The Dynamics of the HDD Industry
and its Impact on CMP

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The Information Network – What We Do

- Off-The Shelf Technical-Marketing Reports on High-Tech Sectors including HDDs, CMP, Semiconductors, Alternative Energy, LEDs, LCDs, MEMs, Processing Equipment, Processing Materials
- Custom Studies in the above areas
- Proprietary Leading Indicators correlating macroeconomic trends with projections of semiconductor and semiconductor equipment growth

- Formed in 1985
- First report on the market analysis of CMP in the 90s
“The Rumors of My Death Have Been Greatly Exaggerated” – Mark Twain
Disk Drive Industry
1960's

Bryant Computer
Burroughs
Caelus Memories
Century Data Systems
Control Data
Fujitsu
Hitachi
IBM
ISS/Univac
Marshall
Memorex
NCR
NEC
Potter Instruments
Toshiba
Disk Drive Industry
1980's

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Disk Drive Industry 2007

Cornice
Excelsior
Fujitsu
Hitachi GST
Samsung
Seagate
Toshiba
Western Digital

2007 Worldwide HDD Shipment Share
(Percentage of Unit Shipments)

- Seagate: 33.9%
- WDC: 22.0%
- Hitachi GST: 17.3%
- Fujitsu: 6.9%
- Toshiba: 7.2%
- Samsung: 11.1%
- Excelstor: 1.4%
Disk Drive Industry 2012

Seagate

Toshiba

Western Digital

2012 Worldwide HDD Shipment Share
(Percentage of Unit Shipments)

Western Digital 44.6%

Seagate 41.9%

Toshiba 13.5%
Changes taking place in the supply chain for WD with consolidations of the HDD industry

<table>
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<tr>
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<th>Heads Sold</th>
<th>% made</th>
<th>Heads Made</th>
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<td>Seagate</td>
<td>635</td>
<td>0.88</td>
<td>559</td>
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<td>TDK</td>
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<td></td>
<td>858</td>
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<tr>
<td>WDC</td>
<td>561</td>
<td>0.82</td>
<td>262</td>
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<tr>
<td>HGST</td>
<td>319</td>
<td>0.97</td>
<td>262</td>
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<tr>
<td>Toshiba/ Fujitsu</td>
<td>270</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Samsung</td>
<td>155</td>
<td>0</td>
<td>0</td>
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<td><strong>Total</strong></td>
<td><strong>1941</strong></td>
<td><strong>1941</strong></td>
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Hutchinson Technology’s customers include Western Digital Corporation, SAE Magnetics, Ltd/TDK Corporation, Seagate Technology, HGST, and Toshiba.

MPT’s customers include Western Digital Corporation, SAE Magnetics, Ltd/TDK Corporation, and Seagate Technology. SAE Magnetics sells further to Toshiba and Samsung.

NAT Peripheral’s customers include SAE Magnetics, which sells further to Samsung. The NAT Peripheral joint venture has provided SAE Magnetics, Ltd./TDK Corporation the capability to produce suspension assemblies since calendar 2005.

NHK’s customers include Western Digital Corporation, Seagate Technology, and Hitachi.

SunCall’s Customer is HGST.

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<thead>
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<th>Millions of units</th>
<th>Share</th>
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<tr>
<td>Hutchinson Technology</td>
<td>454</td>
<td>23.4%</td>
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<tr>
<td>NHK</td>
<td>763</td>
<td>39.3%</td>
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<td>MPT</td>
<td>645</td>
<td>33.2%</td>
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<td>SunCall</td>
<td>79</td>
<td>4.1%</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>1941</strong></td>
<td><strong>100.0%</strong></td>
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Weak Economy Is the Number One Issue
Weak Economy Is Culprit for Slow PC Growth

Source: IDC
Great WOW Factor – HDDs?
Great WOW Factor = Great Growth

Worldwide Tablet Sales Forecast

Percentage Ultrabooks U.S.

Source: IHS

Source: NPD

Dr. Robert N. Castellano
2012 CMPUG
Old Approach at the Enterprise

Old Approach:
More HDDs = Performance

HDD-ONLY CONFIGURATION
- Slower Mechanical Drives
- Inefficient I/O Transfer Rates
- Smaller Form Factor Drives
- Over-provisioning of HDDs
- Lower Capacity HDDs
- Latency and Bandwidth Issues
New Approach at the Enterprise

New Approach:
SSD + HDD = Cost Savings

HDD-ONLY CONFIGURATION
- Slower Mechanical Drives
- Inefficient I/O Transfer Rates
- Smaller Form Factor Drives
- Over-provisioning of HDDs
- Lower Capacity HDDs
- Latency and Bandwidth Issues

HYBRID CONFIGURATION
- Faster I/O Performance
- Lower System Cost $/GB
- Tiered Data Storage – ‘Hot’ Data on SSDs
- Improved Reliability
- Increased Capacity with a Smaller Footprint
Cache SSDs in Ultrabooks will Help the HDD Industry

- Cache SSDs are a discrete, separate memory component alongside the device’s HDD, with both elements housed separately
  - Discrete cache SSDs and HDDs are much more scalable and efficient for mainstream storage, with a broad selection of drive manufacturers.
- Cost concerns, longer design cycles, and tighter engineering tolerances in the case of hybrid HDDs add to their difficulty of use in ultrabooks.

Source: IHS
Social Media is Demanding Huge Amounts of Storage
Cloud Services: The Great Hard Drive in the Sky
Summary

• Despite:
  – Consolidation
  – Floods
  – Poor Economy
  – Changes to Supply Chain
  – Rapid Advances of WOW Devices
• HDDs will continue to Trudge Along
  – Because of the Need for Massive Storage
• However…. 
While Cost Differential of 25x May Hold

Source: Objective Design
And Strong Growth is Forecast For SSDs

Source: SanDisk
Areal Density for HDD (and SSD) has Slowed to 20%/year

Source: Hitachi
And So HDDs As We Know Them May Hit a Brick Wall Soon

PROBLEM:
• To increase density, need smaller grains
• Smaller grains (~100 Angstroms) are thermally unstable
• To avoid thermal instability, increase grain anisotropy Ku
  – This increases the medium coercivity and makes the medium more difficult to write

SOLUTIONS:
• Work with higher anisotropy:
• Capped and exchange spring media
• Thermally assisted recording (TAR)
• Work with larger ‘grains’: patterned media

Courtesy: Thomas R. Albrecht, HGST
Replaced by Bit Patterned Media (BPM)

Conventional Perp. Media
- Continuous granular recording layer
- Multiple grains per bit
- Boundaries between bits determined by grains
- Thermal stability unit is 1 grain (~6 nm diam.)
- Reaching its limits

Discrete Track Media (DTM)
- Conventional perpendicular media, with patterned tracks
- Multiple grains per bit
- Eliminates track edge noise and reduces adjacent track interference
- Thermal stability unit is still 1 grain (~6 nm diam.)
- Modest areal density gain possible

Bit Patterned Media (BPM)
- Highly exchange coupled granular media (e.g. Co-Pd multilayers)
- Multiple grains per island, but each island is a single domain particle
- Bit locations determined by lithography
- Therm. stab. unit is 1 island (~15 nm diam.)
- Substantial areal density gain should be feasible

Courtesy: Thomas R. Albrecht, HGST
Bit Patterned Media: Fabrication Overview

Graphical representation of the fabrication process:

- **Template Fabrication**
  - Rotary stage e-beam Patterning
  - Directed self-assembly
  - Master template fabrication
  - Template replication

- **Media Fabrication Process**
  - ML or alloy mag film deposition
  - Nanoimprint
  - Pattern transfer (etch/implant)
  - Planarization
  - Lube and burnish
  - Inspection
  - Patterned imprint resist
  - Etching
  - Ion implantation
  - Planarization
  - Mask removal

- **1 master (e-beam + self-assembly)**
- **10,000 replicated nanoimprint templates**
- **100,000,000 patterned disks**

Courtesy: Kurt A. Rubin, HGST
Challenges in TFH CMP

- Total thickness variation (TTV) of AlTiC substrates
- CMP results are sensitive to pad surface
- Wafer flats
- Final thickness control
- Pre-CMP film non-uniformity
- Corrosion of exposed metal on the head device
- Most IC CMP advancements take place at 300mm while the bulk of GMR Head manufacturing is being done on 150 to 200mm wafers

Source: Strasbaugh

SiO₂ Fill
Si Adhesion
C Stop

Courtesy: Kurt A. Rubin
TFH: Fabrication Example

- AITiC substrate;
- Undercoat (Al2O3) deposition and polishing (UC CMP);
- First shield (NiFe) pattern, deposition/plating, fill, and CMP (S1 CMP);
- First gap (Al2O3) deposition, GMR film deposition, GMR track-width definition/hard bias/leads, GMR stripe-height definition;
- Second gap (Al2O3) deposition;
- Second shield (NiFe) pattern and plating, separating gap deposition, first write pole (NiFe) pattern, plating, fill, and CMP (P1 CMP);
- First write pole extension P1P (NiFe, CoNiFe, or CoFe) and first layer write copper coil pattern, plating, fill, and CMP (P1P CMP);
- Write coil insulation and writer gap deposition, second write pole (CoNiFe, CoFe) pattern, plating, pattern of second pole width into first pole by ion milling, fill, and CMP (P2 CMP);
- Second layer write coil and P3 (NiFe) yoke plating, copper connections, overcoat (Al2O3) deposition and polishing (OC CMP);

Source: HGST
Vast Array of TFH Stacks With New Materials and Thinner Films

Source: Veeco
Huge R&D Costs in Supply Chain
With Technology Advances

Machine Inputs
Carrier and Pressure Control
Pad Conditioning
Post CMP Clean

Cost
Yield

Slurry
Abrasives
Particle Size
Distribution
Hardness

Pads
Groove Type
Hardness
Density

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Small Market, Big Concerns

- Only a handful of customers left after consolidation
- Market extremely small
  - Will Equipment, Slurry, and Pad manufacturers continue to emphasize R&D?
  - Will small customer base force suppliers to get out of the market?
  - Will HDD and platen manufacturers need to spend more internal R&D on planarization material customization to make up the difference?

Source: The Information Network
Thank You