Areal Density, Mbits/inch²

Year


10⁻² 10⁻¹ 10⁻¹ 10⁻² 10⁻³

10⁴ 10⁵ 10⁶

Areal Density of Magnetic HDD and DRAM

DRAM projections after 2001 are based on industry capacities and constant chip area.

25% CGR

40% CGR

60% CGR

100% CGR

Travelstar 80GN

Travelstar 40GN

Microdrive II

Ultrastar 146Z10

Ultrastar 30GN

Ultrastar 18XP

Ultrastar 3380E

Ultrastar 3390-2

1M 4M 16M 64M 256M 1G

256M 512M 1G 2G 4G 8G

25% = 2X per 3 years

Ed Grochowski

HGST

AREAL2002EN.P.RZ
Hard Disk Drive Areal Density Evolution

Source: Ed Grochowski, IBM

- Tunneling Head!
- Lab demos
- 1st GMR Head: 100%
- 1st MR Head: 60%
- 1st Thin Film Head: 25% CGR
- IBM Disk products
- IBM RAMAC (1st Hard Disk Drive)

Areal density (Gb/in²)

Production Year


100 Gb/in²

Anisotropy keeps the moment pointing in the direction of the track.

The transition width is affected by both the anisotropy and the magnetization.

Stuart Parkin
Magnetic Recording Heads

Anomalous Magnetoresistance (Ni$^{0.8}$Fe$^{0.2}$)

Giant Magnetoresistance (Metallic multilayers)

Colossal Magnetoresistance (Doped perovskite manganites)
Why are we interested in colossal magnetoresis materials?

MAGNETORESISTIVE READ HEAD APPLICATIONS

The basic idea is that the magnetic field of a recorded magnetization in a tape or disk ROTATES the magnetization angle which gives rise to change in resistance.

\[ R = R_0 + \Delta R \cos^2 \theta \]

What is measured then is voltage: \[ V = I R_0 \Delta R \]

Read head sensitivity

ANOMALOUS MR (Ni\text{Fe})
\[ \frac{\Delta R}{R_0} \approx 1\% \text{ in } 4 \text{ Oe} \]

GIANT MR (Magnetic/nonmagnetic superlattice)
\[ \frac{\Delta R}{R_0} \approx 10\% \]

COLOSSAL MR (doped manganites)
\[ \frac{\Delta R}{R_0} \approx 80\% \text{ in } 10k\text{Oe} \]

<table>
<thead>
<tr>
<th>Material Type</th>
<th>Change in Resistance</th>
<th>Thickness</th>
<th>Density</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANOMALOUS MR</td>
<td>( \approx 1% \text{ in } 4 \text{ Oe} )</td>
<td>250nm</td>
<td>1Gb/in^2</td>
</tr>
<tr>
<td>GIANT MR</td>
<td>( \approx 10% )</td>
<td>90nm</td>
<td>~10Gb/in^2</td>
</tr>
<tr>
<td>COLOSSAL MR</td>
<td>( \approx 80% \text{ in } 10k\text{Oe} )</td>
<td>30nm</td>
<td>~100Gb/in^2</td>
</tr>
</tbody>
</table>

3µm
Giant Magnetoresistance (GMR) in Multilayers and Spin-Valve Sandwiches

- metallic spacer between magnetic layers
- current flows in-plane of layers

**Multi-layer**
- $\Delta R/R \approx 110\%$ at RT
- Field $\approx 10,000$ Oe

**Spin-valve**
- $\Delta R/R \approx 8-17\%$ at RT
- Field $\approx 1$ Oe

Stuart Parkin