Thin Film Application in Magnetic Recording

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Read Head Development team
Hitachi Global Storage Technology

AVS North America Plasma Application 4-2013
Company of Vertical Drive Integration

Recording Head/Media are Built on Thin Film and Nano Technology

- Media MFG
- Head Wafer MFG - San Jose/JP
- Head Slider MFG
- Drive Assembly
- HDD Testing and Integration
- Servo/Channel

<table>
<thead>
<tr>
<th>Category</th>
<th>Drive ID</th>
<th>Speed</th>
<th>Size</th>
<th>Max Capacity</th>
<th>Area Density</th>
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<tbody>
<tr>
<td>Enterprise</td>
<td>Ultrastar 15K600</td>
<td>15000rpm</td>
<td>3.5inch</td>
<td>600GB</td>
<td>448Gb/in.sq</td>
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<td></td>
<td>Ultrastar C10K1200</td>
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<td>Ultrastar 7K1201</td>
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<td>100GB</td>
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<td>4000rpm</td>
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<td>100GB</td>
<td>172Gb/in.sq</td>
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</table>
Read Sensor is Key Element in Read Head to Sense Media Signal by Resistance Change.

Read Sensor: Tunneling Magnetoresistive Sensor TMR

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Building Read Head

1. Deposit Multilayer Sensor Stack
   (15-22 PVD Layers in 4-80 Å Level)

2. 193 Photo Mask for Critical Dimension
   (25-50nm Track Width)

3. Ion Mill or RIE Pattern Transfer

4. ALD Isolation and Hard Bias Stack

5. Liftoff

6. RIE Clean

7. Top Contact

8. Top Shield Plating
Read Head and Read Sensor

Fujitsu Reader TEM Image

250GB Earlier Generation Head;
Sensor Total Thickness 35nm.

Sensor/Junction/Isolation/HB/Shield
Read Head/TMR Sensor Working Principle

Reader Magnetic Config and Signal

TMR (Tunneling Magnetoresistive) Field-Resistance Sensor

FM1 //FM2

J. Zhu Chart

FM1 anti//FM2

NVE IEEE 2004

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Z. Gao
Read Sensor General Structure and Function

- **Capping Layer**: (10-50 Å; 1-3 Layers)
- **Free FM Layer**: (30-80 Å; 1-5 Layers)
- **Barrier Layers**: (~10 Å; 1-4 Layers)
- **Ref. + Pinned Layers**: (~30-60 Å; 2-10 Layers)
- **AFM Pinning Layer**: (40-80 Å; 1 Layer)
- **Seed Layers**: (> 20 Å, 2-5 Layers)

All Layers (>20) are Deposited in PVD Cluster w/o Vacuum Break (BP 5E-09)
Thin Film Plasma Treatment

Low Power Plasma Treatment Smoothes Film w few Å Removal

Hf Reduction and MR ratio Improvement:
Ref Layer (~20 Å) Roughness Reduction;
High Quality Growth of Spacer layer;
Improve Density and Resistivity of Ref FM Layer.

US Patent 026470A1 2004 IBM
Magnetic Anisotropy is Important for Both Reader and Writer.

Oblique Deposition

- Surface Morphology
- Strain Anisotropy $\Rightarrow$ Induced Magnetic Anisotropy
- Microstructure/Orientation

NiFe$_{25}$nm

NiFe$_{25}$nm/Ta$_{25}$nm

US Patent 6818961B1, Freescale, Filed 2003
NiCo Oblique, CNRS France, J. Appl. Phys 1992
Strong Anisotropy on Oblique Ta, NIST, J. Appl. Phys 2000
Large MgO TMR Ratio Observed due to Spin Filtering Effect

- Crystalline MgO barriers act as a spin filter → Large TMR (> 100%).
- Low electron effective mass → Low electrical resistance


$\Delta_1$ state decays rapidly in antiparallel alignment

$\Delta_2$ and $\Delta_5$ states are filtered out by barrier

IBM S. Parkin 2004

AIST Y. Yuasa 2004
MgO TMR Ratio Highly Sensitive to Barrier Process and Chamber Condition /Target Quality

Sputter Condition

Annealing Condition

Surface Roughness

Stack: Sub/Ta5/UL50/Ta5/NiFe5/IrMn8/CoFe2/Ru8/CoFeB3/MgO/CoFeB30/Ta5/Ru15 (nm)

Tohoku Univ. and Hitachi Ltd.
Thin Film Read Magnetic Sensor

MgO RA MR Ratio are Highly Sensitive to Interface Material and Structure in Atomic Level

Stack configuration:
- Top electrode
- Co$_{60}$Fe$_{20}$B$_{20}$ (3 nm)
- Co ferrite (x nm)
- MgO (1.2 nm)
- Co$_{70}$Fe$_{30}$ (3 nm)
- Ru (0.9 nm)
- Co$_{70}$Fe$_{30}$ (2.5 nm)
- IrMn (7 nm)
- Ru (5 nm)
- Bottom electrode

Thermally oxidized Si wafer

Anneal: 360°C, 2 h, 11

Intermag Jan 2013 Anelva
PVD Tools for Magnetic Sensor

Anelva 7100

Singulus TIMARIS

Ulvac ENTRON™-EX

Multiple DC/RF Cathode

Ultra High Vacuum (-9 to -10 Torr)

Angstrom level of control with uniformity

Wafer Size 150mm to 300mm
Summary

HDD is Abundant with Every Engineering Discipline

Thin Film Magnetics and Micro Fabrication Process Play Important Role in Recording Head Build and Head Performance

Thank You