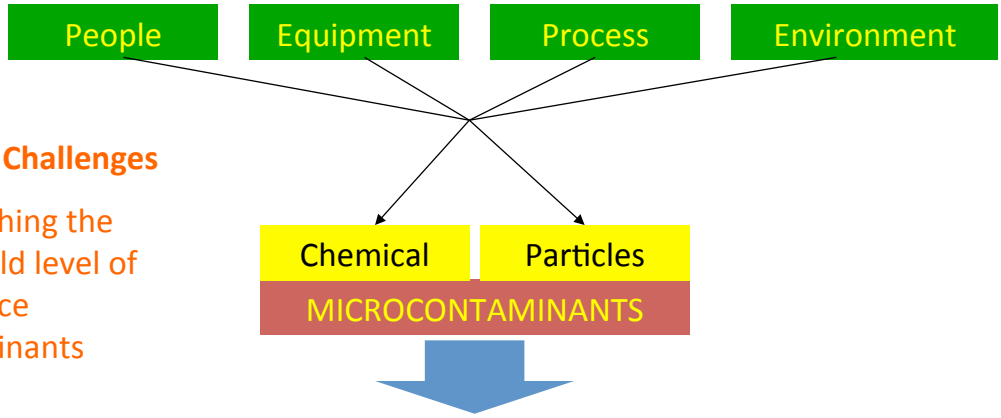
Figure 2 an illustration of Seagate demonstration of an integrated HAMR drive. The sector BER was captured using an HAMR drive with an integrated head and FePt medium.

Kai-Zhong Gao, etc, "From Perpendicular Magnetic Recording to Heat Assisted Magnetic Recording", Invited Paper, 2012

EMI/EMC

- More wires
- Closer wires
- High data rate
- damaging crosstalk power levels
- write-to-read coupling

DEFECTS ANALYSIS AND CONTAMINATION CONTROL



Metrology Challenges

(1) Establishing the threshold level of ultratrace contaminants

(2) Defect analysis & finding the root of failure

Device failures

Stiction/wear
Crash
Corrosion
Read/write error

Component defects

Heads & media defects
Corrosion

CONCLUSION

1. Metrology is key in quality control for manufacturing and integration of components from global supply chain

2. Metrology can help in the quality and reliability the design of new processes and products

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THANK YOU

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