DEVELOPMENT OF BIT-PATTERNED MAGNETIC RECORDING MEDIUM

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Overview

- UH Patterned Medium Project
- Patterned Medium Materials
- Ion-beam Proximity Lithography
- Patterned Medium Characterization
- Magnetization Reversal
- Summary
UH Patterned Medium Project goals

- **Bit-Patterned Medium Development**
  - Materials synthesis (using combinatorial sputtering)
  - Development of patterning approaches (ion/atom beam lithography)
  - Patterned medium evaluation
  - Self-assembly & molecular imprint extensions

- **Recording physics**
  - Micromagnetic modeling of magnetization reversal
  - Playback physics and reader design
  - Recording performance testing

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Patterned Medium Materials

- Materials parameters:
  - thermal stability
  - high intergranular exchange coupling

- Specific choice:
  - Extensibility
  - Possibility of patterning at nanoscale

- Options:
  - CoCr alloys
  - L10’s
  - Multilayers
Co/Pd multilayers

- High ($K_u > 0.5 \times 10^7$ erg/cc) and easily controllable (via thicknesses of Co and Pd layers) vertical anisotropy
- Strong intergranular exchange coupling
- Potential of electrochemical deposition (for ultra-high density patterning)

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optimization for continuous medium
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**Graph:**
- Kerr signal (a.u.) vs. Field (kOe)
- ITO buffer layer
- Ta buffer layer

**Images:**
- ITO buffer
- Ta buffer
Combinatorial Synthesis

- Magnetron sputtering is used for synthesis
- Combinatorial approach enables rapid optimization of materials parameters
- Vertical M-H loops are mapped using scanning polar MOKE
Co and Pd thickness calibration

- Co ~ 3-4 Å
- Pd ~ 3-7 Å

Intensity (arb. log units)

<table>
<thead>
<tr>
<th>Curve</th>
<th>Percentage</th>
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<tbody>
<tr>
<td>a</td>
<td>12%</td>
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<td>b</td>
<td>19%</td>
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<tr>
<td>c</td>
<td>30%</td>
</tr>
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<td>d</td>
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<tr>
<td>e</td>
<td>41.5%</td>
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<tr>
<td>f</td>
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Lattice parameter [Å]

Angle 2θ [°]

Percent Co
Published data suggest that (111) texture promotes higher vertical anisotropy
Ion Beam Proximity Lithography

- 30keV He beam (ion beam can be neutralized)
- Low secondary electron range (<1-2nm)
- Nearly no diffraction
- High resolution low density stencil masks can be fabrication using e-beam lithography
- Stencil openings can be shrunk, e.g., using conformal Au coating
- For typical configuration, elongation of the beam due to tilting is < 1nm
Direct Write Atom Beam Lithography

100 nm structures fabricated in massive parallel fashion
Stencil Masks

- While Si masks are in general superior, SiN$_x$ are significantly easier to fabricate.
- Protective coatings are required to minimize ion-implantation damage.
SiN$_x$ stencil masks

- 5 x 4 array of 300µm x 300µm squares.
- Feature size 150 - 300 nm.
Ultra-thin scattering masks

Ultrathin objects scatter the beam sufficiently to generate sufficient contrast for pattern transfer
Ion-beam Patterning Issues

- **Mask fabrication**
  - Reliable mask fabrication is critical. We have adopted SiNx membrane stencil masks – inexpensive and reliable alternative to Si membrane based stencil masks.

- **Pattern transfer**
  - Metal patterning at nanoscale is a challenge – anisotropic etching processes are not readily achievable.
  - The only high resolution negative resist available on the market (HSQ) has reliability issues.
  - Utilization of positive resists (e.g. PMMA) requires extra processing steps for tone reversal.
Pattern Transfer

- A negative photoresist Hydrogen Silsesquioxane (HSQ) is spun on (CoPd)\textsubscript{10} multilayer sample.

- The mask pattern is replicated on the multilayer sample which is placed \(~400\) µm away from the mask. A dose of \(9\) µC/cm\(^2\) is used to obtain the patterns.

- The pattern in the photoresist is transferred into the multilayers using sputter etching or ion milling.

High resolution process; however, at present, commercial HSQ has stability issues.
Patterned Medium

10x10 arrays
Size Distribution

Average size = 187 nm
Standard deviation = 5.85 nm
Patterned vs. Continuous Films

- Co: 3.2Å, Pd: 6.3Å
- Co: 5.1Å, Pd: 6.3Å

Field (kOe) vs. Kerr Signal (a.u.)

Continuous medium
Patterned Medium
Combinatorial wafer was patterned into array of dots. Variations in magnetic properties after patterning are observed.
Deposition Pressure dependencies

- **Patterned Medium**
- **Continuous Medium**

Increase in deposition pressure →
- Increase in coercivity and nucleation field of continuous medium
- Decrease in coercivity and nucleation field of patterned medium
Switching Field Distribution

Kerr Signals (a.u.) vs. Field (kOe)

Patterned medium

Continuous medium

Remnance Curve
hysteresis loop

remnance
hysteresis
• A positive field is applied to saturate the dots.

• A reversal field (Hr) is applied to the dots to partially switch the bits.

• MFM images are taken.

\[ \text{Switching } R = \frac{\text{Num. of switched dots}}{\text{Num. of total dots}} \]
Bit Size Effect on Switching

Switching field correlates with demag field.
Neighborhood influence

Switching field variations in excess of 30% are possible depending on adjacent bit magnetizations. Increasing spacing between the bits help minimize this dependence.
- Over-etched SUL is treated micromagnetically.
- Imaging boundary lowered to the etched surface
- $A=1.3 \cdot 10^{-6}$ erg/cm. $M_S=860$ emu/cm$^3$.
- The etched SUL acts as a ‘flux guide’.
Head-Bit Misregistration

The best writing conditions are not when the head is centered over the bit.
Summary

- Medium patterning available today is adequate for patterned medium physics studies.
- Continuing improvements of the patterning technology are critical.
- Magnetic multilayers represent a promising class of patterned medium materials.
- Open questions remain regarding the mechanisms of magnetization reversal and the factors affecting the switching field distribution.