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Effect of Sliding Contact on the Structure of Cu-X Nanolaminates

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Introduction:
Metallic nanolaminates consist of alternating nano-scale metallic layers and have increased resistance to dissolution flow due to high density of interfaces when compared to other composites. They have potential as both freestanding high-strength foils3 and wear-resistant coatings. Their mechanical properties (strength) can be tailored by controlling the component layer thicknesses1,2. Aims:
- Understand the effects of initial stress on mechanical behavior of model nanolaminates systems.
- Determine dislocation (and deformation zone) evolution of model nanolaminates as a result of dynamic loading.
- Elucidate residual stress evolution in nanolaminate films during thermal cycling.

Experimental Methods:
Fabrication of Cu/Nb and Cu/Ag:
- Substrate: (100) P-type silicon (R: < 2 nm).
- Deposition rates: 4.0 mm/min (Cu), 2.8 mm/min (Ag), and 2.8 mm/min (Nb).
- Total coating thickness: 1 μm (1000 nm).
- Individual layer thickness: 20 or 100 nm.
- Kunt J. Lesker magnetron sputter deposition system (COMSET).

Characterization of Sliding Deformation:
- Linear reciprocating wear tests conducted using CETR UMT-2.
- Counterface: 440C SS 3/8” ball bearing.
- Table 1 shows parameters used for the scratch testing.
- Plastic deformation observation using non-contact profilometry (Wyko white light interferometer) and field emission scanning SEM (Hitachi S-4800).

Table 1 Scratch test parameters used for this study.

<table>
<thead>
<tr>
<th>Load (N)</th>
<th>Velocity (μm/sec)</th>
<th>Length (cm)</th>
<th># of Passes</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>1</td>
<td>0.2</td>
<td>20 Passes</td>
</tr>
</tbody>
</table>

Results:

Initial Properties of Nanolaminate Systems:
- Hardness of nanolaminate systems exhibits similar trend described by the confined layer slip model2,3. Decreased layer thickness shows elevated hardness (Fig. 3A). Initial nanolaminate structures were formed (Fig. 3B, 3C, 3D).

Scratch Damage of Cu/Ag Systems:
- Upon observing morphology of the scratch path, a shift from flowing abrasion in the thicker system to cutting abrasion in the thinner system was noted. Additionally, a deeper scratch path on the 100 nm system shows that the thicker system undergoes more damage due to the sliding contact. These results are consistent with those described by previous work1, 2.

Sliding Friction of Cu/Ag Systems:
The coefficient of friction increases with the increase in bilayer thickness (Fig. 6), similar to trends described by previous researchers.

Scratch Damage of Cu/Nb Systems:
- When sliding contact was imposed on the 100 nm Cu/Nb systems, the films buckled due to compressive stress. Additionally, when viewed in cross-section, plastic deformation was observed. This deformation in the upper surface of the film was due to the scratching and not the delamination. Also, it was seen that this deformation was localized to the uppermost layers and did not penetrate through the thickness of the film.

Future Work:
- Further examination of friction progression in nanolaminates using scratch and wear testing.
- Examination of CuNi systems to complement CuAg and Cu/Nb.
- Use of FIB and TEM to examine dislocation evolution in individual layers due to deformation.
- Correlation with theory in dislocation dynamic simulations. Image taken from Miura1.

References:

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