Practical Stress Control in Electroforming

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The Nature of Things

(Definitions)

**STRESS** (Noun):

- The act, condition, or effect of exerting force on someone or something

*(Roget's Electronic Thesaurus)*

Deposit Stressed in tension (expanded spring) is “trying” to contract relative to the substrate.

Compressively Stressed Deposit (contracted spring) is “trying” to expand relative to the substrate.
Stress-Related Electroforming Problems

(A very condensed list)

- Loss of reproduction fidelity
- Electroform distortion (warpage, deformation, etc.)
- Premature form/mandrel separation resulting in the loss of mandrel and form
- Form oversized or undersized resulting in mandrel separation difficulty
- In extreme cases - loss of electroform integrity (cracking)
Manual Techniques for Measuring Internal Stress

Quantifying the problem

1. Spiral Contractometer

2. In-Tank Stress Cell and Bent Strip on Stand
In-Tank Stress Measurement Schematic

Digital Power Supply

Stress Cell or Spiral Contractometer

Plating tank

Anode Bar
## Bent Strip and Spiral Contractometer Comparison

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Bent Strip</th>
<th>Spiral Contractometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution (4μm/.00015 in deposit)</td>
<td>~10 Mpa*</td>
<td>~55 Mpa</td>
</tr>
<tr>
<td>Resolution (8 μm deposit)</td>
<td>~2 Mpa</td>
<td>~14 Mpa</td>
</tr>
<tr>
<td>Resolution (16 μm deposit)</td>
<td>- - -</td>
<td>~4 Mpa</td>
</tr>
<tr>
<td>Typical Setup Time</td>
<td>5 min</td>
<td>25 min</td>
</tr>
<tr>
<td>Typical Test Duration</td>
<td>~20 min</td>
<td>~60 min</td>
</tr>
<tr>
<td>Maximum Test Frequency</td>
<td>2 per hour</td>
<td>1 per day per available helix</td>
</tr>
<tr>
<td>Substrate cost</td>
<td>$3.00 ea.</td>
<td>$75.00 ea. (reusable)</td>
</tr>
<tr>
<td>Ability to Use Different Substrates</td>
<td>No</td>
<td>Yes, with purchase of add-l heli</td>
</tr>
<tr>
<td>Cost of Measuring System</td>
<td>&lt;$250</td>
<td>$1000 ($2000 w/ ext. Anode)</td>
</tr>
</tbody>
</table>

*Conversion: 1 Mpa = 145 psi*
Stress Profiles and Process Windows

Stress Profiles
(Nickel Plating Electrolytes)

Deposit Internal Stress, psi Thousands
0 5 10 15 20
Current Density, A/Dm^2

-10
-8
-6
-4
-2
0
2
4
6
8

Compressive Sulfamate
Watts-Type Bright
Conventional Sulfamate 1
Conventional Sulfamate 2
Conventional Sulfamate 3
Some Factors Affecting Deposit Internal Stress

(A partial list)

- Current density
- Concentration of most plating bath components (metal salts, conductive salts, buffering agents, wetters, etc.)
- Concentration of additives (organic or inorganic)
- Concentration of impurities (chemical and particulate)
- Bath temperature
- Agitation rate and direction of flow
- Solution pH
- Plating cell geometry (relative position/size of parts/anodes, shields, robbers)
- Composition and condition of anodes
- Anode/cathode surface area ratio
- Quality of DC power (ripple)
Practical Ways of Controlling Internal Stress in the Deposit

- Current density adjustment. Used primarily in automatic systems with a real-time stress monitoring device.
- Temperature adjustment. Can be used in the same mode as above.
- Organic additives. Can be used in manual or automatic modes.
- Ni-Speed system with S-free (‘passive’) auxiliary anodes.
- Periodic Reverse or Pulse Plating.
Some Useful Papers
On Deposit Stress Measurement and Control

Stress Control Summary
(Not a Recipe but Close)

1. Settle on a stress measurement technique
2. Study your chemistry and define variable(s) with a strong influence on deposit stress
3. Choose one control variable (the one you will be changing) and stabilize the rest
4. Decide on the frequency of testing and adjustments to the control variable
5. Implement the system and observe results
6. If unsatisfactory, go back to steps 1 or 2 and repeat all steps until happy with the result. If satisfactory, go to the next slide.
Stress is Eliminated

Sweet Victory