The Ultra Small HDD for the Mobile Applications

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Outline

• Target consumer for ultra-small HDD and the comparison with the flash memories

• Mechanical feature of 0.85” HDD
  - Shock durability –

• To keep the data capacity growth per year
  - New perpendicular magnetic recording -
## Today’s HDD Capacity & Target Market

<table>
<thead>
<tr>
<th>Size</th>
<th>Data Capacity</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.5”</td>
<td>200GB-600GB (150-180GB/pl.)</td>
<td>Desktop PCs, Servers, HDD video recorders</td>
</tr>
<tr>
<td>2.5”</td>
<td>40GB-200GB (80-100GB/pl.)</td>
<td>Notebook PCs, Small size network servers, Car applications</td>
</tr>
<tr>
<td>1.8”</td>
<td>20-80GB (40GB/pl.)</td>
<td>Mobile PCs, MP3 players, Portable video cameras &amp; players</td>
</tr>
<tr>
<td>0.85” -1”</td>
<td>2-10GB</td>
<td>Cellular phones, MP3 players</td>
</tr>
</tbody>
</table>
1.0” HDD size is the same as Compact Flash.
0.85” HDD size is the same as SD card.

<table>
<thead>
<tr>
<th></th>
<th>Compact Flash</th>
<th>SD card</th>
<th>1.8&quot; HDD</th>
<th>1.0&quot; HDD</th>
<th>0.85&quot; HDD</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Size</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Width</td>
<td>36.4 mm</td>
<td>24 mm</td>
<td>54 mm</td>
<td>36.4 mm</td>
<td>24 mm</td>
</tr>
<tr>
<td>Length</td>
<td>42.8 mm</td>
<td>32 mm</td>
<td>78.5 mm</td>
<td>42.8 mm</td>
<td>32 mm</td>
</tr>
<tr>
<td>Height</td>
<td>3.3 mm</td>
<td>2.1 mm</td>
<td>5 / 8mm</td>
<td>5 mm</td>
<td>5 mm</td>
</tr>
<tr>
<td><strong>Shock Durability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On data access</td>
<td>2000 G</td>
<td>1000 G</td>
<td>500 G</td>
<td>200 G</td>
<td>1000 G</td>
</tr>
<tr>
<td>Off data access</td>
<td>2000 G</td>
<td>1000 G</td>
<td>1500 G</td>
<td>2000 G</td>
<td>2000 G</td>
</tr>
<tr>
<td><strong>Temperature</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On data access</td>
<td>0 ~ 60 °C</td>
<td>0 ~ 55 °C</td>
<td>0 ~ 60 °C</td>
<td>0 ~ 70 °C</td>
<td>0 ~ 70 °C</td>
</tr>
<tr>
<td>Off data access</td>
<td>-25 ~ 85 °C</td>
<td>-20 ~ 65 °C</td>
<td>-40 ~ 80 °C</td>
<td>-40 ~ 80 °C</td>
<td></td>
</tr>
<tr>
<td><strong>Altitude</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On data access</td>
<td>24000 m</td>
<td>3000 m</td>
<td>3000 m</td>
<td>3000 m</td>
<td>3000 m</td>
</tr>
<tr>
<td><strong>Input Voltage</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3.3 V</td>
<td>2.7 ~ 3.6 V</td>
<td>3.3 V / 5 V</td>
<td>3.3 V / 5 V</td>
<td>3.0 V</td>
</tr>
<tr>
<td><strong>Transfer Rate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>16.6MB/sec</td>
<td>12.5MB/sec</td>
<td>100MB/sec</td>
<td>10MB/sec</td>
<td>12.5MB/sec</td>
</tr>
</tbody>
</table>
Mechanical Feature of 0.85” HDD
The sensitive parts of HDD with external shock

(1) Disk winding and rolling

(2) Head suspension hitting on disk

Example of HDD mechanical roll analysis by FEM simulation
Load/Unload System

To avoid Head/Disk interaction by external shock, the heads frequently unload from the disk surface to the ramp potion while idling.

= There are no damage on head/disk interaction when the head escapes on the ramp. The shock durability while head unload state is higher than that while head on disk.
Some of mobile gadget have large buffer memories to temporarily store the HDD data, which minimize both the electric power and the head access frequency on disk in HDD.

ex. MP3 Player
Data size (1 song) 4–6 Mbyte
Play time 4–5 minutes (250-300 sec)
Buffer Memory size 64 Mbyte
HDD Data Transfer Rate 12.5 Mbyte/sec
HDD Data Access Time 0.4-0.5 sec

During 1 song play-out, the read head has to be on disk for data readings for only 0.3% term of whole play-out time.
Even in the ultra small 0.85” HDD, the basic structure is the same as the other large size HDD. JUST down-scaling!
The smaller radius disks are easy to show the higher shock robustness because of its small rolling and light weight.

The shorter head suspension arm length also shows higher shock robustness.

Therefore small sized HDD could achieve better shock durability.
Short Summary

• 0.85” HDD was developed for the large data capacity storage device which has the compatible size with the SD card memories.

• The head Load/Unload system is applied for the higher shock durability mobile device.

• The 0.85” small radius disk and the short head suspension realize almost same shock durability specification as the Flash card memory.
Keep Data Capacity Growth
What makes the areal density limit of the magnetic recording?

Thermal Magnetization Fluctuation

If the thermal energy “$kT$” is larger than the magnetic anisotropy energy “$K_u V$”, the particle magnetization is always easy to flip and very unstable.

Based on previous many experimental results, “$K_u V/kT$” should be larger than 60 to keep the magnetization amplitude for 10 years.

$$K_u V/kT > 60$$

$K_u$: anisotropy coefficient
$V$: volume of particle
$k$: Boltzmann constant
$T$: temperature
There are many magnetic particles in one data recorded bit to get fine S/N ratio.

The larger data capacity = Higher recorded density = Smaller data bit size = Smaller particle size

If $K_u V/kT$ becomes close to 60, …

- Smaller volume with same $K_u$, $= \times$ unstable magnetization
- Smaller volume with higher $K_u$, $= \circ$ stable magnetization, $\times$ hard to re-write the information with write head

The write head ability would define the limit of $K_u$. Then minimum particle volume $V$ will be limited to keep $K_u V/kT > 60$. 
Longitudinal Recording System

Write Ability:
Maximum recording field near gap
= 0.5 x head yoke magnetic flux density

Medium particle orientation:
- 2D random in disk plane
- About 50 particles in one data bit to keep fine S/N ratio

Higher linear density = thermally unstable
Lower linear density = thermally stable

MR/GMR/TMR Reader
Ring Write Head Yoke
Longitudinal recording field generating between head gap
Perpendicular Recording System

Write Ability:
Maximum recording field near gap = 1.0 x head yoke magnetic flux density = 2 times of LMR field limit

Medium particle orientation:
- Single orientation perpendicular to disk plane
- About 30 particles in one data bit to keep fine S/N ratio

Higher linear density = thermally stable

Lower linear density = thermally unstable
Remanence of high Hn medium keeps good thermal stability under low density demagnetized field

Temperature dependence of M-H loop of CoPtCrO Media

e.x. M-H loop of low squareness medium
1.2Mbit/inch (1200kbit/inch) linear density achieved with 137nm magnetic write track width head.

Over 1MBPI Performance

Required minimum Bit-Error-Rate

INTERMAG2005
MWW=184nm, uMRW=97nm

Longitudinal recording limit

MWW=137nm, uMRW=75nm

BER

BPI [MBPI]
Perpendicular recording HDD tends to higher BPI/TPI ratio than previous longitudinal HDD, which means the perpendicular HDD makes higher data transfer rate more easily.
# 8GB / 10GB 0.85” HDD Basic Specification
(Proto-type released in CES2006)

<table>
<thead>
<tr>
<th></th>
<th>4GB Commercial product</th>
<th>8GB Proto-type</th>
<th>10GB Proto-type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disk</strong></td>
<td>1 platter</td>
<td>1 platter</td>
<td>1 platter</td>
</tr>
<tr>
<td><strong>Head</strong></td>
<td>2 heads</td>
<td>2 heads</td>
<td>2 heads</td>
</tr>
<tr>
<td><strong>ArealDensity</strong></td>
<td>84 Gbpsi</td>
<td>159 Gbpsi</td>
<td>198 Gbpsi</td>
</tr>
<tr>
<td><strong>Track Density</strong></td>
<td>113 kTPI</td>
<td>165 kTPI</td>
<td>165 kTPI</td>
</tr>
<tr>
<td><strong>LinearDensity</strong></td>
<td>743 kBPI</td>
<td>960 kBPI</td>
<td>1195 kBPI</td>
</tr>
<tr>
<td><strong>Recording System</strong></td>
<td>Longitudinal</td>
<td>Perpendicular</td>
<td>Perpendicular</td>
</tr>
<tr>
<td><strong>Density Increment</strong></td>
<td>–</td>
<td>189%</td>
<td>236%</td>
</tr>
</tbody>
</table>
TOSHIBA

HDD Areal Density Trend

Areal Density

[Gb/inch^2]

1000

100

10

1

100%

60%

30%

MR Head, ID-less

CDR

Thin Film Head

Glass Media

MIG Head, Sputtered Media

FDB Motor

GMR

Ramp Load

PRML

Oriented Media

AFC Media

Perpendicular Recording & TMR Head

CPP GMR Head

30GB/Disk (2.5” Disk)

35-40%/Year

New Technologies

HDD Areal Density Trend

Year

88 89 90 91 92 93 94 95 96 97 98 99 00 01 02 03 04 05 06 07 08 09 10 11 12 13
Summary

• 0.85” HDD was developed for the large data capacity storage device which has the compatible size with the SD card memories.

• To utilize the ramp load system & temporary buffer memories, 0.85 HDD shock durability is almost cleared about 2000G on end-user operating.

• Applying the perpendicular recording technology, 8/10GB proto type HDDs were realized. This technology will keep areal density growth over 35%/year in coming 5-10 years.