# Fast and Accurate Deposit Internal Stress Determination

*Berl Stein, CEF, NiCoForm, Inc., Rochester, NY*

Internal stress in plated deposits is a common problem that unchecked may affect the coating functionality and cause distortions in electroformed items. Ability to determine deposit stress in real time offers the plater a tool for preventing rejects before they occur. A modified bent strip technique for conducting stress measurements directly in the plating tank, developed several years ago and proven in a number of critical applications, will be described and compared to the traditional spiral contractometer method.

For more information, contact:
Berl Stein
NiCoForm, Inc.
72 Cascade Dr.
Rochester, NY 14614

Phone: 716/454-5530
Fax: 716/454-5167
e-mail: *platerb@earthlink.net*

Virtually all electro-, electroless and conversion coatings are deposited with some degree of internal stress. As plating and surface finishing applications diversify, more and more deposits must be obtained in a low stress or stress-free condition in order to function correctly. Electroforming imposes even more stringent requirements in terms of freedom from stress due to the heavy thicknesses of electrodeposits obtained and tight dimensional tolerances of electroforms in many applications.

Table 1 summarizes general guidelines assuring the quality of electrodeposits and integrity and dimensional stability of electroforms obtained under the listed internal stress conditions.

**Table 1**
**General Stress Guidelines for Quality Electroplating**

| **Type of Application/Deposit Thickness** | **Internal Stress Range, MPa** |
|---|---|
| Electroless or electroplating, 3 - 5 Fm | ≤ 500 |
| Electroless or electroplating, up to 25 Fm | ≤ 100 |
| Heavy electrodeposition, up to 100 Fm | ≤ +/- 30 |
| General electroforming, 1 - 2 mm | ≤ +/-15 - 20 |
| Optical electroforming, 1 - 2 mm | ≤ +/- 5 |

The demand for tighter deposit stress control in the more critical applications created a need for a fast, accurate and simple internal stress measurement method that could be used by line personnel in real time under actual manufacturing conditions. Such a test method, described below, has been recently developed by incorporating a number of improvements into the oldest stress measurement technique described by G. G. Stoney[1] in 1909.

Stoney's original idea was to coat one side of a thin metal strip with a non-conductive varnish and plate the exposed surface to the desired thickness in a particular plating bath. The radius of curvature that the plated strip assumed as the deposited layer underwent expansion or contraction under the influence of its internal stress in conjunction with the deposit and strip


**Figure 1 - Test Strip on Stand**

thickness and their mechanical properties could then be used to calculate deposit internal stress[2]. Difficulties associated with accurately measuring the radius of curvature of a single strip must have contributed to the fact that this simple, sensitive and straightforward method had been all but abandoned in favor of the spiral contractometer that had become the approved instrument[3] for testing plating baths for internal stress.

But a simple improvement, proposed in 1982 by Frank Leaman of Electrochemical Co., Inc., saved the old bent strip test. Adding a second strip facing in the opposite direction

**Figure 2 - Test Cell**

and a scale that the plated specimen could be mounted on (see Fig. 1) allowed to use a linear separation

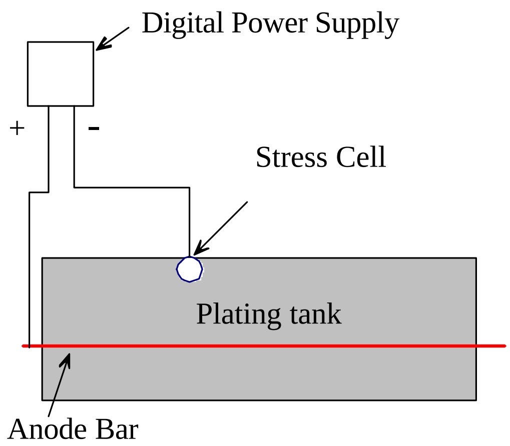


**Figure 3 - Stress Testing Schematic**

measurement instead of estimating the radius of curvature of a single strip. The additional benefit of this approach came from the fact the two strips were facing in opposite directions and, therefore, averaged the conditions in the plating cell (agitation and flow patterns, anode-to-cathode distance, etc.) providing for a more representative reading. Finally, since conditions in the plating tank can never be exactly duplicated in a test cell and one needs to have a measurement reflecting true tank conditions, a miniature in-tank test cell[4] was developed in 1995 (see Fig. 2).

Testing with the modern incarnation of the century-old idea is carried out directly in a plating tank, using tank anodes and a small separate power supply (see Fig.3). A study carried out to compare the spiral contractometer and the modernized bent strip method[5] resulted in data presented in Table 2.

The improved speed, convenience and accuracy of the bent strip stress testing method opened up new opportunities to the engineer who can now not only

**Table 2. Summary of characteristics of two stress measurement methods**

| | ***Bent Strip*** | ***Spiral Contractometer*** |
|---|---|---|
| Resolution (4 Fm/.00015 in deposit) | ~10 Mpa | ~55 Mpa |
| Resolution (8 Fm deposit) | ~2 Mpa | ~14 Mpa |
| Resolution (16F m deposit) | - - - | ~4 Mpa |
| Typical Setup Time | 5 min | 25 min |
| Typical Test Duration | ~20 min | ~60 min |
| Maximum Test Frequency | 2 per hour | 1 per day per available helix |
| Substrate cost | $3.00 ea. | $75.00 ea. (reusable) |
| Ability to Use Different Substrates | Limited to SS & Cu | Yes, with purchase of add-l helix |
| Cost of Measuring System | <$250 | $1000 ($2000 w/ ext. Anode) |

measure stress in a bath at a given set of conditions, but quickly record bath stress profiles, define process windows and select the optimum plating parameters based on this data. As an example, stress profiles for sulfamate nickel and nickel-cobalt baths are shown in Fig. 4. Obviously, the nickel-cobalt bath exhibits a wider process window offering greater process flexibility.

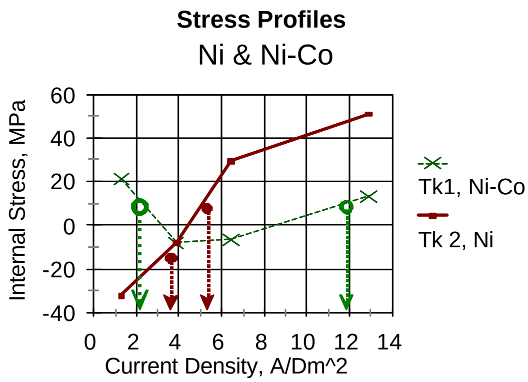


**Figure 4**

The advantages of the dual bent strip stress testing method may well change our approach to both monitoring and controlling the performance of existing processes and developing new ones. As daily stress monitoring becomes a routine 20-minute operation, having a stress history of a chemistry's performance will allow the chemist to spot early changes in the tank's behavior and develop quantitative methods for maintaining or restoring the desired stress level in the tank. Daily accurate control of electroforming tanks makes it possible to achieve higher reproduction fidelity for sensitive optical and electronics applications, opening up to electroforming a whole new range of products. And, finally, when new processes are developed, a low stress requirement can be incorporated into the design with little additional expense.

## References

1. Stoney, G.G., *Proceedings of the Royal Society*, A82:172; 1909
2. Popereka, M. Ya., *Vnutrennie Napryazheniya Elektroliticheski Osazhdayemych Metallov*. Novosibirsk, 1966
3. Test Method B 636-84, ASTM, Philadelphia, Pa.
4. B. Stein, *AESF Electroforming Symposium*, March 27-29, 1996, Las Vegas, NV.
5. G. Richardson and B. Stein, *1997 Electroforming Course and Symposium*. NIDI and AESF, San-Diego, CA.