Study of the Magnetoresistance Mechanisms in Pd - Ni multilayer system

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Outline

① Introduction
② Sample Preparation
③ Structure & Magnetic Profile
④ Electrical Measurements
   Experimental
   Data Analysis
⑤ Summary - Conclusions
Introduction

Magnetic multilayers: key configurations in Magnetoelectronics

- Utilization of unique micromagnetic, magnetooptic magneto-electronic phenomena which cannot be realized on the basis of conventional materials
- Interesting phenomena arising from: surface/interface effects, low-dimensional properties, coupling
- Anisotropic Magnetoresistance effect (AMR) is a galvanomagnetic mechanism known for more than 140 years
- Prototype hard disks heads based on AMR thin films
- Relation between microstructure, magnetism & electrical transport

Giant or Anisotropic magnetoresistance?
## Sample Preparation

### System

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$Pd_m$-$Ni_n$</td>
<td></td>
</tr>
<tr>
<td>Deposition Technique</td>
<td>e-beam evaporation</td>
</tr>
<tr>
<td>Parameters</td>
<td>$P=10^{-8}$ Torr, $T=400$ K</td>
</tr>
<tr>
<td>Buffer / Overlayer</td>
<td>30 nm Pd/5 nm Pd</td>
</tr>
<tr>
<td>Substrate</td>
<td>mica</td>
</tr>
<tr>
<td>Total Thickness Structure</td>
<td>200 - 400 nm</td>
</tr>
<tr>
<td>XRD, TEM</td>
<td></td>
</tr>
</tbody>
</table>

### Diagram

- **Pd**: 5 nm, 30 nm layers
- **Ni**: 1 < $m$ < 20
- **Total Thickness**: 200-400 nm
- **Substrate**: mica
Structure & Magnetic Profile - 1

- epitaxial growth
- [111] direction
- small-angle grain boundaries
- double-positioning &
- embedded twinning
- wavy form
- no columnar growth

non monotonic dependence on m,n for short wavelengths

structural modification & interlayer coupling
Structure & Magnetic Profile

$Pd_m\text{-}Ni_2$

![Graph showing magnetic properties](image)

$m$
- 2
- 3
- 4

$M_s : 50 \text{-} 70\%$

$m$ increase

Development of PMA
Structure & Magnetic Profile

\[ K = K_{u1} - 2\pi M_s^2 \]

- \( K_{u1} \) max values
- \( M_s \) variation 36%
- Shape anisotropy \( \sim M_s^2 \)
- \( K_{u1} \sim M_s^3 \)

\( Pd_4-Ni_2 \)
Electrical Measurements

Experimental setups

1\textsuperscript{st}: ramping applied field at fixed angle

2\textsuperscript{nd}: rotation of constant field

\[ \rho_{//} \leftrightarrow \rho_{\perp} - \rho_{//} \leftrightarrow \rho_{T} - \rho_{\perp} \leftrightarrow \rho_{T} \]

\[ \Delta \rho/\rho \% = [\rho(0,T) - \rho(0,T)]/ \rho(0,T) \]
Electrical Measurements – Experimental 1

\[ \rho_{\parallel} \leftrightarrow \rho_T \]

**Pd\textsubscript{2}-Ni\textsubscript{2}**

![Graph showing MR as a function of angle and magnetic field](image)

\[ \rho_{\parallel} \leftrightarrow \rho_\perp \]
Electrical Measurements – Experimental 2

\[ \Delta \rho / \rho \% \]

- **LN2 Temperature**
- **Room Temperature**

\[ m = n \]

\[ T = 300 \text{ K} \]

\[ H_s (Oe) \]

\[ M_{rem} / \text{m} \]
$$\rho(\Theta) = \rho_\perp + \Delta\rho_{AMR} \cos^2 \Theta$$

$$\Delta\rho_{AMR} = \rho_\parallel - \rho_\perp$$
AMR = Δρ/ρ_{av}, \quad Δρ = ρ_{∥} - ρ_{⊥}, \quad ρ_{av} = \frac{1}{3} ρ_{∥} + \frac{2}{3} ρ_{⊥}
\[ \rho = \rho_0(c) + \rho_{el-ph}(T) + \rho_m(T,H,\theta) \]
Summary - Conclusions

Anisotropic magnetoresistance was studied via two experimental setups in Pd-Ni multilayer system in correlation with structure and magnetic features.

A simple model to isolate the magnetic term from the over-all electrical resistance is proposed.

Size effects seem to play an important role to overall electrical response of multilayer systems.

Interface/bulk scattering mechanism becomes dominant by adjusting modulation parameters.

The optimization of anisotropic magnetoresistance may be achieved and tailor made electric response materials may be fabricated.

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