Scaling the Areal Density Mountain

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Seagate
• Seagate’s HDD technology introductions are consistent with this industry view
  • Tips of arrows indicates approximate capability of technology
  • We have line of sight to capacities exceeding 100TB using these technologies and higher disk counts
# Challenges to Higher Capacity Drives

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<th>Challenge</th>
<th>Solutions</th>
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<td><strong>Thermal Stability</strong></td>
<td><strong>Challenge:</strong> To increase areal density we need to reduce grain size. However, if grain size is reduced too much, they become unstable</td>
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<td><strong>Writer/Reader/HMS Scalability</strong></td>
<td><strong>Challenge:</strong> To increase areal density we need to reduce track pitch. We are fast approaching the limits of how narrow we can make writers and readers</td>
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<td><strong>Fixed Form Factor</strong></td>
<td><strong>Challenge:</strong> To increase drive capacity we can add more heads and disks to the HDA. However, we are constrained by fixed form factors.</td>
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**Solutions:**
- Heat Assisted Magnetic Recording (HAMR)
- Bit Patterned Media (BPM)
- Heated Dot Magnetic Recording (HDMR=HAMR+BPM)

**Writer Solutions:**
- Shingled Magnetic Recording (SMR)

**Reader Solutions:**
- Two-Dimensional Magnetic Recording (TDMR), ie, Multi Sensor Magnetic Recording (MSMR)

**Head Media Spacing (HMS):**
- Thinner coatings, lower clearances, smoother interfaces, new materials, new clearance control algorithms

**Solutions:**
- More discs per HDA - Helium
- New form factors
Innovative Technologies

PMR/CMR
Perpendicular Magnetic Recording
AD Up to \(~1.0\) Tb/in\(^2\)
Current Mainstream Products

He
Helium Filled Hard Drives
Currently Shipping

SMR
Shingled Magnetic Recording
Shipping in various markets

TDMR
2D Magnetic Recording
Product Integration 2016 - 2018

HAMR
Heat Assisted Magnetic Recording
AD \(~1.2\) to \(~4.0\) Tb/in\(^2\)
Product Integration 2016+

HDMR
Heated Dot Magnetic Recording
\(~5.0\) to \(~10.0\) Tb/in\(^2\) AD
Initial Product Integration >2025
Innovative Technologies

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<td>Heat Assisted Magnetic</td>
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<td>Initial Product Integration &gt;2025</td>
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Two Dimensional Magnetic Recording (TDMR)

Problem
Reducing the reader width difficult
Reader sees more of adjacent tracks = noise

TDMR solution
Read adjacent tracks
Calculate interference effects and cancel out noise

Longer term
knowledge of adjacent tracks & clever encoding extend the areal density further by writing tracks closer and closer together

Challenge: How to implement TDMR
Reading multiple tracks with a single reader is too slow

Multiple readers on a single head has engineering challenges
2D Magnetic Recording Works

- 2 or more readers on the same track or partially on adjacent tracks
- Current areal density gains in the 5-10% range
- Future work to get larger areal density gains
- Also get 2x read data rate
Innovative Technologies

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Perpendicular Magnetic Recording
AD Up to ~1.0 Tb/in²
Current Mainstream Products

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Ramping

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Heat Assisted Magnetic Recording
AD ~1.2 to 4.0 Tb/in²
Product Integration 2016+

**HDMR**
Heated Dot Magnetic Recording
~5.0 to 10.0 Tb/in² AD
Initial Product Integration >2025

He Helium Filled Hard Drives
Currently Shipping
Heat Assisted Magnetic Recording Making Significant Progress

- Very stable media to extend areal density
- Media is heated so it can be written.
- Laser is integrated into the HAMR head
- Near field optics allow very narrow and sharp bits to be written.
- Heated, written and cooled in less than a nano-second.

Takeaways

- HAMR need for increase in areal density.
- Significant progress made, still focusing on reliability and area density.
HAMR ADC Growth and Product readiness - It Works!

Accomplishments:

- ADC = +1.6 Tb/in²
- Reliability
- Integrated heads/drive

ADC demo: 2012
1007 Gfpsi
=1975 kfc x 510 kTPI

ADC Demo 2015
1402 Gfpsi
=2084 kfc x 673 kTPI
Innovative Technologies

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Heated Dot Magnetic Recording = BPM + HAMR

- Heated Dot Magnetic Recording
  - ~5.0 to 10.0 Tb/in² AD
  - Initial Product Integration >2025

Takeaways:
- BPM: Multiple grains per bit to a single magnetic island per bit
- Demonstrated 1.5 Tdpsi Spinstand
- HDMR at 5Tdpsi and beyond looks feasible

Continuous FePt film patterned @ 1Tdpsi to 5Tdpsi

Spinstand testing and drive integration

BER = -2.43 @ 1Tb/in²
WHY HARD DISK DRIVES REMAIN ESSENTIAL
2005: Installation Pope Benedict

2013: Installation Pope Francis
Data Never Sleeps 3.0

How much data is generated every minute?

With each post, share and like, the world's data pace is expanding faster than we can comprehend. Businesses today are paying attention to streams of data created by massive information explosions about the future. This trend at Domo can help your business make sense of this deluge.

Sources:
- Facebook
- Twitter
- YouTube
- Instagram
- Instagram
- Netflix
- Reddit
- Amazon
- Vines
- Tinder
- Snapchat

The global internet population grew 18.5% from 2012-2015 and now represents 3.2 billion people.
Move Toward Mobility: Shifting the Location of Data

2010

62% of the storage was shipped into the client market...

77 Exabytes

2020

dramatic shift to the cloud

1,121 Exabytes

Source: Seagate Strategic Marketing and Research
No Replacement for HDD Soon

HDDs dominate the storage market

2020 HDD Shipments: 1.6 - 2 ZB

NAND 2020 Forecasts: < ¼ (HDD EBs)
THANK YOU