1983

Electroplating and electroforming as an Artists' Medium

R Lisa Toser

Follow this and additional works at: http://scholarworks.rit.edu/theses

Recommended Citation

This Thesis is brought to you for free and open access by the Thesis/Dissertation Collections at RIT Scholar Works. It has been accepted for inclusion in Theses by an authorized administrator of RIT Scholar Works. For more information, please contact ritscholarworks@rit.edu.
A Thesis Submitted to the Faculty of
the College of Fine and Applied Arts
in Candidacy for the Degree of

MASTER OF FINE ARTS

ELECTROPLATING AND ELECTROFORMING
AS AN ARTISTS' MEDIUM

R. LISA TOSER
September 1983
I gratefully acknowledge my thesis committee of Amy Davison, John Dreibelbis, Gary Griffin and Graham Marks. Also Chunghi Choo and my experience at the University of Iowa was a very valuable part of this thesis. I especially want to thank my family for supporting my ambitions all along.
APPROVALS

Adviser: Amy Davidson
Date: May 15, 1984

Associate Adviser: John F. Dreibelbis
Date: 11/24/84

Associate Adviser: Gary Griffin
Date: 14 May 84

Associate Adviser: Graham Marks
Date: May 15, 1984

Assistant to the Dean for Graduate Affairs:
Date: 5/15/84

Dean, College of Fine & Applied Arts:
Date: 5/15/84

I, R. Lisa Toser, prefer to be contacted each time a request for production is made. I can be reached at the following address.

R. Lisa Toser
4622 Oxford Road
Harrisburg, PA 17109

Date: May 15, 1984
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Definitions</td>
<td>2</td>
</tr>
<tr>
<td>Use of Electrodeposits</td>
<td>5</td>
</tr>
<tr>
<td>Reasons for Electroforming</td>
<td>7</td>
</tr>
<tr>
<td>Matrix Materials</td>
<td>10</td>
</tr>
<tr>
<td>Attaching the Matrix to the Cathode Wire</td>
<td>15</td>
</tr>
<tr>
<td>Making the Matrix Electrically Conductive</td>
<td>17</td>
</tr>
<tr>
<td>Resists</td>
<td>20</td>
</tr>
<tr>
<td>Process of Electrodeposition</td>
<td>21</td>
</tr>
<tr>
<td>Removing the Matrix</td>
<td>27</td>
</tr>
<tr>
<td>Finishing Techniques</td>
<td>29</td>
</tr>
<tr>
<td>Mold Making</td>
<td>30</td>
</tr>
<tr>
<td>Artist's Statement</td>
<td>32</td>
</tr>
<tr>
<td>Bibliography</td>
<td>36</td>
</tr>
<tr>
<td>Appendix A - List of Suppliers</td>
<td>38</td>
</tr>
<tr>
<td>Appendix B - Silver Compounds</td>
<td>40</td>
</tr>
<tr>
<td>Appendix C - Electrodepositing Set-up</td>
<td>41</td>
</tr>
<tr>
<td>Appendix D - Deposit Rate</td>
<td>42</td>
</tr>
<tr>
<td>Appendix E - Deposit Distribution on Electroforms</td>
<td>43</td>
</tr>
<tr>
<td>Appendix F - Tree Diagrams for Production Pieces</td>
<td>44</td>
</tr>
<tr>
<td>Appendix G - Photographs</td>
<td>45</td>
</tr>
</tbody>
</table>
INTRODUCTION

Electroforming is the vehicle which allows me to create my pieces in an expressive, esthetic style that could not be transmitted with the traditional metalsmithing techniques. This process allows me a directness and flexibility which is intrinsic to my style of working.

Since there are so many different approaches to the use of electroforming, the information here should be regarded as reference and not as a complete source of information. My objective is to use this process for the purpose of making art objects and exploring the technique within that limit.

It is my intent to call to the attention of metalsmiths and other artists the unlimited creative potential of electroplating and electroforming. I also wish to extend metalsmithing techniques to include decorative and practical applications such as an artist's medium or a commercial production line.

The information I am providing refers to what can be achieved with the process once the system is installed. For more technical information and starting your own system you can refer to the bibliography and list of suppliers.  

1Appendix: List of Suppliers.
DEFINITIONS

Electroplating and electroforming require knowledge in chemistry, physics, metallurgy, electrochemistry, electrical engineering, and mathematics. This paper is a summation of my experiences to date with the processes of electroplating and electroforming.

It is necessary, first, to distinguish between the terms electroplating and electroforming and provide a brief description of the process. The words electroplating and electroforming are often used interchangeably; however, they are not synonymous. Electroplating is the process of depositing a coating of metal by means of electrolysis. Generally this is done to improve the appearance of materials, protect against corrosion, improve resistance to abrasion, alter the dimensions or cut down on the cost of various materials. Electroforming is defined as the production or reproduction of an article by electrolysis on a substance that is later removed from the electrodepos.

---


Since the electroform is used as a separate structure, it must have a thicker coating than an object that is plated. The process of electroforming is therefore more time consuming than electroplating.

Electroplating has been used since 1833. Michael Faraday, an English physicist, experimented with electro-chemistry and discovered electroplating which in the early days was referred to as galvenoplasty. The discovery of electroforming is dated at 1838 with reports of it being used for the reproduction of works of art, printing and dental applications.

The term electrodeposition includes the terms electroplating and electroforming. In the process of electrodeposition metal ions are transferred electro-chemically through a solution of electrolyte from a metal source known as the anode to a surface where it is deposited as atoms of plated metal. The deposited surface is referred to as the cathode.

The electrolyte is the medium that carries the current by means of ions. The current can be supplied by dry cell batteries or more practically by an electroplating rectifier which changes the alternating current to direct current. The electricity is carried across the electrolyte by the charged ions and products of electrolysis appear at the electrodes. This is a result of the positively charged ions being attracted to the negatively charged cathode while the negatively
charged ions travel toward the positively charged anode. The charges of the ions are then neutralized by the charges on the electrodes and the products of electrolysis appear at the electrodes.\textsuperscript{5}

USE OF ELECTRODEPOSITS

Both electroplating and electroforming have generally been used as industrial processes, although electroforming is used to a lesser extent. As an art form electroforming has been used for over 100 years.\(^6\) There is an increasing demand for these processes, particularly in the communication and aerospace fields. Rapid progress has been made in recent years with respect to the technology behind electrodeposition. A better understanding of electrochemical factors, the role of addition agents, and closer control of the electrolyte or solution are among the developments, as is more technologically advanced equipment.

Electrodeposited coatings for decorative and protective use are generally less than 2 mils thick. Deposits up to \(\frac{1}{2}\) inch or more are not uncommon for electroformed metal, since it will be self supporting.

I visited Sheller-Globe Corporation in Iowa City, Iowa, the largest electroforming operation in the United States. They electroform over mandrels, usually of fiberglass and plastic, which are sent to them by contractors. The scale and complexity of electroforming varies tremendously there from airplane wings

---

\(^6\) Carlin, p. 463.
and torpedoes, to car parts and dies for industry. The company uses nickel solutions and some of the large pieces are electroformed for forty days to the thickness of .185 of an inch.
REASONS FOR ELECTROFORMING

The reasons for electroforming instead of using more traditional metal techniques are similar for both industry and the artist. Electroforming is often the only practical way of making a piece. In order to make some pieces it may first be necessary to make the tools to machine the piece and then manufacture the piece. This could become quite expensive. Electroforming also becomes an economical means of making complex shapes and seamless objects. An artist can form hollowware in less than a quarter of the time it would take to raise metal. While one piece is forming in the tank, the artist can be working on other pieces, finishing waxes or buffing. Also, more than one piece can be formed at the same time. Saving time and money are the main reasons for industry's using the process of electroforming.

Electroforming has the ability to form metal around dissimilar objects which could not easily be set or incorporated in a piece. For example, an artist may want to join an irregular shaped stone or found object with metal. The possibility of combining media that could be joined no other way, i.e. glass and metal, allow for endless possibilities and recombinations of craft materials. Industrially, this technique allows for parts such as threaded inserts, bearing surfaces, and shafts to be incorporated into the piece by plating onto, over
or around the major piece. These are frequently referred to as "grow-ons." Two parts could also be formed separately by electroforming, machined to mate, and then joined in a second electroforming. By electroforming these separate pieces, operations like welding and other joining techniques can be avoided without any sacrifice in strength.

For the artist there are other advantages in choosing this process. The artist can capture spontaneous expressions by modeling his piece in a material and then forming it in metal. This approach to creativity is in contrast to most traditional metalsmithing methods where careful planning and stress on technique often overlook spontaneity and the design. One may argue that casting allows these freedoms as well, but in casting, there is a weight and size limitation. The size of an electroforming is only limited by the size of the tank.

Probably the best reason for using this technique is that electroforming gives the artist esthetic results that could be attained by no other method. When setting stones, especially free form shapes, one can electroform a bezel very natural in appearance. Textures can be created unlike those produced any other way. Electroforming is a versatile tool especially for the artist working in metal who may use the process in his own creative way to fit his method of metalworking. The
potential of this process can not be fully realized until one forms an object, removes the matrix, and is left with a thin; yet, voluminous structure or shell.
MATRIX MATERIALS

The object which is electroformed over is referred to as the matrix, mandrel, or master. Matrices are generally inorganic or synthetic so that there is no contamination of the plating solution. Organic materials may be used if they are sealed, i.e. with wax, lacquer, or varnish. Tests should be conducted to assure no contaminate enters the solution. One should take a sample of the solution and soak the piece in it for an hour. If the object remains unchanged and the solution does not cloud, the object most likely will not contaminate the solution. This is not a foolproof test. Sometimes a substance may contaminate the solution without altering the matrix, therefore, one must be cautious about organic materials.

In the case of a copper sulfate solution, the matrix must be able to withstand the concentration of the copper sulfate of the bath. In other cases, it may be necessary to see if the matrix will withstand the temperature of the solution.

Matrices are classified either as permanent or expendable. Permanent mandrels can be separated from the electroform without damage to the mandrel. An expendable mandrel is used where there are undercuts. These mandrels must be dissolved or melted out, in order to free the electroform. Occasionally the entire mandrel or portions
may remain an integral functional part of the electroform in the case of glass or clay.

I have experimented with electroforming over several permanent mandrels, namely plastics and porcelain. Plastics offer a wide range of possibilities with the availability of sheet, tubing, and rod and a variety of transparent, translucent, and opaque colors. These materials may be machined and heat formed and metal can be designed over the surface with electroforming. Epoxy resins, noted for their chemical stability, excellent water resistance, and remarkable reproduction of fine detail, offer electroforming possibilities as well.\(^7\) When acrylic is used as a matrix, one might want to roughen up the gloss surface to assure good adherence to the metal. A shotblasted or sandblasted surface will suffice.

Electroforming on porcelain is another permanent mandrel I have experimented with. I chose porcelain instead of other clay bodies because of its high vitreousity when it is fired to temperature. The chemicals of the electrolyte can leach into other clay bodies and contaminate the solution. When forming metal over a glazed clay surface the same problem of metal adherence encountered when forming over acrylic occurs. There are several workable solutions to this problem which may be

\(^7\)Lester F. Spencer, "Modern Electroforming" Metal Finishing (February 1973), p. 69.
adapted to the acrylic surface as well. One may create a textured surface where the metal is to be deposited, to give the metal an adherent base. Also, one could design the piece and have as many areas as possible going around corners or provide undercuts. By designing areas that would be under stress the metal would cling to the clay surface through tension. Another alternative, instead of using glazes for color, is to add colorants directly to the clay body. Thus, the metal does not have a tendency to peel off because of the texture of the clay.

A metal matrix may be used as a permanent part of a piece. The metal must be thoroughly cleaned and finished to the point of perfection. Before entering the electro-forming tank it should be cleaned electrically in an electrocleaning solution.

Of the expendable matrix materials I am basically electroforming over styrofoam, microcrystalline wax, injection and dental waxes. Each type of matrix has its own peculiar qualities and one must experiment to explore other possible matrices.

Wax is probably used most often by the artist. There is a wide variety of waxes to choose from. One type of wax, microcrystalline wax, has the widest range of possible working techniques of any material and may be formed and refined with rasps and files. When it is heated, microcrystalline wax may be used as a liquid dip or paint, when cooled slightly, may be spread like paste or
modeled, and when frozen, has the ability to be machined. Given this wide range of possibilities, wax can be prepared in sheets, slabs, and wires or objects can be created by dipping, casting, pouring, and sculpting. Microcrystalline wax may be melted with waxes that are harder, for example paraffin so that there are more workable possibilities with the material.

By borrowing techniques and processes from metal-working and other craft areas one can apply these ideas to electroforming. By dropping hot wax into water, as is done with hot metal, one can achieve interesting accidental results that may then be electroformed.

I also use dental waxes and injection waxes for matrices. These wax materials may be approached in the same manner as a piece for casting would be prepared; however, instead of attaching them to sprue wires, it is necessary to design metal racks which will be discussed later in the section dealing with production electroforming. In this way, numerous small scale pieces can be produced at the same time.

Styrofoam is another major matrix material which I have used extensively in my experiments. This material can be carved, sawed, sanded, or laminated with thin wax layers. Since it is a health hazard to burn styrofoam, one should avoid modeling the surface with heat and wear a respirator while working with this material. Chemicals that will dissolve the styrofoam may create some exciting
designs and textures. In my work, I generally use styrofoam in combination with wax.

Low melting point alloys are commonly used as expendable mandrels. This metal would be removed from the electroformed metal. A number of proprietary mold lubricants are required to insure separation, such as silicones and dispersed graphite. After electroforming, the matrix material is removed by immersing it in hot silicon oil. Plaster mandrels may also be used and then chipped out. Difficulty of removal is a disadvantage to metal and plaster matrix materials.
ATTACHING THE MATRIX TO THE CATHODE WIRE

No matter which matrix material or combination of materials is used, a piece of copper rod or wire should be attached to the matrix when it is completely finished. The connection of the wire should be in an inconspicuous place, ideally at an opening or at the bottom. Since this wire serves to conduct electricity, it must make contact with the areas to be electroformed if the electrical circuit is to remain unbroken.

It is simple to attach this cathode wire to the wax. Heat the rod and insert it in the wax. The wire and the matrix are referred to as the cathode. The metal around the contact point of your matrix must be clean and free from wax.

The acrylic matrix can be connected to the cathode rod by drilling a hole in the acrylic at the side or end. The cathode wire is inserted in this hole. The connection can be insured by using epoxy. An alternative could be to design the piece so that an extra section would be cut off later which attaches to the cathode wire.

Connecting wires to the clay pieces can be a problem. If the circumstances allow, simply wrap copper wires around the porcelain piece or in other cases make a metal basket and lay the ceramic object in the basket. It will make contact points at several places. However, turn the work at regular intervals to insure even plating and to prevent attachment to the basket.
Styrofoam presents its own problems and the major one is its tendency to float. If the matrix can be weighted down with another material that would be advantageous. I usually use two cathode rods to steady the piece in the tank, making deep holes first for the rod and filling them with hot wax, then inserting the rod. One could also design a piece with an extra section which would later be cut off, as suggested with the acrylic matrix material.

The connection of the cathode wire to a piece of metal is strongest if it is soldered. It can be sawed off afterward.

The size of the wire used for the cathode is dependent upon the scale of the piece. The current will flow better with a heavier wire. If the wire is too small it will heat up, indicating that both the cathode and the rectifier are being over taxed with possible detrimental effects to the matrix.

Any portion of the cathode wire not making contact with the area to be plated can be coated with lacquer, wax, or electrical tape to prevent the bare wire from robbing the deposit. The current will still flow through the metal, but there will be no unnecessary plating. Remember to leave bare wire about \( \frac{1}{4} \) to \( \frac{1}{2} \) inch above the contact point with the matrix and at the area where the rod will make contact with the cathode bar of the electro-forming tank.

-16-
MAKING THE MATRIX ELECTRICALLY CONDUCTIVE

When the cathode wire is attached to the matrix, it must be made conductive. It is best not to handle the matrix surface in any way once it reaches this stage. Make sure the piece is free from dust or contaminating particles on the surface.

Making the matrix conductive may be done in a variety of methods; the simplest is to paint the object with a silver conductive lacquer. These paints contain 60-70% silver pigment. Most commonly, the lacquer is brushed on the matrix either with an air gun or by hand. Since the lacquers are expensive, industry uses an air gun. In this way, a thinner consistency of paint can be used, an even application can be assured, and time can be saved. The artist can save money by using an air gun and by coating matrix materials that are absorbent like styrofoam with a thin layer of wax or polyvinyl alcohol (Elmer's Glue).\(^9\)

Acheson Colloids Company in Michigan produces an excellent silver lacquer under the brand name of "Electrodag 416" and Dupont makes a silver conductor, No. 4817. These companies make other compositions; however, those listed above are most widely used in electroforming.\(^{10}\)

\(^9\) Appendix B: Silver Compounds. Burt Bricker, Inc.

\(^{10}\) Appendix B. Silver Compounds.
One major difference in these companies’ products is the drying time of the lacquers. The Dupont conductors dry in 24 hours while Acheson's product is approximately ten minutes. The lid must be kept on these paints as much as possible due to the high evaporation rate of the solvents. These lacquers must be thoroughly mixed before using and may be thinned with ethyl alcohol.

The next step is to apply the conductive lacquer wherever the metal is to be deposited. A line of conductive lacquer needs to connect the cathode rod to the edge of the matrix. There should be no breaks or interruptions to the painted design. If it does not connect in any way to the design, it will not plate. After the first coat has dried, it is necessary to touch up areas on the piece that are thin. Avoid bristles and particles on the surface of the matrix. Any texture will be evident on the piece. The quick drying Electrodag should be placed directly in the electrolyte once it has thoroughly dried because the silver content will begin to tarnish when exposed to the air.

For those who are interested in other methods of metalizing the matrix, I will list some alternatives. A more descriptive methodology may be found in Lowenheim's book Modern Electroplating. There is a chapter devoted to metalizing non-conductors. One way to make a surface conductive is to use metal powders. They are applied to a varnished surface while it is still tacky. Graphite may
be used to make a surface conductive. This process can be done either by dry brushing or with a suspension of graphite in water. These surfaces are frequently further coated with copper to improve conductivity. Metalizing by chemical reduction or mirroring is another method; however, these chemicals are dangerous and if anyone is interested in this process extensive research must be done. Metallic paints and lusters from the ceramic and glass industries may be used also.
RESISTS

If there are areas that are not intended to be electroformed or plated a resist will have to be used. This is done by leaving that area unpainted in the case of electroforming or stopping out the area in electroplating. In electroplating, a resist must be applied to the area that is to remain unchanged and protected from the chemical action of the bath. Wax, shellac, lacquer, etching resist, or commercial stop out lacquers may be used. For example, Micropeel manufactured by Michigan Chrome and Chemical Company is excellent because it will peel off when it is ready to be removed.

The potential of stop outs is another facet of electroplating and electroforming that can be explored. By plating different metals and stopping out various areas, a new form of marriage of metals can be experimented with. Stop outs offer a means of precise demonstration and their use can go far beyond that of utilitarian protection. Patterns can be created and the technique of applique can be explored.
PROCESS OF ELECTRODEPOSITION

From this point on, the processes of electroplating/electroforming are similar, the variables being current, time, and brightner agents. The two processes can be used in combination. A piece of metal can have a wax form on it and be electroformed while the metal is plated. The wax surface should not be electrically cleaned because the solution is heated, and it would melt the wax. The wax should be cleaned chemically and the metal with pumice. Electroforming can also be combined with other metalsmithing techniques, raising, casting, even enameling.

The three metals most commonly used as electroforms are nickel, copper and iron.\footnote{Carlin, p. 470.} A copper sulfate acid solution is most likely the starting point for the crafts-person who becomes interested in the electroforming process. This bath is the easiest to maintain when compared to other metal plating solutions. The initial cost of a copper sulfate solution is also minimal. Cyanide baths have found greater applications in industry because they can be used to plate on steel and other base metals. In comparison to the acid bath, cyanides have better throwing and covering power of objects and this type of
electrolyte will produce better results with complex shapes; however, precautions must be taken with cyanides.

Before handling these chemicals much research must be done and precautions must be taken. Ventilation is a critical safety factor, as is wearing rubber gloves, safety glasses, and protective clothing. The cyanides are the most toxic substances encountered in electrodeposition. When cyanides are brought in contact with acids, even weak solutions, a highly toxic gas, hydrocyanic acid is released. For this reason chemicals of acid and cyanide are never stored in the same cabinet or area.

It would be expensive to electroform a piece in a silver forming solution, but if the piece was formed in copper, it could be plated with this precious metal afterwards. Gold plating is used to a great extent as a coating on other metal. In the electronics industry gold plating is used, due to its inertness to many chemical environments and its excellent electrical properties.\textsuperscript{12}

By plating, the craftsperson and industry can maximize the use of less expensive baths to build up the base metal and use a modest amount of more precious metal for the finishing touch.

When I plate silver over copper I use a nickel strike, a quick plating of nickel over the copper which helps the silver adhere. I am also using an acid solution and then

\textsuperscript{12}Spencer, p. 54
a cyanide one, so I must be absolutely sure that each piece is rinsed thoroughly before using the different electrolytes. If a person working with these chemicals suspects that these two solutions were mixed and hydrocyanic gas forms, leave the area immediately until the gas dissipates. I cannot emphasize enough how highly caustic these chemicals are and the knowledge and care that is necessary before handling them.

The basics of an electrodepositing system consist of the following: a tank which holds the electrolyte and three bars, usually of copper or stainless steel, that run the length of the tank to conduct electric current. The two outer bars hold the metal anodes which are dissolved by the solution and provide the metal which forms on the piece. In some cases, the metal is already in solution and must be replenished. The center bar is the cathode rod from which the piece is suspended. The anodes should be evenly distributed around the piece for an even deposit. It is essential that all of these bars be clean so that the contact points are not insulated by the crystallization of the electrolyte. These bars can be cleaned by sanding them with emery cloth or rinsing them with deionized water. If they are sanded, it is important to avoid having dust fall in the solution. There should be a clean connection on the inside of the cathode rod, where it connects to the cathode bar. These connections can be held together by various means, C-clamps, ring clamps, or even electrical
tape. A filter system to remove impurities is also important to the set-up as is a means of agitation to speed up the rate of deposition and keep the solution mixed. A heating unit may also be useful. Finally, there is the power supply which produces the electrical current.\footnote{13}

Prior to submerging the cathode in the solution, the power source should be turned on so that there is a good initial contact. You will probably start plating at a low current. If the current is too high, it might burn the conductive paint or cause poor adherence. The piece should be checked about 20 minutes after it is put in the solution. By this time the entire piece should have a thin coat of metal plated on it. The piece should not be kept out of the solution for more than a few moments when checking the work, since this would result in a lamination of the layers which could present problems if the piece is going to be soldered or filed.

If part of the piece is not plating or an area was missed, it should be removed from the tank, rinsed in distilled water, and given time to dry. The poorly plated areas are then repainted with the silver lacquer. Once it has dried, it should be returned to the solution. The current may be increased once the piece has been checked and then left to form to the desired thickness. There are charts available from the various plating chemical companies.
on plating speeds. Once you are familiar with electro-forming, the prior experience will help determine the plating time without complete reliance on a chart.

Another way of determining the thickness of the plating on the piece would be by weighing the piece with the cathode rod before and after it is electroformed. If the artist could afford the tools of industry he could precisely determine the thickness of his piece by the use of an electronic caliper. This instrument measures the time it takes to send a microwave from the surface of the metal to the mandrel and back again and gives a digital read out.

If the piece is not thick enough, it can always be replated once the matrix is removed. It would be treated as electroplating and would need to be electrocleaned. It is absolutely essential to remove all the matrix material, especially if it is wax, because it will act as a resist and prevent plating, as well as contaminate the electrocleaning solution.

It is also important to note that the entire piece of an electroforming does not plate uniformly. Areas that are recessed are referred to as the low current density areas, and these will form at a slower rate than the edges and the high current density areas. It is important to design your

---

14 Appendix D: Deposit Rate, The Udylite Corp.
piece taking this into account.\textsuperscript{15}

\textsuperscript{15}Appendix E: Deposit Distribution on Electroforms, Metal Finishing (February 1973).
REMOVING THE MATRIX

Once the thickness of the piece is sufficient, the matrix must be removed. Electroformed metal has the quality of being harder than rolled metal of its same gauge. The molecular structure is made of hardened and condensed metal ions and is known to the metalsmith as an unannealed state. Once it is annealed or soldered with a hard solder it loses this characteristic and can only be regained when the piece is electroplated again.

The safest way to remove the wax matrix is by boiling it out in water. The surface of the piece will remain wax free if a soap is added to the water when boiling. It may also be necessary to wash the piece in an ammonia and detergent solution to remove the film. The cathode rod should be sawed free and once the wax has melted or the styrofoam chemically dissolved, the rod should release easily. This will provide a hole for the material to escape. The remaining wax can be dissolved with a wax solvent or if there is good ventilation and the artist is cautious, the remaining wax can be burned out using an oxygen flame and dripping the wax into water. Often more harm than good can be done this way because the pieces can warp, become annealed, or break down in the thin low density areas.

In the case of removing the styrofoam matrix,
chemicals like methyl ethyl ketone and miccropeel reducer can be used. These fumes are very strong and good ventilation and gloves are mandatory.

The acrylic and porcelain matrices will remain in the form since they will not be affected by the temperature conditions as the wax would or retain chemicals from the electrolyte as the styrofoam would.

The next step is to remove the silver lacquer. This can be reduced with a paint thinner, ethyl alcohol, or a solution of nitric acid which will etch it away. Any film must be removed from the surface of the pieces since again it may act as a resist. By scrubbing with a degreaser, pumice, or abrasive cleanser, a clean surface can remove the lacquer.
FINISHING TECHNIQUES

Since the electroforms are metal, they may be finished for the most part like other metal forms. They can be filed, sanded, sandblasted, shotblasted, buffed or given a patina, depending on the desired finish. If the electrolyte is plating at its optimum and brightners are used, the piece will have a beautiful shiny surface which will need practically no finishing.

One of copper's greatest advantages is its variety of color. A finish developed by chemical oxides and salts which reacts with the copper is referred to as a patina. Various solutions produce different colors. One can create tones of white, yellow, red, blue, green, purple and dark values as well. Modification in the colors can be obtained by changing the treating time and concentration of the solution. These chemicals are applied by brushing, dipping, dabbing, and spraying and are used hot and cold. The surface of the metal must be absolutely clean, even to the point of electrocleaning if possible, to assure good adherence and an even application. After the patina forms, it may be useful to coat the parts with boiled linseed oil, lacquer or wax.¹⁶

When considering jewelry and metal production pieces, knowledge of moldmaking is almost essential. There are several types of molding materials that may be used. In production jewelry, vulcanized rubber is commonly used for reproducing objects which are later injected with wax. This process may be applied to electroforming as well. Just as the sprue wire would be used in casting, a network of wires can be constructed so that many waxes can be electroformed at the same time. These wires can be masked except for the connection areas so that they do not rob the metal that is being plated.

By soldering rows of copper wires onto a main branch, a tree configuration may be constructed. The design of the tree will vary depending upon the size of the bath and the pieces to be plated. 17

The injected waxes are connected onto these networks. I have found it useful to drill a small hole into the waxes, heat the wire and push the wax onto the wire while it is still hot. This allows for a secure connection system, which is essential for good plating. These pieces are then painted, preferably using an air gun, after which the wires are masked and submerged in the electrolyte.

Another type of molding one can experiment with in

17 Appendix F: Tree Diagrams for Production Pieces

-30-
small scale jewelry is silicon rubber molding by Ferris Company. One very important advantage becomes apparent when one begins to cut the mold with this material. Since the molding compound becomes clear when it is cured one can see exactly where to cut the mold and very intricate objects can be molded and cut with precision. There are many other molding materials which can be used, such as the RTV silicon rubber by Dow/Corning.
ARTIST'S STATEMENT

In the next section of the thesis I will discuss my work, inspirations, and philosophies in relation to the technique of electroforming.

I use the word conglomerate when discussing my work with electroforming. This is a geological term meaning a rock composed of many fragmented rocks which are cemented together through natural processes. To me this word is appropriate to describe my work because I am taking images from several sources and combining the ideas. The motifs and inspirations come from fragments of nature, including rock formations, sea forms, plant and animal life. I choose to create these conglomerates because of the great appreciation I have for nature, and its intrinsic design. I am intrigued with its rich textures and details and inspired by the beautiful designs and structures. The conglomerates are made with the intent that the viewer will become involved in a search for these details and in relating the imagery to nature. Although the imagery speaks of nature, nature could not possibly create these combinations.

The idea of forming metal objects and witnessing their growth excites me as much as does the study of all other natural phenomena. The nodulation that forms on the edges serve as an example. They can be visualized as moss or coral. The delicate balance within the
electrolyte is a similar relationship to the balance of nature and ecological systems. Imbalances cause different variations of pattern and growth.

I visualize some areas in my pieces as aerial views of plowed corn fields, cuts in mountain formations, sea-life fragments of shells, crabs and the like. I have always been in awe of the power nature holds, a force man cannot control. The variety of colors, patterns, and shapes along with the stages of life and growth are factors that influence my art work. The beauty of processes like weathering and erosion, fossilization and other changes due to the forces of nature are significant inspirations to me. It is here where the artists' sensitivity discerns the unique expressive qualities of electroforming.

There is a significance to my coloring methods. The patinas and heat coloring treatment are in harmony with both the imagery and the materials. To me this is the most natural way of coloring metal. I feel it is necessary to project a natural appearance to these pieces and that is why I use patinas as colorants and natural dyes for the raffia used in some of my wall pieces. Conditions in nature would color the materials the same way, but at a much slower rate. Chemical coloring allows for variations as far as intensity of color and concentration of the solution. This color variation along with the flexibility of the wax matrix material give my pieces a
painterly style, which is how it is often described.

I have a jeweler's background, and although most of my metalwork is no longer jewelry, I can't help but project this attitude in my work. I feel as though my wall pieces and table sculptures invite the viewer to come within close range and observe the textures, details and subtleties that require close attention. In my functional electroformed hollowware there is a reference to nature and although it is minimal, one can't help but feel the texture and relate it to nature. I believe that an intimate feeling is realized when one views these pieces at a close range, the same as if it were jewelry.

There are so many facets to electroplating, electroforming, and mold making, the scope of which could not be covered in this paper. There is information available; however, more can be learned through contacting suppliers, going to industries which employ these techniques, and experimenting yourself. Electrodeposition is a process that requires much background information. Electroforming was initially practiced as an art form and often resulted in erratic results. The potentials of this process are just being explored. Aside from being a less expensive and quicker way of making metal objects, it has many inherent characteristics.

It is up to the artist to accept the potentials and set the limitations of the materials. By applying
creativity and esthetics, electroforming can be used as an artists' medium.
BIBLIOGRAPHY


APPENDIX A

LIST OF SUPPLIERS

Acheson Colloids Company
Box 288
Port Huron, Michigan 48060
- for commercial electroconductive coatings

Allied-Kelite Products Division
Witco Chemical Corporation
81 Industrial Road
Berkeley Heights, New Jersey 07922
- for various electroplating and electroforming equipment and chemicals

Burt Bricker, Inc.
P. O. Box 171
Wilmington, Delaware 19899
- for Dupont commercial electroconductive coatings

Fischer Scientific Company
Chemical Manufacturing Division
Fair Lawn, New Jersey
- for acids, solvents, solutions

Kerr Manufacturing Company
28200 Wick Road
Romulus, Michigan 48174
- dental waxes, injecting waxes, other mold making supplies

Michigan Chrome and Chemical Company
8615 Grinnell Avenue
Detroit, Michigan 48213
- manufacturer of Miccropeel stop-off lacquer

Serfilco Company, Ltd.
1234 Depot Street
Glenview, Illinois 60025
- for pumps, filters
The Udylite Company
Division of Oxy Metal Finishing Corporation
5400 McDermott Drive
Berkeley, Illinois  60163
   - for various electroforming equipment and supplies
January 19, 1983

Lisa Toser
622 Oxford Road
Larrisburg, PA 17109

Dear Ms. Toser:

The enclosed literature describes available Du Pont Conductive Silver preparations useful in electroplating and/or electroforming. We would particularly call your attention to Compositions No. 4817 and No. 4922.

No. 4817 is a low viscosity preparation for brush, dip or spray application designed to provide electrical conductivity over normally nonconductive surfaces such as wood, plastic, paper, etc. No. 4817 will cure in 2 to 4 hours at room temperature or the cure can be accelerated by 20 to 30 minute exposure to low temperature oven or even a hair dryer might be used for this purpose.

No. 4817 may be further diluted to a preferred operating viscosity by the addition of either toluene or butyl acetate, adding little or none for brush application and as much as 15% to 20% by volume for dip or spray.

When the silver is dry it is ready for the plating baths. An acid copper flash may be followed by chromium or bright nickel and the gold cyanide. The binders in the subject silver preparations are organic and hence alkaline plating baths are not recommended.

Composition No. 4922 is of the same family as No. 4817 but of a somewhat higher viscosity and metal content, initially designed for brush application. However the addition of butyl acetate or toluene will convert No. 4922 to a spray preparation with properties quite like those of No. 4817. A 20% to 25% addition of thinner, by volume, is usually adequate for the conversion.

While No. 4817 is most widely used in electroplating and/or electroforming, there are circumstances where No. 4922 might be preferable. For example: No. 4817, with a flash point (tag open cup) of 0°F., is considered to be a flammable preparation and is unacceptable for passenger carrying aircraft, hence restricting its shipment to surface or freight carriers. No. 4922, with a flash point of 160°F., is accepted on any aircraft, including first class air mail.
CONDUCTIVE SILVER COMPOSITIONS

DISTRIBUTOR

BURT BRICKER, INC.

For coating porous surfaces such as sea shells, sand dollars, etc., polyvinyl alcohol (Elmer's Glue) is suggested for sealing the surface prior to the application of the conductive silver. The PVA can be diluted with water, up to 50% by volume, to provide minimum surface build-up, hence maintaining optimum surface detail, yet will provide maximum penetration. After 5 to 10 minutes immersion, remove the pieces from the polyvinyl alcohol bath and allow them to drain and dry.

For electric circuitry repair (rear window defoggers, etc.) application may be made by camel hair brush or stylus (even a toothpick or matches stick). Allow to dry until the shine leaves, and then turn on the circuitry to complete the cure.

The attached pricing schedule is self-explanatory.

As questions arise, please do not hesitate to call upon us. We will be glad to be of possible assistance.

Yours truly,

[Signature]

Burt Bricker

Closures
**CONDUCTIVE SILVER COMPOSITIONS**

**DISTRIBUTOR**

**BURT BRICKER, INC.**

**PRICE SCHEDULE**

**DOLLARS/CONTAINER**

<table>
<thead>
<tr>
<th>50* (1.6 T.O.)</th>
<th>100* (3.2 T.O.)</th>
<th>150* (4.8 T.O.)</th>
<th>300* (9.6 T.O.)</th>
<th>600* (19.3 T.O.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>55.25</td>
<td>108.50</td>
<td>149.25</td>
<td>259.25</td>
<td>458.75</td>
</tr>
<tr>
<td>54.50</td>
<td>107.00</td>
<td>147.00</td>
<td>255.25</td>
<td>450.25</td>
</tr>
<tr>
<td>56.75</td>
<td>111.50</td>
<td>153.50</td>
<td>268.25</td>
<td>476.25</td>
</tr>
<tr>
<td>41.75</td>
<td>81.50</td>
<td>108.75</td>
<td>178.75</td>
<td>297.25</td>
</tr>
<tr>
<td>51.50</td>
<td>101.00</td>
<td>138.00</td>
<td>237.00</td>
<td>414.25</td>
</tr>
<tr>
<td>52.50</td>
<td>103.00</td>
<td>141.25</td>
<td>243.50</td>
<td>426.50</td>
</tr>
<tr>
<td>52.50</td>
<td>103.00</td>
<td>141.00</td>
<td>242.75</td>
<td>425.50</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>-</td>
<td>216.75</td>
<td>373.50</td>
</tr>
<tr>
<td>53.75</td>
<td>105.50</td>
<td>144.75</td>
<td>250.25</td>
<td>440.50</td>
</tr>
<tr>
<td>48.50</td>
<td>95.00</td>
<td>129.25</td>
<td>219.25</td>
<td>378.50</td>
</tr>
<tr>
<td>51.25</td>
<td>100.50</td>
<td>137.00</td>
<td>235.00</td>
<td>410.00</td>
</tr>
<tr>
<td>47.75</td>
<td>93.50</td>
<td>126.75</td>
<td>214.25</td>
<td>368.50</td>
</tr>
<tr>
<td>47.75</td>
<td>93.00</td>
<td>126.00</td>
<td>212.75</td>
<td>365.25</td>
</tr>
<tr>
<td>44.75</td>
<td>87.50</td>
<td>117.50</td>
<td>196.00</td>
<td>332.00</td>
</tr>
<tr>
<td>45.25</td>
<td>88.50</td>
<td>119.00</td>
<td>198.75</td>
<td>337.50</td>
</tr>
<tr>
<td>55.00</td>
<td>108.00</td>
<td>148.00</td>
<td>257.25</td>
<td>454.25</td>
</tr>
<tr>
<td>49.75</td>
<td>95.50</td>
<td>132.75</td>
<td>226.50</td>
<td>393.00</td>
</tr>
<tr>
<td>51.50</td>
<td>101.00</td>
<td>138.00</td>
<td>237.25</td>
<td>414.50</td>
</tr>
<tr>
<td>53.25</td>
<td>104.50</td>
<td>143.00</td>
<td>247.00</td>
<td>433.75</td>
</tr>
<tr>
<td>48.25</td>
<td>94.50</td>
<td>128.25</td>
<td>217.50</td>
<td>375.00</td>
</tr>
<tr>
<td>48.00</td>
<td>94.00</td>
<td>127.25</td>
<td>215.75</td>
<td>371.25</td>
</tr>
</tbody>
</table>

**IER**

| 12.50          | 22.75          | 39.75          |

11783/1205 y

P. O. BOX 171 WILMINGTON, DELAWARE 19899 PHONE 302 764-6305
CONDITIONS OF SALE

STANDARD PACKAGING

<table>
<thead>
<tr>
<th></th>
<th>50 GRAMS</th>
<th>100 GRAMS</th>
<th>150 GRAMS</th>
<th>300 GRAMS</th>
<th>600 GRAMS</th>
</tr>
</thead>
</table>

Note: For smaller than standard packaging add $3.00/container.

Seller reserves right to supply smaller containers at no added cost if a standard container is not available in inventory.

TERMS

(a) CHECK or MONEY ORDER accompanying order.
(b) C.O.D.
(c) OPEN TERMS - Net 10 Days, by prior arrangement.

SHIPPING

(a) UPS (United Parcel Service) surface - F.O.B. Destination.
(b) FEDERAL EXPRESS (Overnight air service), F.O.B. Origin.
(c) PRIORITY MAIL (May be used for products having flash point above 100° F.) F.O.B. Destination.

INSURANCE

All shipments F.O.B. Destination include full coverage.
All shipments F.O.B. Origin are insured to extent of requested coverage.

DELIVERY

Shipment within 48 hours, normally within 24 hours, from receipt of order.

RETURN OF MATERIALS

No goods will be accepted for return without prior written authorization.

WARRANTY

Seller makes no warranty of any kind, express or implied, as to goods sold or as to results in use of such goods.
### GROUP I SILVERS

<table>
<thead>
<tr>
<th>Composition</th>
<th>% Ag</th>
<th>Viscosity at 25°C</th>
<th>Thinner</th>
<th>Cure</th>
<th>Sheet Resistivity Ω/□</th>
<th>Coverage cm²/g [in²/g] at 50 µm (2 mil) wet film thickness</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Print</td>
<td>70</td>
<td>52.69 HBF</td>
<td>4</td>
<td>10</td>
<td>Butyl Cellosolve® Acetate</td>
<td>1 h at 100°C &lt; 0.05</td>
<td>72 [11]</td>
</tr>
<tr>
<td>4929</td>
<td>70</td>
<td>55.80 HBF</td>
<td>4</td>
<td>10</td>
<td>Butyl Cellosolve Acetate</td>
<td>1 h at 100°C &lt; 0.2</td>
<td>72 [11]</td>
</tr>
<tr>
<td>7941†‡</td>
<td>70</td>
<td>38.54 HBF</td>
<td>4</td>
<td>10</td>
<td>Butyl Acetate</td>
<td>1 h at 100°C &lt; 0.05</td>
<td>72 [11]</td>
</tr>
<tr>
<td>Dip/Spray</td>
<td>43</td>
<td>0.200-0.250 LVT</td>
<td>2</td>
<td>60</td>
<td>Butyl Acetate</td>
<td>1 h at 60°C &lt; 0.1</td>
<td>120 [18.5]</td>
</tr>
<tr>
<td>4817</td>
<td>46</td>
<td>0.720-0.980 RVT</td>
<td>4</td>
<td>20</td>
<td>Butyl Acetate</td>
<td>1 h at 100°C &lt; 0.1</td>
<td>120 [18.5]</td>
</tr>
<tr>
<td>Primer 7106</td>
<td>0.045-0.085 LVT</td>
<td>1</td>
<td>60</td>
<td>–</td>
<td>10 min at 160°C</td>
<td>–</td>
<td>Improve adhesion of air-dry composition to phenolic board</td>
</tr>
</tbody>
</table>

### GROUP II SILVERS

<table>
<thead>
<tr>
<th>Composition</th>
<th>% Ag</th>
<th>Viscosity at 25°C</th>
<th>Thinner</th>
<th>Cure</th>
<th>Sheet Resistivity Ω/□</th>
<th>Coverage cm²/g [in²/g] at 50 µm (2 mil) wet film thickness</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Print</td>
<td>70</td>
<td>90-120 HBF</td>
<td>5</td>
<td>10</td>
<td>Benzyl Alcohol</td>
<td>1 h at 150°C &lt; 0.2</td>
<td>72 [11]</td>
</tr>
<tr>
<td>9793†‡</td>
<td>70</td>
<td>20-30 HBT</td>
<td>4</td>
<td>10</td>
<td>Benzyl Alcohol</td>
<td>1 h at 150°C &lt; 0.2</td>
<td>83 [13]</td>
</tr>
<tr>
<td>Stylus/Brush</td>
<td>63</td>
<td>22-32 RVT</td>
<td>5</td>
<td>5</td>
<td>MCA/BA blend</td>
<td>1 h at 150°C &lt; 0.2</td>
<td>80 [13]</td>
</tr>
<tr>
<td>9965†‡</td>
<td>60</td>
<td>1.4-1.8 RVT</td>
<td>2</td>
<td>10</td>
<td>Methyl Cellosolve* Acetate</td>
<td>1 h at 150°C &lt; 0.2</td>
<td>83 [13]</td>
</tr>
<tr>
<td>Dip/Spray</td>
<td>60</td>
<td>1.4-1.8 RVT</td>
<td>2</td>
<td>10</td>
<td>Methyl Cellosolve* Acetate</td>
<td>1 h at 150°C &lt; 0.2</td>
<td>83 [13]</td>
</tr>
</tbody>
</table>

### GROUP III SILVERS

<table>
<thead>
<tr>
<th>Composition</th>
<th>% Ag</th>
<th>Viscosity at 25°C</th>
<th>Thinner</th>
<th>Cure</th>
<th>Sheet Resistivity Ω/□</th>
<th>Coverage cm²/g [in²/g] at 50 µm (2 mil) wet film thickness</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screen Print</td>
<td>70</td>
<td>68.92 HBF</td>
<td>4</td>
<td>10</td>
<td>Butyl Cellosolve Acetate</td>
<td>(see text) &lt; 0.1</td>
<td>72 [11]</td>
</tr>
<tr>
<td>5504</td>
<td>75</td>
<td>37.50 HBF</td>
<td>4</td>
<td>10</td>
<td>Butyl Cellosolve Acetate</td>
<td>(see text) &lt; 0.05</td>
<td>62 [9.5]</td>
</tr>
<tr>
<td>Dip/Spray</td>
<td>55</td>
<td>0.800-0.950 LVT</td>
<td>2</td>
<td>30</td>
<td>Butyl Cellosolve*</td>
<td>(see text) &lt; 0.1</td>
<td>100 [15.5]</td>
</tr>
<tr>
<td>5815</td>
<td>55</td>
<td>0.950 HBF</td>
<td>4</td>
<td>10</td>
<td>Butyl Cellosolve*</td>
<td>(see text) &lt; 0.1</td>
<td>100 [15.5]</td>
</tr>
</tbody>
</table>

25 µm (1 mil) film thickness

†‡Non-inventoried products requiring 3 kg minimum order

The information given herein is based on data believed to be reliable, but the Du Pont Company makes no warranties express or implied as to its accuracy and assumes no liability arising out of its use by others. This publication is not to be taken as a license to operate under, or recommendation to infringe, any patents.
CONDUCTIVE SILVER COMPOSITIONS
AIR-DRY AND THERMOSET

The compositions described in this bulletin are suspensions of specially prepared silver powders combined with a variety of organic binder systems. They are designed to produce electrically conductive paths, patterns or films over nonconductive surfaces. They are air-dry of low temperature-curing formulations for application on substrates which will not generally tolerate high-temperature firing. They are formulated to produce electrically conductive paths on paper, plastic, rubber, cloth, wood, etc., and may be applied by dip, spray, brush, stylus, syringe or screen print.

These highly conductive air-dry/thermoset (epoxy) compositions exhibit versatility and are useful over a broad range of applications. Suggested uses are:

- Printed Circuitry
- Tantalum Capacitors
- Static Shielding
- Electrical Games and Toys
- Recording Tape
- Microwave Applications
- Tabulating Cards
- PC Board Repair
- Electroplating Base
- Electroforming Base

The compositions described in this bulletin are divided into three groups based on similarities in composition, cure, properties and end uses.

Choice of an air-dry or thermosetting conductive silver composition for a given use is dependent upon the method of application preferred and the required properties in the end product. Trade-offs in final film properties are sometimes necessary.

Drying rate is a function of the solvent system in a composition and method of application is dictated by viscosity, a function of binder to solvent ratio. Dry strength, flexibility, solderability, adhesion and temperature stability are functions of the binder system. No one binder system exhibits optimum capabilities of all functions. Lower metal contents are generally least expensive if cost is a primary consideration. Higher metal contents develop maximum conductivity and load carrying capabilities, and are more easily soldered.

Application Methods

Du Pont conductive silver compositions are formulated for application by screen printing, spraying, dipping, brushing, banding or stylus. In most cases the compositions are produced to a consistency suitable for use as received and require only stirring to redisperse the solids.

Recommended thinners for individual compositions may be added, with thorough blending, to replace solvent losses or to make slight adjustments for ease of application. Only the recommended thinner should be used. In handling and using organic solvents, the safety precautions recommended by the solvent supplier should be observed.

Effect of Curing Temperatures

This bulletin discusses two types of compositions: air-dry and thermoset (epoxy). In an air-dry system, the metal-binder film is formed when the
solvent system is evaporated or “dried.” In a thermost system, there is a drying step where the solvent is removed, followed by a chemical reaction of binder materials in the system to give a higher temperature resistant binder film for the metal. The later chemical reaction is called “curing” and is different than drying.

While some compositions, if given sufficient time, will adequately dry or cure at room temperature, a more effective result is achieved in much less time through low temperature thermal exposure with a moderate time/temperature curing or curing. Optimum properties in air-dry and low-temperature-cure compositions are developed only after the compositions have been properly dried or cured.

The drying or curing cycle for most compositions is a function of time versus temperature up to the point of degradation of the organic system. In a system which will dry or cure in from 12 to 16 hours at room temperature (25°C) the same degree of drying or curing can be achieved in less than 2 hours at 60°C and in less than 1 hour at 100°C.

Elevated temperature drying or curing of these compositions can be continuous, box oven or infrared. The heat should be applied from the bottom up to permit internal gases to escape before the top surface is completely dry. “Flash drying,” a momentary exposure to excessively high temperatures, is likely to form a surface skin that traps internal gases, resulting in bubbles in the dried film.

Failure to achieve rated conductivity indicates either that the applied composition is too thin with poor uniformity or that it has been incorrectly dried and/or cured.

Soldering

Some Du Pont air-dried and thermost compositions are more commonly used as conductive cements in lead attachment, attachment of discrete components or in simple interconnections. For these applications, solderability is not important, but frequently the capability of accepting solder is a requirement.

Most of the Du Pont air-dry and thermost compositions are suitable for direct solder. Because the binders are organic and they do have temperature limitations, low temperature solders, preferably silver bearing, for lower solder leaching should be used at their lowest workable temperature. Exposure to the soldering iron or pot should be minimized.

A typical 62% tin, 36% lead, 2% silver solder at a pot temperature of 210°-215°C provides acceptable results. Any noncorrosive flux is suitable for use in soldering Du Pont air-dry conductive silver compositions. Laboratory data indicate Alpha 611 and Alpha Flux #100 (Alpha Metals, Inc.) are suitable.

If loss of adhesion for a particular solder application is a problem, the introduction of Du Pont Primer 7106 under the silver film will promote adhesion to most substrates and will enhance solder acceptance.

Electroplating/Electroforming

The use of Du Pont air-dry/thermoset conductive silver compositions as bases for electroplating and electroforming is widespread. Ease of application, broad curing ranges, high conductivity and dimensional stability mark Du Pont Group I compositions as leaders in the field.

A typical acid copper plating system is suggested:

- **Copper Sulphate Crystals**: 202 g/ℓ (27 oz/gal)
- **Sulphuric Acid**: 49 g/ℓ (6.5 oz/gal)
- **Temperature**: 25°-50°C
- **Current Density**: 16-43 mA/cm²
  (15-40A/ft²)
- **Voltage**: 0.75-2.0 V
- **Anodes**: Rolled and sealed copper

Storage and Shelf Life

Group I and II compositions (air-dry) should be stored at room temperature. Shelf life of material in unopened containers is a minimum of six months. Group III material (thermoset) should be refrigerated at 2°-4°C (35°-40°F). Shelf life of material in unopened containers under these storage conditions is a minimum of three months. Shelf life can be extended considerably by storage at temperatures of -18°C (0°F) or below. Materials should be allowed to return to room temperature before opening to preclude moisture condensation in the jar, to assure that the proper viscosity has been reached, and to assure consistent results with whatever cure cycle is being used.

Coverage

Coverage of silver compositions depends on metal content and thickness of application. Screen print compositions printed with a 165- or 200-mesh...
screen will generally result in a cured film 15-25 μm (0.6-1.0 mil) thick. Brush band, dip or spray application will normally result in film thickness of 13-18 μm (0.5-0.7 mil). Thinner films (increased coverage) can be applied by thinning the compositions with the recommended thinner; however, this will result in a cured film with a higher sheet resistivity. Thicker films can be achieved by brushing or spraying simply by applying more material.

The coverage figures shown in Table III are for typical cured thicknesses of 13-25 μm (0.5-1.0 mil) as outlined above.

Viscosity

Viscosity measurements are based on Brookfield viscometer readings. Based on a drag of a rotating disc or cylinder, while immersed in the product, direct dial readings are obtained. Instrument classifications include the LV, the RV, and HA, and the HB models designed for measuring low to high viscosity compositions, respectively. Combinations of spindle sizes and speeds are selected to provide mid-dial readings.

Viscosity readings should always be taken at 25°C. Variations in room temperature can cause significant viscosity changes in silver compositions.

Group I

Group I conductive silver compositions exhibit a moderately fast drying rate, good adhesion to most substrates and high conductivity. They are used to produce electrically conductive patterns on surfaces of paper, film, plastic, rubber or wood as well as on conventional ceramic substrates. They are widely used in the manufacture of tantalum capacitors to metallize the anode, making it a good electrical contact and solder receptive surface.

For dip, spray, brush or screen print application, Group I compositions can be cured in 16-20 hours at room temperature (25°C) or may be oven cured in 1 hour or less at 60°-100°C.

With minimum time/temperature exposure, they are suitable for direct solder using a rosin non-activated flux with conventional tin/lead/silver solders at 210°-215°C.

4817, for spray or dip application, is widely used in electroforming, in electroplating, in static shielding, in magnetic tapes and in the manufacture of tantalum capacitors. Its low metal content places 4817 in a moderate price range attractive for many applications.

4922 is a high metal content, high viscosity version of 4817 suitable for brush, stylus or machine banding application where its somewhat higher conductivity is desired. 4922 is widely used in circuit board repair and in the manufacture of tantalum capacitors. 4922 may be thinned with butyl acetate to achieve optimum application properties.

4929 is a paste version of 4922 for screen print or stylus application where it is desired to deposit a circuit or pattern as in electronic circuitry, microwave applications, computer punch cards, ballistic targets, or in toy and game circuitry.

7941 is a flexible version of 4929 for use where some flexing of the substrate such as in paper, cloth, film etc., is to be encountered.

7106 is a primer for use under Group I and II compositions to promote adhesion to substrate and to enhance solderability.

Group II

Group II conductive silver compositions display high temperature stability, up to 200°C for short periods, excellent adhesion to most substrates and when properly dried, exhibit good conductivity with resistance values less than 200 mΩ/□. While these compositions will adequately dry at room temperature if given sufficient time, a more effective procedure is to dry partly at room temperature followed by drying at elevated temperature. Optimum properties of these compositions are developed only after they have been properly dried. Generally recommended is drying 30-60 minutes at room temperature followed by 30-60 minutes at 150°-175°C. Dried properly these products find acceptance in the manufacture of tantalum capacitors, in lead and discrete component attachment, and circuit board repair. The thinner films exhibit a high degree of flexibility making them useful in film and tape applications.

9960 is for dip/spray applications. It develops a highly adhesive and conductive film, shows good thermal stability and is used in tantalum capacitors to metallize the anode, making it a good electrical contact and solder receptive surface. It also can be used for static shielding and in the manufacture of magnetic tapes.

9965 has higher viscosity and is primarily for stylus or brush-application. It is widely used in circuit
9793 and 4049 are for screen printing circuits onto plastic substrates. They are particularly suitable for use on Mylar* and other polyester materials.

**Group III**

Group III compositions are single component, epoxy based preparations suitable for use as conductive cements in lead and discrete component attachment. They exhibit good conductivity, high adhesion and excellent resistance to abrasion. These compositions are divided into two types: anhydride-cured and amine-cured. Anhydride-cured compositions display excellent thermal stability up to 250°C whereas amine-cured products start to degrade appreciably at temperatures above 200°C with attendant loss of properties. Both systems, however, can withstand short excursions to higher temperatures.

While not suggested for direct solder, the compositions may be electroplated to provide a solderable surface or may be overlaid with one of the Group I solderable compositions.

Optimum cure for Group III compositions will depend on process and equipment parameters as well as the mass, heat capacity and transfer, and sensitivity of the materials involved. Cure schedules listed in Table I are recommended as minimal starting points with compositions 5504 and 5815 after applying and allowing to air-dry until tack free. The drying time can be accelerated by heating to 50°C. Longer cure schedules may be required to optimize properties depending on end-use requirements. For example, in die-attach application, a cure schedule of 2 hours at 200°C has been found to yield stable and reliable die-to-substrate interfaces capable of withstanding a high degree of thermal and physical stress.

The cure schedules shown in Table I are also applicable to compositions 6838 and 8072. Because of the amine-curing system used in these compositions, properties are optimized under somewhat milder conditions and adequate curing can be effected at temperatures even below 100°C over long curing times (e.g. 3 days at 85°C).

**Safety and Handling:**

These products contain organic solvents and materials. They should be handled using the following precautions.

- Use with adequate ventilation
- Avoid prolonged contact with skin
- Avoid prolonged breathing of vapor
- Keep away from sparks and open flame

<table>
<thead>
<tr>
<th>Temperature °C (°F)</th>
<th>Time hours</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 (392)</td>
<td>0.7</td>
</tr>
<tr>
<td>180 (356)</td>
<td>1.5</td>
</tr>
<tr>
<td>160 (320)</td>
<td>2.5</td>
</tr>
<tr>
<td>140 (284)</td>
<td>10.0</td>
</tr>
<tr>
<td>120 (248)</td>
<td>14.0</td>
</tr>
<tr>
<td>100 (212)</td>
<td>24.0</td>
</tr>
</tbody>
</table>

Typical physical properties of properly cured Group III compositions are shown in Table II.

<table>
<thead>
<tr>
<th>Sheet Resistivity — 25 μm (1 mil) film thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specification ......................................</td>
</tr>
<tr>
<td>Typical .............................................</td>
</tr>
<tr>
<td>Bulk Resistivity ..................................</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Adhesion Strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile — Specification ..........................</td>
</tr>
<tr>
<td>Typical .............................................</td>
</tr>
<tr>
<td>Lap Shear ..........................................</td>
</tr>
<tr>
<td>Thermal Conductivity ................................</td>
</tr>
<tr>
<td>Specific Heat ......................................</td>
</tr>
<tr>
<td>Coefficient of Thermal Expansion ..............</td>
</tr>
<tr>
<td>Modulus of Elasticity (tensile) ................</td>
</tr>
<tr>
<td>Poisson’s Ratio ...................................</td>
</tr>
</tbody>
</table>

*Reg. U.S. Pat. & Tm. Off.*
12 January 1983

R. Lisa Toser
4622 Oxford Road
Harrisburg, PA 17109

Dear Miss Toser,

Thank you for your recent inquiry into Acheson products. In accordance with your letter, I am enclosing data sheets for Electrodag 416 and 415, along with quotations.

If you have any further questions, please do not hesitate to contact Mr. Dan Delaney, our representative for your area, or us direct. We will be happy to assist you.

Yours truly,

ACHESON COLLOIDS COMPANY

James J. Coniglio
Assistant Marketing Manager
Electrical Products

JJC:mrb
Enclosures
ELECTRODAG 415*
(56.3% Silver)

<table>
<thead>
<tr>
<th>Container Size</th>
<th>Price Basis</th>
<th>Price corresponding to number of containers per shipment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>40 Grams</td>
<td>$/Gram</td>
<td>$0.631</td>
</tr>
<tr>
<td>155 Grams</td>
<td>$/Gram</td>
<td>$0.603</td>
</tr>
<tr>
<td>1550 Grams</td>
<td>$/Gram</td>
<td>$0.500</td>
</tr>
<tr>
<td>5900 Grams</td>
<td>$/Gram</td>
<td>$0.402</td>
</tr>
</tbody>
</table>

Minimum order is $50.00 per shipment.

*Silver containing Electrodag prices shown are based on a spot price of $12.00/troy ounce.

Adjustments are made based on percent total solids and current spot price on date of order shipment.
ELECTRODAG 416*
(44.5% Silver)

<table>
<thead>
<tr>
<th>Container Size</th>
<th>Price Basis</th>
<th>1</th>
<th>2-3</th>
<th>4-11</th>
<th>12 &amp; Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 Grams</td>
<td>$/Gram</td>
<td>$0.580</td>
<td>$0.470</td>
<td>$0.427</td>
<td>$0.400</td>
</tr>
<tr>
<td>155 Grams</td>
<td>$/Gram</td>
<td>$0.542</td>
<td>$0.442</td>
<td>$0.404</td>
<td>$0.380</td>
</tr>
<tr>
<td>1340 Grams</td>
<td>$/Gram</td>
<td>$0.380</td>
<td>$0.349</td>
<td>$0.344</td>
<td>$0.342</td>
</tr>
</tbody>
</table>

Minimum order is $50.00 per shipment.

*Silver containing Electrodag prices shown are based on a spot price of $12.00/troy ounce.

Adjustments are made based on percent total solids and current spot price on date of order shipment.
This is one of a series of Electrodag coatings designed to provide controlled electrical properties.

**Description:**

Electrodag® 415 is a dispersion of finely divided silver in a thermoplastic resin that rapidly air dries to form a conductive EMI/RFI shield, RF reflective, or ground coating on plastics and other nonconductive substrates. It exhibits excellent adhesion and provides controlled electrical properties in coatings as thin as 0.0003 inches.

Easy spray application, using standard paint-spray techniques, makes Electrodag 415 an ideal material for prototype and production work. It is also used for field repair and touching-up other shielding coatings.

**Typical Applications:**

EMI shielding of electronic equipment housings  
Precoat for electroplating nonconductors  
Reflective coating for plastic antennas

**Physical Properties:**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pigment</td>
<td>silver</td>
</tr>
<tr>
<td>Binder</td>
<td>PVC resin</td>
</tr>
<tr>
<td>Diluents</td>
<td>MIBK, MEK, acrylic lacquer solvents or SB-1</td>
</tr>
<tr>
<td>Color</td>
<td>silver</td>
</tr>
<tr>
<td>Consistency</td>
<td>liquid</td>
</tr>
<tr>
<td>Density</td>
<td>14.0 lbs/gal (1.7 kg/l)</td>
</tr>
<tr>
<td>Solids content</td>
<td>62%</td>
</tr>
<tr>
<td>Flash point</td>
<td>68% F (20°C)</td>
</tr>
<tr>
<td>Shelf life</td>
<td>six months under original seal</td>
</tr>
<tr>
<td>Coverage</td>
<td>340 sq ft/gal @ 1 mil.</td>
</tr>
</tbody>
</table>

**Physical Properties:**

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>Silver</td>
</tr>
<tr>
<td>Maximum service</td>
<td>220°F (104°C)</td>
</tr>
<tr>
<td>temperature</td>
<td></td>
</tr>
<tr>
<td>Sheet resistance</td>
<td>.01 ohms/square @ 1 mil</td>
</tr>
<tr>
<td>Pencil hardness</td>
<td>HB</td>
</tr>
</tbody>
</table>
Physical Properties:
(as supplied)

- Pigment: silver
- Binder: cellulosic resin
- Diluent: ethanol
- Consistency: fluid
- Density: 12.03 lbs./gal. (1.444 KG/liter)
- Solids content: 40.8%
- Flash point: 6° C (43° F)
- Coverage: 200 sq. ft./gal. (4.910 sq. meters/liter)
- Shelf life: six months minimum under original seal

Physical Properties:
(as cured)

- Color: silver
- Service temp.: 65° C (149° F)
- Sheet resistance: 2 ohms/square @ 1 mil

Electrical resistance varies according to the thickness of the coating, as shown in Fig. 1:

**Method of Use:**

**Surface Preparation**
Substrates should be clean and dry. A solvent wipe and air dry are usually sufficient for parts that are greasy or dirty.

**Mixing and Application**
Electrodag 416 is supplied ready for use when applied by brush. Dilute as required for dip or spray application (approximately 1:1 dilution ratio, or 20 to 22 seconds in a No. 4 Ford cup).

Stir Electrodag 416 thoroughly immediately before application.

**Curing**
Coatings of Electrodag 416 air dry in about 20 seconds, depending on film thickness and humidity, and are then ready for use.

**Precautions:**
Employ the customary safeguards when storing, handling, or applying highly flammable materials of this type.

Spray booths or areas should be adequately ventilated.

**Containers:**
1 oz. (28.5 grams) and larger as required.

**Note:**
Electrodag is a registered trademark of Acheson Industries, Inc.

---

Information presented in this product data sheet is considered reliable, but conditions and methods of use, which are beyond our control, may modify results. Before adopting our products for commercial use, the user should confirm their suitability. In no case should recommendations or suggestions for the use of our products be understood to sanction violation of any patent.
**Product Data Sheet**

**Description:**
Electrodag® 416, a compound of highly refined silver particles in a special resin system, is specifically designed to produce exceptionally fine definition of substrate detail in electroforming and electroplating applications. Electrodag 416 coatings air dry in seconds, making it possible to utilize heat-sensitive original materials such as wax, plastic and rubber as well as metals, glass and ceramics. Specific advantages offered by Electrodag 416 include:

- high conductivity
- excellent adhesion to virtually all substrates
- thin, tenacious film
- fast room-temperature cure
- variable electrical resistance
- one component, supplied ready for use
- no pretreatment required
- easy to apply

Electrodag 416 is supplied ready for use if applied by brush; dip and spray methods require dilution with ethanol.

**Typical Applications:**
- Electroplating
- Electroforming
- Shielding
- Printed Circuit Repairs
- Electrostatic Screening
- Sensing Ink

Styrofoam, wax, a praying mantis—nonconductors coated with Electrodag® 416 are easily and elegantly electroplated with gold. Wax forms are then removed by melting in hot water, leaving a shell of pure gold.
**Method of Use:**

**Substrate preparation:** Surfaces to be coated must be clean, dry and free from dust.

**Mixing and Dilution:** Using a mechanical stirrer or paint shaker, mix Electrodog 415 thoroughly, until it is of uniform consistency. Check to see that no sediment remains in the bottom of the container. Pour into suitable container for dilution (i.e., pressure pot, etc.).

Electrodog 415 should initially be diluted 1:1. Final production dilution ratios may vary slightly according to individual needs. To dilute, add solvent to Electrodog 415 and continue stirring until mixture is of uniform color.

**Application:** For the optimum combination of shielding protection and coating economy, dry film thickness of Electrodog 415 should be between 0.3 and 0.4 mil.

For small production work and prototypes, a suction cup gun may be used, providing Electrodog 415 is thoroughly mixed prior to spray application. For intermediate production runs or many small parts, propeller-type attachments should be used on the suction gun to ensure coating uniformity. Full production is most efficiently handled with propeller-agitated pressure pot systems.

Note: Handle Electrodog 415 as you would a quality automotive lacquer. AVOID DRY SPRAY, as this will cause poor adhesion.

To reduce overspray, use the minimum atomization pressure required for adequate coverage.

Further dilution of Electrodog 415 may be desirable to improve product yield, since any overspray will contain less silver.

**Drying:** Air dry coated parts approximately 10 minutes (depending on humidity) before carrying out resistance checks. Drying time for production operations can be accelerated by passing the coated parts through infrared heat or through batch or conveyor ovens.

<table>
<thead>
<tr>
<th>Container sizes:</th>
<th>40 grams</th>
<th>1.55 kilograms</th>
</tr>
</thead>
<tbody>
<tr>
<td>155 grams</td>
<td></td>
<td>5.90 kilograms</td>
</tr>
</tbody>
</table>

**Precautions:**

FLAMMABLE. Harmful if swallowed, inhaled, or absorbed through skin. May cause eye irritation. Wash thoroughly after handling. Keep away from heat, sparks, and open flame. Keep container tightly closed when not in use. Use with adequate ventilation. Avoid breathing vapor. (See product label for proper first aid instructions.)

**Note:**

The data contained on this sheet represents typical properties and is not to be used as a basis for preparation of specifications. Contact the Electrical Department, Acheson Colloids Company, before writing specifications on this product.

Information presented in this product data sheet is considered reliable, but conditions and methods of use, which are beyond our control, may modify results. Before adopting our products for commercial use, the user should confirm their suitability. In no case should recommendations or suggestions for the use of our products be understood to sanction violation of any patent.
APPENDIX C

Electrodepositing Set-Up

![Diagram of Electrodepositing Set-Up]

- Rectifier-DC
- Positive Lead Wire
- Negative Lead Wire
- Anode Bus Bar
- Cathode Bus Bar
- Solution Level
- Cathode (base object)
- Heater
- Air Agitation Pipe
- Anode Bag
- Anode (source of metal ions)
- Filter Pump
APPENDIX D

DEPOSIT RATE

The acid copper sulfate bath deposits copper at approximately 100% cathode efficiency throughout the useful plating range. The following table shows the time necessary to deposit varying average thicknesses of coating at varying current densities. It is based on a requirement of 1062 ampere-minutes per square foot per 0.001" copper. An average current density range of 30 to 60 amperes per square foot is suggested. However, optimum current density depends on air agitation, bath temperature, copper sulfate and sulfuric acid concentrations, shape of article to be plated, racking, and anode to cathode distance.

<table>
<thead>
<tr>
<th>Thickness in Inches</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>60</th>
<th>70</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>.0001</td>
<td>4.25</td>
<td>3.55</td>
<td>3.04</td>
<td>2.66</td>
<td>2.36</td>
<td>2.13</td>
<td>1.77</td>
<td>1.52</td>
<td>1.33</td>
</tr>
<tr>
<td>.0005</td>
<td>21.30</td>
<td>17.75</td>
<td>15.20</td>
<td>13.30</td>
<td>11.80</td>
<td>10.65</td>
<td>8.85</td>
<td>7.60</td>
<td>6.65</td>
</tr>
<tr>
<td>.0010</td>
<td>42.50</td>
<td>35.50</td>
<td>30.40</td>
<td>26.60</td>
<td>23.60</td>
<td>21.30</td>
<td>17.70</td>
<td>15.20</td>
<td>13.30</td>
</tr>
<tr>
<td>.0020</td>
<td>85.00</td>
<td>71.00</td>
<td>60.80</td>
<td>53.20</td>
<td>47.20</td>
<td>42.60</td>
<td>35.40</td>
<td>30.40</td>
<td>26.60</td>
</tr>
</tbody>
</table>

The Udylite Company
## APPENDIX E

**DEPOSIT DISTRIBUTION ON ELECTROFORMS**

<table>
<thead>
<tr>
<th>Flat Bottom Grooves or Sharp Angle Indentations</th>
<th>Blind Holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside and outside angles should be rounded generously</td>
<td>Blind holes are usually exempt from minimum thickness requirements</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fins</th>
<th>V-Shaped Protrusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fins increase the electroforming time and costs for a specified minimum thickness</td>
<td>Crown the base, round off corners</td>
</tr>
<tr>
<td>Build-up of jut will rob corners of their share of the deposit</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>V-Bottom Grooves</th>
<th>Deep Scoops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deep V-shaped grooves cannot be electroformed satisfactorily; shallow rounded grooves are better</td>
<td>Deep scoops increase electroforming time and costs for a specified minimum thickness</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Slots</th>
<th>Concave Recesses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow closely spaced slots cannot be electroformed satisfactorily unless the corners are rounded</td>
<td>Electroforming concave recesses is dependent upon dimensions</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rings</th>
<th>Ribs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electroforming is dependent on dimensions. Round off corners and crown from center line, sloping toward both sides.</td>
<td>Narrow ribs with sharp angles are difficult to electroform: wide ribs with rounded edges impose no problem. Taper each rib from its center to both sides and round off edges. Increase spacing if practical.</td>
</tr>
</tbody>
</table>
Variation on a Tea Cup. Vessels. Electroformed copper. Sizes vary in height from 3½" to 5½". 1983.
Winter's End. Wall piece.
Electroformed copper, acrylic, dyed raffia. 10" x 9". 1982.