HDD Opportunities & Challenges, Now to 2020

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May, 2013
Areal Density Growth

- Late 1990s – super paramagnetic limit demonstrated through modeling
- Perpendicular expected to extend to 0.5-1 Tb/in²
- Additional innovations required at that point
  - heat-assisted recording
  - bit patterned media recording

- Inductive Writing & Reading
- Inductive Writing/ MR reading
- Inductive Writing/ GMR reading
- Perpendicular Writing & GMR
- HAMR
- HAMR+
- BPM

- Areal Density CAGR 40%
- Transfer Rate CAGR 20%

Single particle superparamagnetic limit (estimated)
Charap’s limit (broken)

• 1989
• 1991
• 1993
• 1995
• 1997
• 1999
• 2001
• 2003
• 2005
• 2007
• 2009
• 2011
• 2013
• 2015
• 2017
• 2019

year
gigabit / in²
Areal Density Trends

PMR CAGR slowing from historical 40+% down to ~8-12%

What is the Plan?
Exabyte Growth Over the Last 5 Years

Averaged $40\%$ per Year

While Areal Density Is

Growing at only $<10\%$ per Year

Source: Seagate Strategic Marketing and Research 2013
Particle Trends

A Recording Head under SEM

Media magnetic grain is ~9-10 nm diameter
Today’s data bit is ~ 25 nm wide.
Critical magnetic and contamination features are nm scale.

100 Gb/in\(^2\)  —  0.20 x 0.032 \(\mu\)m, 130 ktpi x 800 kbpi

1 Tb/in\(^2\)  —  50 nm x 12.7 nm, 500 ktpi x 2,000 kbpi

2 Tb/in\(^2\)  —  38 nm x 8.5 nm, 660 ktpi x 3,000 kbpi

We are here

300K TPI
1700K BPI
\(\approx\)500 Gb/in\(^2\)
Recording Bit Scaling

Areal Density \( \equiv \text{TPI} \times \text{BPI} \) (Tracks Per Inch X Bits Per Inch)

1 Tb/in\(^2\)

- 2,000 kbpi x 500 ktpi
- 2,202 KBPI x 380 KTPI \( \approx 1.4 \times 8 \) grains
- 1,700 KBPI x 300 KTPI \( \approx 1.6 \times 11 \) grains
- 1,450 KBPI x 240 KTPI \( \approx 2.1 \times 13 \) grains
- 1,359 KBPI x 190 KTPI \( \approx 2.3 \times 16 \) grains
- 907 KBPI x 151 KTPI \( \approx 3.4 \times 21 \) grains

Decreasing Bit Size → Increase Areal Density

D = 8.2 \(+/-\) 1.3 nm

~2.1x13 grains
Materials for Higher AD

Anisotropy

Areal Density Scale Factor

FePt

CoPt

Fe$_{14}$Nd$_2$B

HAMR

Traditional Recording

Co/Pt

Co$_3$Pt

Co/Pd

CoCrPt

Co/Pt

MnAl

FePd

CoPt$_3$
Heat Assisted Magnetic Recording (HAMR)
Heat Assisted Magnetic Recording (HAMR) Technology

- HAMR takes advantage of magnetic media materials with higher thermal stability to push out the onset of the superparamagnetic effect limiting Perpendicular Magnetic Recording (PMR) technology used in current hard disk drives.
- These magnetic materials with higher thermal stability are heated with a tiny laser spot for just long enough to write the magnetic data bits, allowing smaller bit sizes and therefore higher areal densities and capacities than conventional PMR technology.
- A laser is integrated into the HAMR recording head.
- Seagate demonstrated HAMR areal density of 1 Tbit/in² in March 2012.
- Seagate CEO Steve Luczo gave a presentation to Wall Street analysts using a fully functional HAMR drive on Sept. 21, 2012.
- PMR technology is likely limited to ~1 Tbit/in², HAMR is thought to push that limit to ~5 Tbit/in².
- Market introduction of drives using HAMR technology is currently envisioned for 2015/2016.
Technology Alignment:
1. Industry (ASTC) and Seagate staged for HAMR Technology
2. Bit Patterned Media (BPM) post HAMR introduction
Component Technology Strategies:
1. PMR Extension & Shingled Magnetic Recording (SMR)
2. HAMR/Extension
   - 2015-2016 Product Introduction
   - 20-40% CAGR
3. BPM+HAMR
Conclusion

• Worldwide need for storage continues to grow and there is no viable alternative to HDDs in sight to meet this demand.

• To address the slowing areal density growth, HDD technology roadmap and component strategy includes:
  – Extending Head/Media perpendicular recording technologies
  – Productizing shingled magnetic recording (includes new Writer Design & Media optimizations)
  – Introduce HAMR technology (integrated laser on head heats media)