Electroforming Course & Symposium Feature Latest Advancements

By Dr. James H. Lindsay

During the first three days in October, 49 attendees at the latest AESF/NiDI Electroforming Course and Symposium in San Diego, received a technical treat in the form of an excellent and informative program. Following on the success of a similar conclave in early 1996, the AESF and the Nickel Development Institute (Toronto, Canada) combined forces to produce another exemplary program.

Organized under the auspices of the AESF Electroforming Committee and the able talents of co-chairpersons Ron Parkinson (NiDI) and Dr. George DiBari (INCO), the meeting consisted of an updated version of the very successful short course on electroforming, plus a review of the latest technology in the field during the symposium program. Considerable credit goes to Parkinson, who literally created the course materials from scratch. It was a brilliant effort and reflects on his many years of experience. Dr. DiBari did an outstanding job in organizing a symposium that contained the latest developments in electroforming.

Electroforming involves fabricating a complete article by electrodeposition, generally by plating on a mandrel (or, loosely, a mold) and separating the formed part from that mandrel. Sizes range from surface areas on the order of square meters to thickness levels of Angstrom units in electronics. If you drive a car, wear an item of clothing with a printed fabric, listen to music in a CD player or use CD-ROM software, you are directly benefiting from electroforming.

Opening session speakers at the AESF/NiDI Electroforming Symposium were (l-4): Jim Logsdon, Glenn Malone, Jack Horner, and organizers Ron Parkinson and Dr. George DiBari.

Following an introduction, the course was divided into several sections:

1. Basic principles and metals selection;
2. Deposit properties and their measurement;
3. Mechanical properties;
4. Mandrels;
5. Technology for compact discs, holograms and screen products (those print fabrics again!);
6. Electroformed molds and tooling;
7. Aircraft and aerospace components; and
8. Other end uses, including metal foils and foams, seamless belts and currency.

In the symposium that followed the short course, there was something interesting for everyone. The wide range in scale of electroforming operations was best illustrated by three papers, dealing with electronics, compact discs and aerospace applications.

Electronics & Electroforming

The electronics end of electroforming was very well presented by Dr. Lubomyr Romankiw of IBM. The size, detail and precision with which circuit elements can be electroformed today is impressive. Electroforming has been applied to printed circuit boards, connectors, chip carriers, input/output devices, storage devices and memory/logic devices. New copper plating technology has facilitated the dream of a "computer on a chip." X-ray lithography has allowed resolution of patterned conductive paths down to the Angstrom level, with aspect (height-to-width) ratios as high as 120:1. Perhaps the most impressive item that Dr. Romankiw described was an electroformed planar motor, done with lithographic patterning, which

Others appearing on the program included (l-r): David Bolser, Dr. Lubomyr Romankiw, Berl Stein, Glenn Malone, Darrell Engelhaupt, Myron Browning, CEF, and Gary Giles.

was 1.5 cm in diameter. Each magnet in the assembly had 108 conductive copper coils wound around it, all formed by electrodeposition. A video showing it operating at 800 rpm (with the potential of reaching 10K rpm) drove the point home dramatically.

Compact discs (CDs) have become so commonplace in our lives, that it is hard to believe that the bulk of recorded music was on vinyl LPs and computer storage was on 5.25 in. magnetic floppies a mere 10-12 years ago. Every single disc exists, thanks to nickel electroforming technology. David Bolser, of Sony Music Entertainment, described the vital role of our industry in CDs. The fidelity required in reproducing surfaces of CDs is considerably greater than that required for LPs. Thirty CD tracks will fit within a single groove of a conventional LP, which is itself the diameter of a human hair. Each of those 30 tracks are spaced 1.6 µm apart and contain precisely shaped pits with minimum lengths of 0.83 µm. The new digital video disc (DVD) technology is more challenging, with 0.74 µm track spacing and minimum pit lengths of 0.40 µm. It was interesting to learn that an atomic force microscope is used as a reliable non-destructive tool for quality-control measurement.

The nickel electroform on a CD is nominally 300 µm thick. Initially, the electroforming solutions for CDs were the same as that for LPs, but the stresses induced in conventional processes posed problems. Bolser described how the process was reformulated with a chloride-free sulfamate process, using pure nickel anodes. Bromide was substituted for chloride to promote proper anode corrosion. In record-manufacturing terms, the result was a “stamper” that was “dead flat,” with very low stress at the production thickness, while still holding the pit geometry definition.

Large-scale Electroforming

In terms of large-scale electroforming, Glenn Malone, of Electroformed Nickel (ENI), described several interesting examples in his talk, “Copper Electroforming Success Stories.” This scale of operation, where one electroforms rocket thrust chambers and other more esoteric devices, has its own special challenges, which Malone has met well throughout his career. One device used in physics research to measure the energy created through certain laser devices consisted of an oblate spheroid (kind of a cross between a football and a bagel, without the hole), 26 in. in diameter, with a built-in water cooling manifold with connecting copper tubes. An epoxy mandrel, replicating the inner surface of this device, was fabricated, conductive-painted and plated with copper to a thickness of 0.32 cm (1/8 in.). Acid copper with periodic current reversal was the key to low stress and dimensional stability. The fittings were also grown in place, which is called “stage electroforming.” Final finishing and the challenge of removing the mandrel, more easily said than done, were also discussed.

Malone also described the copper electroforming of 192 formed tubes for a tube bundle rocket thrust chamber. The tubes, having been formed and arranged in their design position, were electroformed on the outside with copper. The first stages required that the deposit consist of the smallest equiaxed grains possible. This was accomplished again with periodic reverse plating. Once the spaces between the tubes were filled in, more conventional plating techniques could be used to complete the job.

The sulfamate bath has been the mainstay of nickel electroforming. For a variety of reasons, including high strengths and other physical properties, interest in nickel-tungsten alloy electroforms has come to the forefront. The main problem has been the high internal stress of alloy deposits versus the pure nickel metal. Chein-Ho Huang, of Soochow University in Taipei, Taiwan, described work to develop a low-stress nickel-tungsten deposit suitable for electroforming. He reported success, using a variety of stress reducers. Both low and high current density areas benefited (current range from 2.5 to 80 A/dm^2). The tungsten content was 4 percent.

Concern with internal stress is not just limited to alloys. Electroforming of pure metals requires meticulous control of stress. There are many methods of measuring it, and G. Richardson and B. Stein, of Reflexite Precision Technology, reported their work on comparing three stress measurement methods. They were:

- The spiral contractometer
- The I-S, or change-of-length meter, where the deposit stress causes a change in the length of a calibrated strip
- The bent strip test, where stress induces curvature in a straight strip. The authors found the length change meter to have advantages in terms of resolution, ease of setup, test duration and cost

Computer Control

Computer control in electroforming technology has received much attention in recent years. It was the subject of two papers in the symposium. In the first, Dr. Darrell Engelhaupt, of the University of Alabama at Huntsville, discussed the automated control of electroforming. His experience has been in the very property-critical field of large optical mirrors. In addition to controlling solution chemistry of a sulfamate bath, he focused heavily on internal stress, which is critical to successful electroforming of mirrors. The concept of monitoring current density/stress relationships and letting the computer do what was necessary to keep the stress at zero was discussed. Dr. Engelhaupt also enlightened the audience on computer control considerations for passivation of mandrels, to facilitate separation of the part from the mandrel.

In the second computer-related paper, Gary Giles, of Oak Ridge National Laboratory, discussed BEPLATE, an electroforming design tool. By using boundary element techniques, this deposit distribution program moves the growing surface, modifying the current distribution at the same time. In the first generation of this program, the model predicted the actual experimental distribution within 4 percent. Giles cautioned listeners that the program was adequate for some models, but had limitations in calculating what happens at corners. Nevertheless, it appears to give a reasonable estimate of distribution for the geometries considered in his work.

The Electroforming Course and Symposium provided an excellent review for the experienced practitioner, or for those just entering the field. The combined events provided the most up-to-date information on this increasingly sophisticated technology. P&SF