PMR Media Technology

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Outline

• PMR Media
  • State of the art granular oxide media
  • Key current issues with PMR media
  • Media improvement opportunities
  • Beyond current media structures and designs
• Summary
Areal Density and Capacity vs. Time
95 mm Disk Capacities and Technology Transitions

- 100% CAGR
- 80% CAGR
- 40% CAGR
- Capacity/Platter (95mm)

Year of Product Introduction

Areal Density (Gbit/in²)

100% CAGR
80% CAGR
40% CAGR
Capacity/Platter (95mm)

DTR, BPM, HAMR?
Perpendicular
Long, SAF
Longitudinal

LMR and PMR Recording Geometries

Read Shield
Read Element
Write Shield
Recording Layer
Soft Magnetic Underlayer

LMR
PMR
LMR Media Structure

- Top Magnetic Layer
- Bottom Magnetic Layer
- Exchange Enhancing Layer
- Stabilizing Layer

CoCrPt-Oxide Perpendicular Media Structure

- Overcoats
- Capping Layer
- CoCrPtO Hard Magnetic Layer
- Ru-Alloy Interlayer
- Seed Layer
- SAF Soft Magnetic Under Layer
- Adhesion Layer
- Substrate (AlMg or Glass)
Comparison of LMR and PMR Media Cross-Sections

Typical Magnetic Domains in SUL Structures
Nucleation Layer

• Main purpose is to:
  • Break magnetic exchange between SUL and Recording layer
  • Control recording layer crystallographic orientation
  • Control recording layer grain size
  • Help with recording layer grain isolation

• These nucleation layers provide smaller magnetic grain sizes and more magnetic grain isolation.

Rocking Curves of Co and Ru (0002) Peaks

<table>
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<th>Ru ((\Delta \theta_{50}))</th>
<th>Co ((\Delta \theta_{50}))</th>
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<tr>
<td>S7817</td>
<td>2.68</td>
<td>3.29</td>
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<td>S7176</td>
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<td>2.26</td>
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<td>P8035</td>
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Magnetic Grain Morphology LMR/PMR

LMR

PMR

Current Issues with PMR Media

- **Production Ramp of PMR media**
  - Yields and Utilization
  - Cost Reduction
- **Learning curve for**
  - Drive and head integration
  - Measurements – magnetic and recording
  - Process monitor and control
- **Ruthenium problem**
  - Price went from <$200/troy oz. to over $800/troy oz in the last 4 months.
  - HDD industry is now the biggest consumer of Ruthenium
  - ~ 1M troy/oz mined per year = 1 m$^3$ of metal
  - Production of Ruthenium tied to Platinum mining (Quantity mined is not likely to increase on the short term).
PMR Media Improvements

- SUL domain noise is not a problem with SAF SUL structures.
- C-axis orientation is already very good.
- Physical grain size is rather small already.
- Magnetic grain size is optimized (increased somewhat) by adding intergranular exchange.

Given the above,
Where can we expect improvements to come from?

PMR Media Improvement Opportunities

- SUL Domain and Magnetic Noise Reduction
  - SAF SUL Structure improvements
  - Domain free SULs
- Grain Size Uniformity
  - DC noise reduction
  - Narrower transition parameter
- IL Thickness Reduction
  - Better writability \(\rightarrow\) Higher Hc
  - Sharper head field gradients \(\rightarrow\) Narrower transition parameter
- Improved Magnetic Layer Structures
  - ECC Media/Exchange Spring Media
  - Narrower transitions, better DC noise, better writability
How Much Improvement?

At the Intermag 2006 Conference:

- Limit of PMR recording using non-patterned granular media is placed at ~400-500 Gb/in$^2$ (E.g., R. Wood (CA01), S. Greaves (ER02), M. Kryder (ZA)).

- Current (or about to be launched) commercial PMR programs are designed at 130-180 Gb/in$^2$ recording.

- Assuming 3 to 4 dB SNR needed for every doubling of areal density, we will need to deliver 6 - 12 dB of SNR improvement on non-patterned, granular oxide media (of any kind).

Interlayer Thickness Reduction Effects

With IL thickness reduction we expect:

- Stronger writing fields
- Sharper write field gradients
- Higher OW
- Higher SNR
Optimizing Exchange in Granular Media

Intergranular exchange coupling is key for overwrite, SNR and nucleation field optimization. However, each of these properties optimize at different points so, tradeoffs must be made when optimizing media performance as a whole. Various approaches and schemes have been proposed to facilitate this task, e.g.,

- Capping layer media
- Coupled granular composite media, CGC

The capping layer approach is the most practical for performance and manufacturability.

Capping Layer Effect

Nucleation field improvement for ATI robustness
ECC and Exchange Spring Media

Introducing ECC media

Material with extremely high anisotropy $K_u$ and volume $V_{hard}$.
Store information. Provide thermal stability.

$\tilde{\xi} = \frac{2\Delta E}{M_s H V} \frac{K_u V_{hard}}{V_{hard} + V_{soft}}$

Soft material with volume $V_{soft}$ Facilitate switching of the grain.

This figure of merit term can be used to compare the switching fields of different kinds of media with the same thermal barrier, volume and magnetization.
Introduction to ECC media

\[ \xi = \frac{2\Delta E}{M_s H_V} \]

Perpendicular Media
\[ \xi = 1.0 \]

45° tilted Media
\[ \xi = 2.0 \]

ECC Media
\[ \xi \approx 2.0 \]

ECC Media Summary

- The switching process of ECC media include two steps: first, magnetizations of the soft regions coherently rotate to a certain angle; second, complete switching of each grain.

- ECC media switches more rapidly than conventional media.

- ECC media impervious to misalignment (up to 20°) of easy axes.

- The write field profile associated with ECC media is narrower in the cross track direction than that associated with conventional perpendicular media.

- The combination of enhanced thermal stability and reduced adjacent track erasure should allow recording at 1 Terabit/inch².
**Coercive Field of Hard Soft Structures**

\[ H_c = \frac{2K_{\text{hard}}}{J_{\text{hard}}} \left( 1 - \varepsilon_K \varepsilon_A \right) \left( 1 + \sqrt{\varepsilon_K \varepsilon_A} \right)^2 \]

\[ \varepsilon_K = \frac{K_s}{K_H} \quad \varepsilon_A = \frac{A_s}{A_H} \quad \varepsilon_J = \frac{J_s}{J_H} \]

\[ J_s = J_H \quad A_s = A_H \]

\[ H_c = \frac{1}{4} \times \frac{2(K_{\text{hard}} - K_{\text{soft}})}{J_{\text{hard}}} \]

\[ H_c = \frac{1}{4} \times \frac{2K_{\text{hard}}}{J_{\text{hard}}} \quad K_s = 0 \]

\[ H_c = \frac{1}{5} \times \frac{2K_{\text{hard}}}{J_{\text{hard}}} \quad K_s = K_{\text{soft}}/5 \]

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**Energy Barrier**

\[ \Delta E = 4F\sqrt{AK_i} \]

\[ L_H = \sqrt{\frac{A}{K_i}} \]

\[ \Delta E = 4F\sqrt{5AK_i} \]

\[ L_H = \sqrt{\frac{A}{5K_i}} \]

Hard layer thinner by 45%

Gain in energy barrier a factor of 2.24

Courtesy of Dr. Dieter Suess
Angular Dependence of Switching Field

Expected Exchange Spring media behavior

H₀ and Kᵤ V/kT of ES Media

n = 2/3 and fₜ = 1 GHz
**DTR LMR Process**

1. Clean textured NPP
2. DTR processing to form grooves by wet-etch process.
3. Sputter Full Stack LMR Media
4. Finished DTR LMR Disk

**DTR PMR Structure**

1. Clean Polished NPP
2. DTR processing to form grooves by wet-etch process.
3. Sputter Full Stack PMR Media
4. Finished DTR PMR Disk

- SAF Soft Underlayer (SUL)
- Etched NiP

NiP groove width/depth: 155 nm / 33 nm at 380 nm TP
Summary

- We are working on both performance and manufacturability aspects of PMR media.
- Much improvement in grain size, intergranular exchange, SUL noise and c-axis dispersion has already been accomplished.
- Opportunities for SNR improvement remain with IL thickness reduction mainly (must have appropriate heads to take advantage of such improvement).
- Additional improvements will be possible with new structures incorporating concepts from ECC and exchange spring media structures.
- Given the head and media strong interactions with PMR recording, need to work closely with customers to identify other areas of improvement based on specific applications.