Optical Properties of Ni\(_{1-x}\)Pt\(_x\) Alloys and Ni\(_{1-x}\)Pt\(_x\)Si

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Funding Source: NSF (DMR-1104934)
Fundamental Equation Of Ellipsometry:

\[ \rho = \frac{R_p}{R_s} = \frac{E_{rp}}{E_{ip}} \cdot \frac{E_{is}}{E_{rs}} = \tan \Psi e^{i \Delta} \]

Angle of incidence

\[ \langle \tilde{n} \rangle^2 = \sin^2 \phi \left[ 1 + \tan^2 \phi \cdot \left( \frac{1-\rho}{1+\rho} \right)^2 \right] \]

\[ \tilde{n} = n + ik \quad \text{Complex index of refraction} \]

\[ n, k : \quad \text{Optical constants} \]

\[ \tilde{\varepsilon} = \varepsilon_1 + i \varepsilon_2 \]

\[ \varepsilon_1 = n^2 - k^2 \]

\[ \varepsilon_2 = 2nk \]
Data analysis

Experimental data

Build a model

Change model’s parameters

Generate data

Compare exp. and gen.
Match ???

No

Yes

<table>
<thead>
<tr>
<th>Layer</th>
<th>Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO2</td>
<td>2000 Å</td>
</tr>
<tr>
<td>Drude+Lorentz</td>
<td>100 Å</td>
</tr>
</tbody>
</table>
Lorentz Model: Oscillating Field

\[ m_0 \frac{d^2 x}{dt^2} + m_0 \gamma \frac{dx}{dt} + m_0 \omega_0^2 x = -eE(t) \]

Free Electron Model: Drude

\[ m \ddot{x} + \frac{m}{\tau} \dot{x} = -eE \]

Scattering Time

\[ \varepsilon = 1 + \frac{A}{E_0^2 - E^2 - i \gamma E} \]

\[ \varepsilon = 1 + \frac{-A}{E^2 + i \gamma E} \]
Samples and Experimental Details

- Films were deposited using **Physical Vapor Deposition**.
- Different Pt concentrations (0%, 10%, 15%, 20%, 25%)
- with/without annealing (500°C for 30 s)
- Room temperature measurements.
- **Fourteen angles of incidence (20° to 80°, steps of 5°)**
- Broad photon energy range (0.6 to 6.6 eV), 20 meV steps, 300 data points per angle. **2 nm resolution (1 mm slits)**
- Each measurement lasts **24 hours**
Dielectric Function

\[ \varepsilon_1 \quad \varepsilon_2 \quad \text{Describes absorption} \]

Optical Conductivity

\[ \sigma_1 = E \varepsilon_0 \varepsilon_2 \]

\[ -\sigma_2 = (1 - \varepsilon_1) E \varepsilon_0 \]

d to s Interband transition

d - Intraband transition
Ni$_{1-x}$Pt$_x$ optical conductivity for different compositions
Discussion:

Oscillator Model:
- Drude oscillator (free electrons)
- Lorentz @ 1.5 eV (d-intraband transition)
- Lorentz @ 4.7 eV (interband transition)
- IR pole @ 0 eV (???, see IR analysis later)
- UV pole @ 11 eV

- Same peaks were observed in pure nickel

- Annealed samples show higher conductivity than as deposited samples due to improved crystallinity

- Absorption peak gets broader with increasing Pt content
Formation of NiPt Silicides

START PHASE

At 500°C
Monosilicide

(Unreacted metal)
(Ni$_{1-x}$Pt$_x$)$_3$Si
Si

Room temperature
metal rich silicide

(Ni$_{1-x}$Pt$_x$)Si
Si
After annealing: Monosilicidès $(\text{Ni}_{1-x}\text{Pt}_x)\text{Si}$

- $\text{Ni}_{1-x}\text{Pt}_x$ (0%, 10%, 20%, 30% Pt)
- 500°C for 30 s
- Thickness of resulting silicide = 2*metal thickness
- $\text{SiO}_2$ is native oxide on NiSi.

Pseudo dielectric function for mono Ni silicide (0% Pt)
Results: Optical Constants of Monosilicide

0% Pt
240 Å

10% Pt
230 Å

20% Pt
220 Å

30% Pt
200 Å
Dielectric function for monosilicide

The graph shows the dielectric function as a function of photon energy (eV), with different concentrations of Pt (0%, 10%, 20%, 30%) depicted by distinct lines. The figure highlights two peaks, labeled as $\alpha$ and $\gamma$, which are significant in understanding the optical properties of monosilicide.
In $\text{Ni}_{1-x}\text{Pt}_x$ alloys, overlapping between Ni 3d states and Pt 5d states causes Ni DOS enhancement at low energies.

Same effect was seen in $\text{Ni}_{1-x}\text{Pt}_x$ monosilicides as Pt seemed to broaden the $\gamma$ absorption peak.

The dielectric function of monosilicides shows a Drude behavior driven by nickel as well as an interband absorption due to Si DOS.