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Electrodeposition of Metal onto Glass

Janice Whitcraft

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ROCHESTER INSTITUTE OF TECHNOLOGY

ELECTRODEPOSITION OF METAL
ONTO GLASS

A THESIS SUBMITTED TO
THE FACULTY OF THE SCHOOL FOR AMERICAN CRAFTSMEN
IN CANDIDACY FOR THE DEGREE OF
MASTER OF FINE ARTS

DEPARTMENT OF METALCRAFT AND JEWELRY

BY
JANICE CAROL WHITCRAFT

ROCHESTER, NEW YORK
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PREFACE

In writing this thesis, my major concentration is on the area of electrochemistry which is of importance specifically to electroplating copper onto glass. Specific areas of basic electrochemistry have been purposefully omitted to allow for more room to concentrate on this specific area. It is my intention to concentrate on the aspects of (1) preparing the glass surface for subsequent plating, and (2) discussing the structural considerations necessary for forming the glass to be plated. It is my hope that this paper will be of as much value to a glass craftsman as to a metal craftsman. I gratefully acknowledge the assistance of Mr. Frank Beuckman, to whom I dedicate this thesis.

CHAPTER I

DEFINITION AND DESCRIPTION OF ELECTRODEPOSITION

Electrodeposition may be defined as a process whereby "metal ions are transferred electrochemically through an electrolyte from an anode to a surface where it is deposited as atoms of plated metal."¹ The two types of electrodeposition processes which will be dealt with here are electroplating and electroforming. These two types of processes are somewhat different, the major difference being that in electroplating, the mandrel or object which provides the core for the plating, remains as a permanent part of the plated object. In electroforming, the mandrel is removed once the electroform is sturdy enough to support itself.

Electrodeposition is based on the principle that certain substances, when dissolved in water or other suitable solution, will conduct electricity. The electrons in an electric current do not pass through the solution as they would across a wire but "are carried across the solution by an atom or group of atoms known as ions."² In the case of electrodeposition, the power source would be any direct current source, such as a battery, dynamo or rectifier. This power source would be connected to a solution of metallic

¹Lester F. Spencer, "Modern Electroforming," Metal Finishing Guidebook (February 1973): 64.

²E. A. Ollard, Elementary Science for Electroplating Students and Foremen, with a Foreword by E. A. Ollard (Teddington: Robert Draper, Ltd., 1969), p. 43.

salts of the type of metal to be plated by two connections; an anode, or positive pole, and a cathode, or negative pole. The solution, or electrolyte, in which are suspended metal ions, would complete the circuit.

In a copper bath, the electrolyte, or solution of metal salts, is composed of copper sulfate, sulfuric acid, and distilled or de-ionized water.³ When in solution, the constituents of the bath are atoms which have been broken down into copper ions and sulfate ions. These ions can therefore be thought of as incomplete atoms with positive or negative charges depending upon the number of electrons each is carrying. In the case of the copper ion, it is short two of its electrons, thus having a positive charge. The sulfate ion, having two extra electrons, will have a negative charge.

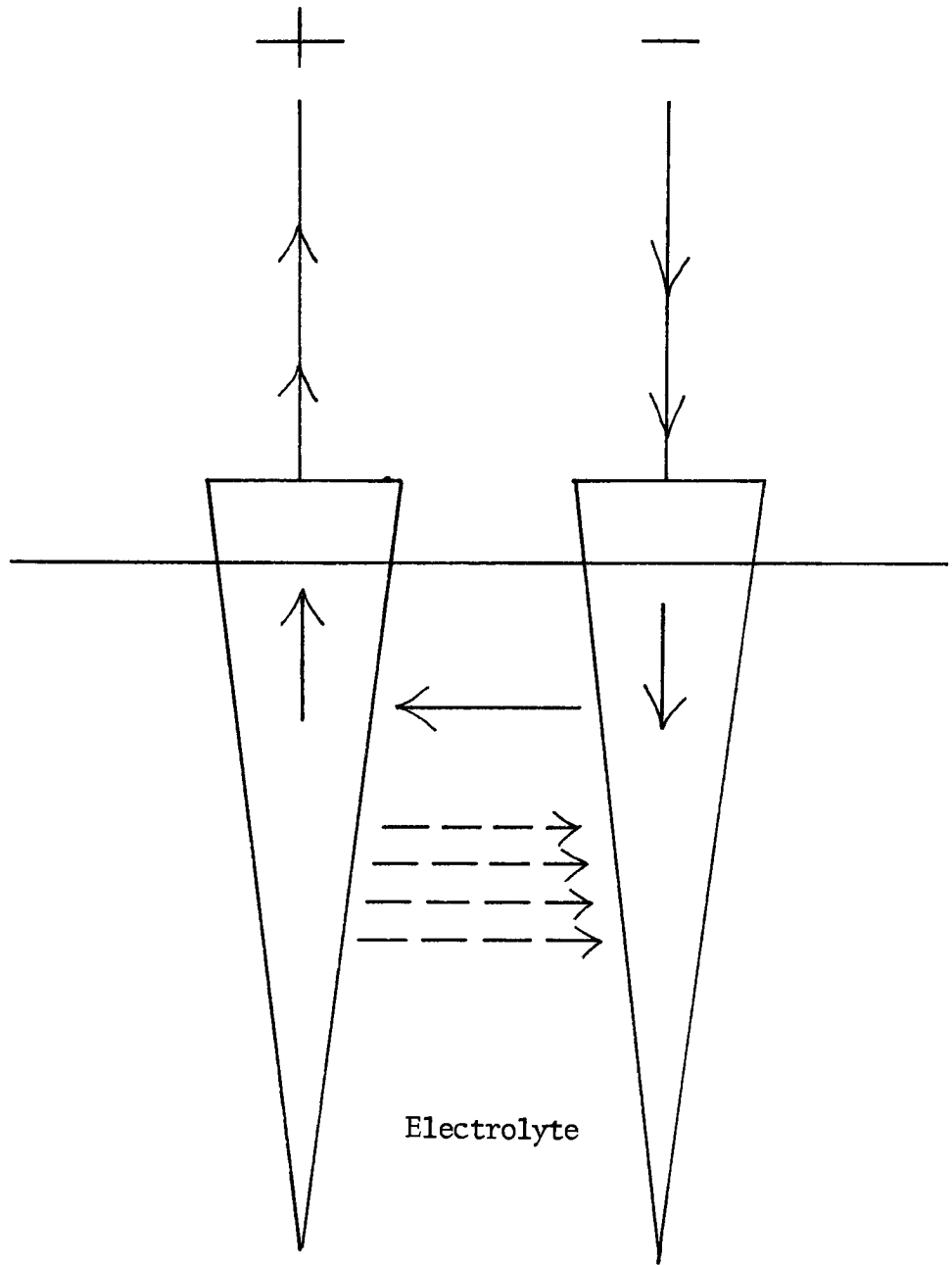
If we pass an electric current through a solution of an electrolyte, the positively charged ions, or cations, will move with the current towards the cathode (or negative electrode) and the negatively charged ions, or anions, will move in the opposite direction.⁴

Thus, the copper ions moving towards the cathode will deposit themselves on the cathode as atoms of copper metal. At this point it should be noted that the flow of copper ions goes against the flow of current. The flow of the current is from the negative to the positive. The ions move from the positive to the negative. (See Figure 1)

In the case of electrodeposition, then, usually a bar of the type of metal to be plated is hung from the positive pole, thus becoming the anode. This anode is not the direct source for the ions which are being deposited on the cathode, rather it is a source for replenishing the ions

³The functions of these constituents are listed in Appendix A.

⁴Ollard, Elementary Science for Electroplating Students and Foremen, p. 16.



→ Flow of current
---→ Flow of ions

Figure 1

suspended in the solution. The object to be plated is then hung from the negative side, thus becoming the cathode. Obviously, for the circuit to be complete, the piece to be plated will have to be conductive also. If the piece is of a non-conductive material such as glass, it must first be made conductive through any one of a number of methods. These methods are listed in Chapter VI, "Metalizing Glass."

As the process of electroplating is much more complex than the description above would lead the reader to believe, it is suggested that anyone seriously considering electroplating should consult a number of books on basic electrochemistry and the electroplating process. Refer to the bibliography for listings. The book, Elementary Science for Electroplating Students and Foremen, by E. A. Ollard is an excellent source for beginners.

CHAPTER II
VARIABLES IN ELECTROPLATING

Apart from the composition of the plating solution, there are four basic variables with which one has to work in plating. These variables are voltage, current density at the cathode and anode, temperature of the solution, and agitation and circulation of the solution.⁵ These four variables must be controlled as accurately as possible for maximum efficiency of the bath.

Voltage

The voltage is a measurement of the amount of force being used to push the current through the electrolyte. The amount of force needed will vary with the composition of the solution, the temperature, the amount of work in the bath and the size of the work. Voltage must be controlled very carefully to avoid rough, dark, crumbling deposits, usually referred to as "burnt deposits." Burnt deposits are a result of plating at too high a current density.

Current Density

Current density is a measurement of the actual amount of current flowing per square foot of the cathode area. As the size of the work in the bath increases, it will become necessary to increase the amount of current flowing through the bath to achieve the same results. This action

⁵Ibid., p. 58.

is stated in Faraday's Laws. The laws are: 1) the chemical effect resulting from electrolysis is directly proportional to the quantity of electricity which is passed through the electrolyte; and 2) the quantity of each substance chemically changed or liberated at an electrode by the passage of a definite quantity of electricity is directly proportional to the equivalent weight of the substance.

Temperature

Most plating solutions have an optimum plating temperature, and this temperature should be maintained as closely as possible. Many solutions do not operate well at room temperature, and some even should be cooled as the passage of current raises the bath temperature.

Circulation and Agitation

Circulation and agitation of the electrolyte are important to keep the solution well mixed especially in the anode and cathode areas. The chemical reactions taking place in these areas require that fresh ions be constantly supplied from the bath. Circulation of the bath is carried out through the whole solution to keep it as constant in composition and temperature as possible. Agitation generally refers to a more violent movement of the solution mainly in the work area either through the introduction of air or through moving the object itself in the solution as in "cathode bar agitation." The object of agitation is to remove as quickly as possible the layer of solution next to the cathode which has become depleted in metal ions. Constantly supplying this area with fresh ions enables the plater to operate the bath at higher current densities, thus enabling him to plate much faster.

CHAPTER III

DESCRIPTION OF PLATING FACILITIES

Power Source

For my power source, I am using a 10 Volt, 50 Amp. rectifier. For electrocleaning purposes it is necessary to have a rectifier which can produce at least 6 volts. The larger the object, the more amperage is necessary to plate it.

Tank

The tank is made by Nalge and is of five thirty-seconds inch polyethylene. It is 12-by-12-by-18 inches in dimension, holds 11 gallons of liquid and comes provided with a lid. To reduce the stress imposed upon the tank when it is filled with the plating solution, I have built a three-quarter-inch plywood frame to support the sides and the bottom. There are three one-inch holes drilled in two of the sides of the tank to support three three-quarter-inch copper rods which act as the cathode bars. The rods are tapped at the ends in order to enable me to bolt the lead wires on from the rectifier. The lead wires are made of insulated copper. (See Figure 2)

Anodes

I am using two phosphorized electrolytic pure copper anodes that are approximately 1 1/2-by-3-by-18 inches. They are suspended from the anode bars by monel hooks which thread into the anodes.

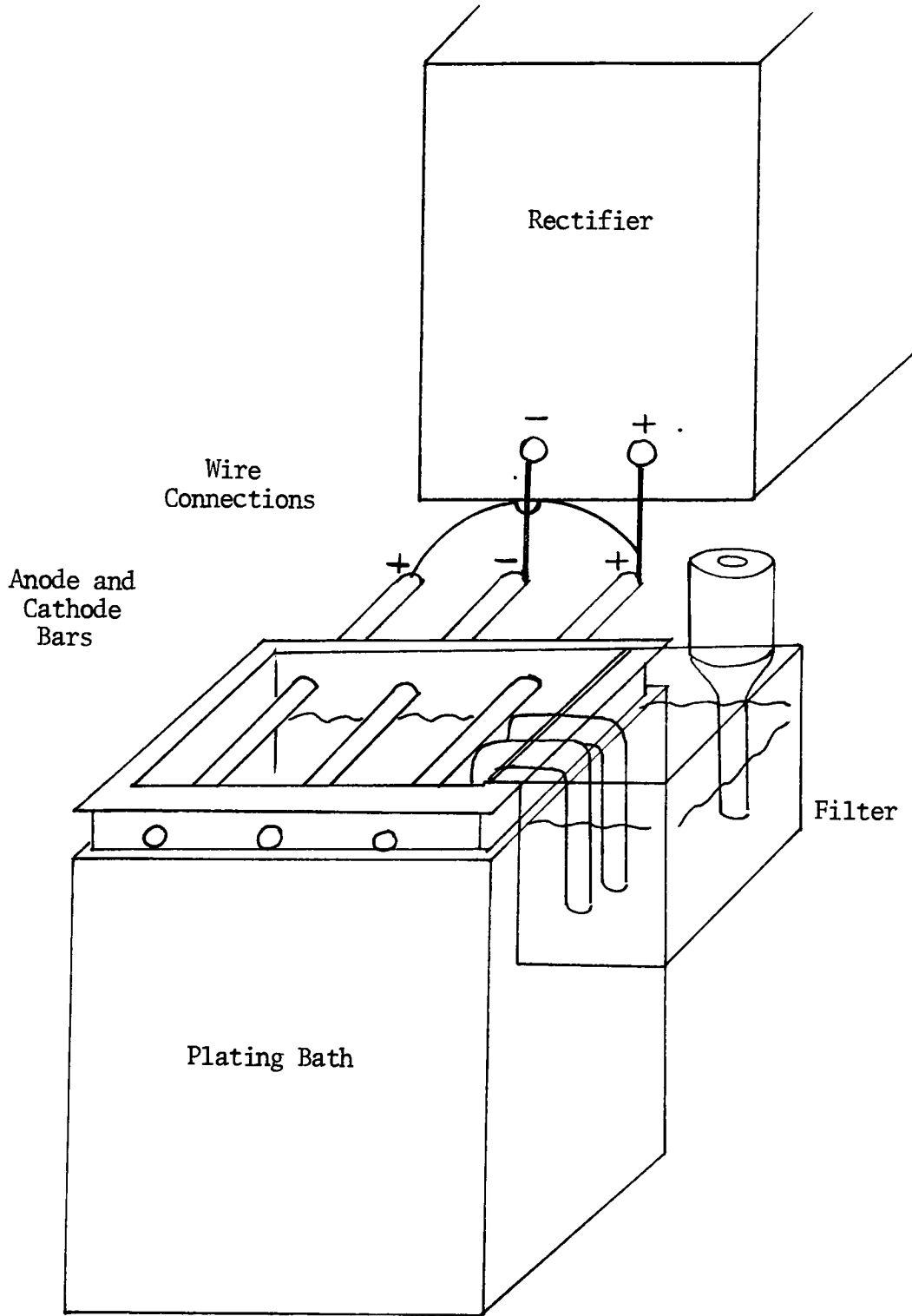


Figure 2

Filtration

I am using a 'Multi-Flo Power Filter' made by 'Cosmic.' The filter tank is filled with polyester fiber. Since I am using levelers and brighteners in the bath, which are basically organic contaminants, no charcoal can be used in the filter as the addition agents would be filtered out. However, diatomaceous earth may be used.

Agitation

1. Mechanical

A polyethylene stirring rod with a small propeller-shaped blade at the bottom is hooked into a small motor. The motor is on a stand which is adjustable for height.

2. Air

Many plating solutions including commercial levelers and brighteners require the use of air agitation for maximum efficiency. For this reason, I am using a 'Silent Giant' air pump (model 120) which is connected to tubing which runs into the tank.

Temperature Control

Since the plating solution I am using lists the temperature for maximum efficiency as 75°, the use of a heater has not been critical. However, from time to time it becomes necessary to burn out the levelers and brighteners and to replace them with new ones. This is usually done by heating the bath to approximately 180°; so for this purpose I have a 200 watt, completely submersible heater by Jäger. The heater is supplied with suction cups to hold it to the side of the tank.

Plating Solution

I have found it to be of great importance to use commercial levelers and brighteners in the plating bath. These addition agents produce smooth, bright deposits which require no finishing. I am using a basic acid-copper bath with addition agents from Lea-Ronal, Inc., and a small amount of hydrochloric acid.⁶ I am using the full formula with the exception of the auxiliary addition agent, B-210.

⁶The constituents of this bath and their functions are listed in the Lea-Ronal technical bulletin #326 in Appendix A.

CHAPTER IV
REASONS FOR ELECTROPLATING GLASS

The use of electroplating on glass is an ideal way of combining the media of glass and metal for several reasons:

1. Types of forms

Electroplating on glass provides free reign of both materials. One can take advantage of the fluid characteristics of the glass and reproduce these forms in metal with high fidelity. These fluid glass forms would be very difficult or next-to-impossible to duplicate by any other metal techniques except perhaps casting or metal spraying techniques. Also, if changes are desired in the shapes, other materials such as wax can be added to the glass and plated at the same time, thus giving the advantages of being able to work the shape while it is cold as well as hot.

2. Weight

Reproduction of glass forms by casting in metal would result in solid metal objects, whereas, with electroplating, the metal is only deposited on the surface of the glass. Electroplated forms would not only be much lighter, but would result in a substantial savings of metal.

3. Fit

Electroplating conforms its shape exactly to the glass, thus alleviating the problem of forming metal parts to fit the glass. Also, because of the nature of the glass, many of the metal working techniques cannot be applied to it. With electroplating techniques, it is possible to completely cover the glass with metal if desired, or to cover recessed areas which

could not be achieved through any sheet-metal working techniques. The potential of breakage during fabrication is minimized.

4. Cold Working

All of the processes involved in electroplating the glass are performed while the glass is cold. This allows the worker to finish the glass with a greater degree of control.

5. Finishing

If the electroplating process is performed correctly, there will be no clean-up involved. The deposits will be smooth and shiny and will not require polishing.

6. Time

Glass and metal can be combined in a fraction of the time it would take to combine the two media with other metal working techniques. While the object is being plated in the bath, the worker is free to work on other pieces. Depending upon the size of the work, more than one piece can be plating at one time.

CHAPTER V
STRUCTURAL CONSIDERATIONS
FOR GLASS WHICH IS TO BE PLATED

Since glass is a non-conductive surface, it must first be made conductive by any number of methods. However, non-conductive surfaces characteristically do not provide as strong an adhesive bond as one would achieve with plating on a metal. If a strong bond is intended, considerable dependence will have to be placed upon mechanical locking devices, either obtained structurally from the shape of the object or by purposely roughening the surface.⁷ It should be noted, however, that one of the drawbacks of a copper plating bath is that it has poor throwing power, meaning that deeply recessed areas will have a tendency to plate less than protruding areas. Therefore, deeply recessed undercuts should be avoided if possible.

1. Structural Devices

Undercuts: In forming the glass, it is helpful to consider mechanical locking systems to hold the metal to the glass. Since the metal does not really adhere to the surface of the glass but merely covers it, it must be held to the glass by undercuts. Undercuts provide a locking device within the shape to keep the deposit in place. (See Figure 3)

⁷H. L. Pinkerton, "Preparing Non-Conductors for Electroplating," in Modern Electroplating, ed. Frederick A. Lowenheim (New York: John Wiley & Sons, Inc., 1942), p. 605.

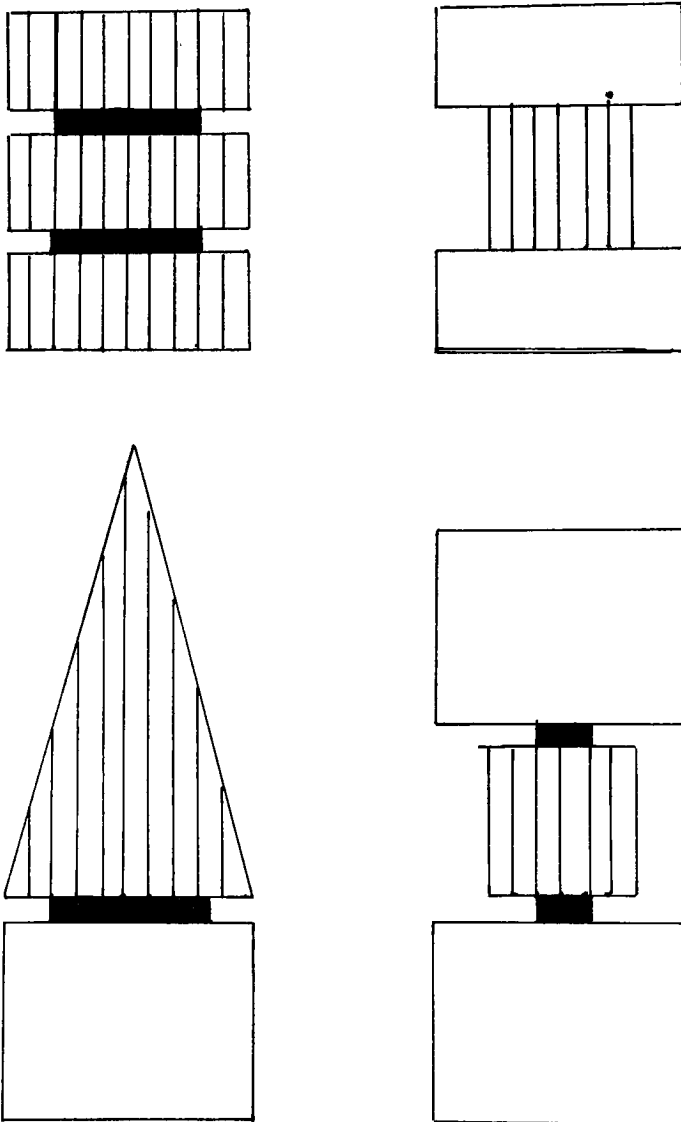


Diagram of Types of Undercuts
Figure 3

2. Surface Roughening

Sandblasting: The surface areas of the glass to be plated can be sandblasted to provide a better adhesive bonding surface for the plating. This surface roughening will not create as strong a bond as undercuts in the piece. The deposit may still come loose and have to be permanently epoxied into place. The deposit of metal will also tend to reflect the sandblasted surface, thus creating a textured metal deposit.

Etching: The surface of the glass can be chemically etched with a solution of hydrofluoric acid and water in a ratio of 1:3. This etch will be much lighter in texture than the sandblasted surface, but the deposit will still be slightly textured. Care should be exercised when working with hydrofluoric acid. Wear neoprene gloves, apron and safety glasses, and use only with adequate ventilation. (See Appendix B, "Hydrofluoric Acid")

3. Chemical Treatment

Fuming or Iridizing: I have found that fumed glass tends to make the deposits grow past the areas which are made conductive. The principle behind this is that the fuming agent used is stannous chloride, a conductor, which is also a sensitizing agent for mirroring glass. In the fuming process, the stannous chloride is taken into the surface of the glass where it exchanges ions with the glass to produce the rainbow effect (called 'Newton Rings').⁸ Electrodeposits have a tendency to grow on areas of the glass which have not been made conductive in any other way but with the

⁸Frank Kulasiewicz, Glassblowing (New York: Watson-Guption Publications, 1974), p. 162.

fuming process and exhibit fairly strong adhesive qualities. The plating tends to grow in a pattern resembling snowflakes, due to the uneven nature of the fuming on the surface of the glass.

CHAPTER VI
METALIZING GLASS

Metalizing glass is basically the same as metalizing any other non-conductive surface. There are two basic types of non-conductive surfaces dealt with in plating:

1. Materials which are porous, absorbent, organic, or sensitive to solutions used in plating. (Wood, plaster, lace, flowers, insects, etc.)
2. Materials which are non-porous, inorganic, and impervious to the plating solutions. (Glass, plastics, wax, etc.)

Obviously, since glass falls into the second category, the problems of making the material impervious to the plating solution are alleviated.

Regardless of what type of deposit is required, the surface of the non-conductive material must be made conductive prior to the plating process. There are several methods of producing a conductive surface on glass. Each has advantages and disadvantages. The easiest method of making the surface conductive is to use a silver conductive paint, but for persons interested in researching other methods, several alternatives have been listed.

1. Metal Powders

This process requires the use of a fine grade of metallic powder such as copper which is brushed over a varnished or lacquered surface. A varnish such as this could be a mixture of 1 part copal varnish to 3 parts turpentine. The tackiness of the surface is critical; it should be tacky enough for the powder to adhere and dry enough so that the powder does not

ball up. After the surface is carefully covered, the contact wires are carefully attached, and the piece is given a silver immersion coating for a few seconds in a solution of:

Silver cyanide	AgNO ₃	22.5 g/l
Sodium cyanide	NaCN	26.3 g/l

This coating is used to improve conductivity. The solution should be clear; if not, a little more cyanide is added to clear it, but the free cyanide should be substantially zero.⁹

The powder below can be sprayed, but care should be taken to hold the gun far enough away from the work to obtain a dry spray leaving a somewhat dull, sandy surface.

Plater's (i.e., oil free) copper bronze powder	10 gr.
Cellulose lacquer (gum-free)	14 ml.
Lacquer thinner	42 ml. ¹⁰

One should allow the lacquer to dry for two to three hours before plating, preferably giving the piece a silver dip as before. If a bright surface appears after spraying, this means that the powder is covered over with lacquer and will not conduct.

2. Graphiting

Graphiting is done either by dry brushing (known in the printing trades as polishing) or with a suspension of graphite in water (wet leading), or with a combination of both.¹¹ Graphited surfaces are frequently further coated with copper for improved conductivity. The object is placed in a

⁹Pinkerton, "Preparing Non-Conductors for Electroplating," p. 607.

¹⁰Ibid.

¹¹Ibid.

solution of 75 g/l of CuSO_4 (Copper sulfate·penta hydrate), and a layer of fine iron powder is sprinkled on the surface. This is a system similar to contact plating, in which the iron, dissolving anodically in contact with the graphite, provides the potential necessary for the copper to coat the graphite. This is not a very successful process, however, because the graphite has a tendency to dissolve in areas of low current density or high agitation.

3. Metalizing by chemical reduction (mirroring)

Practically every known metal can be deposited as a "mirror," however, silver is usually used because of the relative ease with which a suitable film is formed and its high conductivity even in thin films.¹² Because the film is not very adhesive, it is customary to roughen the surface either by sandblasting the glass or chemically with dilute hydrofluoric acid. The surface must be kept clean. Rinse in distilled or de-ionized water after cleaning and especially after sensitizing.

Sensitizing is a process which accelerates the silvering and improves the adhesion of the film to the glass. Of a number of compounds tested, stannous chloride was shown to be the best. The concentration of the stannous chloride sensitizing solution recommended ranges from 0.7 to 150 g/l. This solution may be sprayed, dipped or swabbed onto the surface of the glass. Other stannous chloride solution formulas involve hydrochloric acid, such as:

- | | |
|----------------------|---------|
| 1. Stannous chloride | 10 g. |
| Hydrochloric acid | 40 cc. |
| Water | 1 liter |

¹²Ibid., p. 608.

2. Stannous chloride	180 g.
hydrochloric acid	180 cc.
Water	200 cc. ¹³

After the piece has been sensitized, it is very important to rinse it well in distilled or de-ionized water before a metal surface is precipitated.

There are several formulas for mirroring glass. A standard one is the "Brashear Formula":

a. Silver nitrate solution	
Silver nitrate	20 g.
Potassium hydroxide	10 g.
Distilled water	400 ml.

A precipitate is formed and ammonium hydroxide is added drop by drop until the precipitate just dissolves.

b. Reducing solution	
Cane sugar	90 g.
Nitric acid	4 ml.
Distilled water	1 liter

Immediately before using, mix one part of reducer with four parts of silver. A reaction temperature of 68°F, is preferable.¹⁴ Mirroring solutions are very dangerous to use and, when left to dry, become explosive. (See Appendix B for safety precautions for these and other materials used in the plating process.)

One formula recommended for mirroring glass with less danger involved is:

Solution A	
AgNO ₃ (Silver nitrate)	9.59 g/l
NH ₃ , added as ammonium hydroxide	4.39 g/l

¹³Charles Davidoff, "Metalizing Non-Conductors," Metal Finishing Guidebook (1974), p. 488.

¹⁴Ibid.

Solution B

Hydrazine sulfate (NH ₂) ₂ ·H ₂ SO ₄	19.18 g/l
NaOH (optional) or equivalent KOH	4.79 g/l ¹⁵

The two solutions are mixed in equal proportions. For decreasing the speed of reduction, the sodium hydroxide may be dispensed with, and a still further decrease may be obtained by also increasing the ammonium hydroxide content of solution A. The formulation given is also suitable for spray silvering, as are similar formulations in which glyoxal (CHOCHO) replaces the hydrazine compound as reducing agent.

In industry, these films are produced by spraying with a two-solution gun. Each part of the solution is fed into the gun separately, and they are combined in the air when they come out. This results in increased efficiency and reduction of waste of the solution.

No matter how the film is applied, the maximum thickness is of the order of 0.006-0.01 mil. The properties of the films appear to be improved by drying, especially overnight before plating.¹⁶

4. Deposition of Copper Films

There are many copper film formulas in the literature, however, most of the earlier ones are said to suffer from the drawback that the deposits tend to be non-adherent and spongy. The most widely suggested solution is Fehling's:¹⁷

Anhydrous copper sulfate	2 g.
Silver nitrate	0.2 g.
Rochelle salt	4 g.

¹⁵Pinkerton, "Preparing Non-Conductors for Electroplating," p. 610.

¹⁶Ibid., p. 611.

¹⁷Davidoff, "Metalizing Non-Conductors," p. 488.

Potassium hydroxide	4 g.
Distilled water	100 cc.

Reduce with 5% formaldehyde solution.

5. Metallic Paints or "Lusters"

Metallic paints and lusters come ready mixed to the glass and ceramic industries. Lusters are painted on and fired in a kiln. They can then be plated in the usual manner.¹⁸

6. Conductive Silver Paints

Silver conductive paint is the easiest method of making the glass surface conductive for electroplating.

Silver paint containing 60 to 70% silver metal pigment is preferred for brushing and lesser percentages for spraying. Cellulosic ester and methacrylate type resins are generally used as the binders for these paints. Epoxy bases have now become available. They are sold as proprietary products by several large and small manufacturers under the descriptive name of "Silver Conductive Paint."¹⁹

With all of these conductive surfaces, it is good to remember that the surfaces are very thin and care should be taken in the initial stages of plating not to use too high an amperage. However, coverage should be as quick as possible to minimize attack on the surface by the bath or the appearance of "bipolar effects, whereby the uncovered coating may become anodic to the electrodeposit and begin to deplate."²⁰

¹⁸Pinkerton, "Preparing Non-Conductors for Electroplating," p. 613.

¹⁹Davidoff, "Metalizing Non-Conductors," p. 485.

²⁰Pinkerton, "Preparing Non-Conductors for Electroplating," p. 616.

APPENDIX A

LEA-RONAL BULLETIN # 326

LEA-RONAL COPPER GLEAM ACG-8 ACID COPPER PLATING PROCESS

The Lea-Ronal Copper Gleam bright acid copper plating process supplies the need for an acid copper bath that is stable, produces bright highly leveled ductile deposits, and is economical to operate. The brightness and leveling of the deposit is equal to or better than that secured from present day bright nickel solutions. This process is particularly advantageous for PLATING ON PLASTICS.

Due to the brightness and superior leveling of the Lea-Ronal bright acid copper, properly prefinished steel may be plated directly with copper-nickel-chrome without intermediate buffing of the copper, thus effecting great savings in labor, material, and equipment costs. When plated on unbuffed steel, savings in finishing costs will be achieved due to the ability of this copper deposit to "level" fine scratches or polishing marks. In addition, the deposit is easy to buff and has a hardness of 125-150 Vickers. Since the brighteners have surface activity, the process has good tolerance to organic contamination.

SOLUTION COMPOSITION AND OPERATING CONDITIONS

	<u>Range</u>	<u>Preferred Composition and Conditions</u>
Copper sulfate	28-34 oz/gal.	32 oz/gal.
Sulfuric Acid (Ap.Gr.1.82)	6-10 oz/gal.	8 oz/gal. [by weight]
Lea-Ronal Copper Gleam ACG-8	0.3-0.5% by vol.	0.4% by vol.
Lea-Ronal Copper Gleam B-210	0.01-0.02% by vol.	0.02% by vol.
Chloride Ion	50-100 ppm	75 ppm
Temperature	70-85° F.	75° F.
Agitation	Vigorous (Air, cathode rod or solution)	Air

Cathode current density range 10-100 Amps/Sq. ft.

SOLUTION MAKEUP

Prior to the solution makeup, it is mandatory that the tanks, filter, hose lines, etc., be completely cleaned of grease and dirt. Tanks should be constructed of polypropylene, polyethylene, fiberglass or steel lined with Koroseal. The copper sulfate is first dissolved in [de-ionized] warm water and the sulfuric acid is added using agitation.

CAUTION: Concentrated sulfuric acid should be added very slowly and with solution or air agitation to prevent spattering.

After the chemicals are dissolved, the solution should be carbon treated using 2 lbs. of an approved powdered activated carbon per 100 gallons of solution. It may be desirable at this point to dummy the solution for approximately 8 hours at 10 Amps/sq. ft. to remove metallic impurities.

After dummyming, the Lea-Ronal Copper Gleam brighteners ACG-8 and B-210 are added, the temperature adjusted and the solution is ready for plating.

ANODES

Phosphorized copper anodes are recommended. The anodes are preferably bagged and these bags should be of dynel or polypropylene.

FUNCTION OF THE CONSTITUENTS

Copper Sulfate- This chemical supplies the copper metal to the solution and should be kept at its optimum concentration of 32 oz. per gallon. If the copper sulfate concentration falls below 28 oz. per gallon, the [current density] range will be reduced as well as the ability of the solution to "level."

Sulfuric Acid- Sulfuric Acid provides conductivity and helps the throwing or covering power. Below 5 oz/gal. sulfuric acid, the covering power is greatly reduced. The optimum concentration of this acid is 8.0 oz./gal.

Chloride- Chloride Ion is necessary for proper operation of the process and should be maintained at the specified range. Concentrations of chloride over 100 ppm may result in reduced brightness in the lower current density ranges. With chloride concentrations below 50 ppm, the high current density range is reduced and burning may result.

LEA-RONAL COPPER GLEAM ACG-8

This material is the primary brightener and as such is equivalent to the primary brighteners (aromatic sulfonic acid, or sulfonamide types) of modern bright nickel baths. With ACG-8 alone, the copper deposit will be soft, ductile, bright, and will show fair leveling characteristics. For a new solution, ACG-8 is added at a concentration of 0.04% by volume or 4 gallons/1000 gallons of plating solution. Replenishment of ACG-8 is generally made at the rate of 1 quart for 5,000 ampere hours. Since consumption rates may differ for individual requirements, your Lea-Ronal service laboratory or service engineer should be consulted for a specific replacement schedule. Since no brightener breakdown occurs when the solution is idle, consumption of the ACG-8 is based only on plating time. ACG-8 is removed by carbon treatment.

LEA-RONAL COPPER GLEAM B-210

This brightener is used for both makeup and replenisher. For a new bath, add 3/4 pint/1000 gallons. B-210 is the booster brightener (and leveler) and its action on the copper deposit is equivalent to the action of booster brighteners in bright nickel plating. When used together with ACG-8, the deposit will have its maximum brightness and maximum leveling characteristics. Large excesses (100%) of B-210 should be avoided since this may cause striations. Low current density dullness or lack of throwing power may often be corrected by adding B-210. This brightener should be added often and in small quantities, therefore, dropping bottles are advisable. The replenishing rate of B-210 is 1/2-1 pint every 5000 Ampere hours.

AGITATION

In order to obtain best results, it is necessary to operate with maximum agitation. Air agitation will give the brightest deposits and is therefore preferred. Solution agitation or work rod agitation will produce bright deposits that are satisfactory, but the bright current density range will be narrower and leveling will be reduced.

WETTING AGENTS

Copper Gleam ACW is normally not required. If pitting occurs due to organic contamination, add 1 to 2 pints per 1000 gallons of solution.

TEMPERATURE

The preferred temperature range is 70-85°F. Higher temperatures adversely affect the low current density brightness. Since temperature control is desirable for optimum operation, the use of a titanium heating and cooling coil is suggested to keep temperatures at 75°F.

CURRENT DENSITY RANGE

10-100 Amps/ sq. ft. or higher, depending upon bath temperature, agitation, racking and shape of work.

APPENDIX B
SAFETY PRECAUTIONS

Many of the chemical processes described in this text are extremely dangerous. This appendix deals with safety precautions concerning these processes and certain chemicals. The entries are listed in alphabetical order. All entries preceded by an asterisk (*) are from the Handbook of Industrial Toxicology by E. R. Plunkett.

*AMMONIA

Synonyms:

Ammonia gas. Ammonia water. Ammonium Hydroxide.

Description: Gas with strong, pungent odor

Occupational Exposure:

Chemical synthesis. Tanning. Dyes. Fertilizers.

Artificial silk. Refrigerant. Explosives. Petroleum.

Water Purification. Silvering mirrors.

Threshold Limit Value: 50ppm of air

Toxicity:

Absorption: Inhalation

Pathology:

Irritant and corrosive. Reflex respiratory inhibition.

Signs and Symptoms:

Ulceration of conjunctiva and cornea; corneal and lenticular opacities.

Irritation and burns of skin and mucous membranes.

Headache. Salivation., nausea, and vomiting.

Dyspnea and cough. Bronchitis and hemoptysis.

Pulmonary edema.

Diagnostic Tests: None reported

Treatment:

Irrigate eyes with water, then instill olive oil

Wash contaminated areas of body with soap and water

Oxygen, with use of intermittent positive-pressure breathing apparatus

Bronchodilators and decongestants

Codeine for cough

Sedation if necessary

Cortisone

Symptomatic and supportive

Disability:

Usually not more than 72 hours; damage to eyes may be permanent.

Preventive Measures:

Adequate ventilation. Face shields. Chemical cartridge respirators. Rubber gloves, aprons, boots

Preclude from exposure those individuals with eye and pulmonary diseases

*CHLORINE

Synonyms: None

Description: Chemical element; heavy greenish-yellow gas

Occupational Exposure: Chemical synthesis. Disinfectants. Bleaches.
Paper. Dyes.

Threshold Limit Value: 1 ppm of air

Toxicity:

Absorption: Inhalation

Pathology: Irritant

Signs and Symptoms:

Irritation of eyes. Corneal burns. Dyspnea. Cough.

Retrosternal pain. Hemoptysis. Headache. Epigastric pain.

Nausea and vomiting. Weakness. Cyanosis. Pulmonary edema.

Diagnostic Tests: None established

Treatment:

Irrigate eyes with water. Rest. Oxygen, with intermittent positive-pressure breathing apparatus. Bronchodilators and decongestants. Codeine for cough. Sedation if necessary.

Cortisone. Symptomatic and supportive.

Disability: Usually not longer than 12-24 hours.

Preventive Measures:

Adequate ventilation. Chemical goggles. Chemical cartridge respirator.

COPPER FILMS

The same safety precautions apply to copper films as to
MIRRORING PROCESS.

*CYANOGEN-CYANIDES

Synonyms:

Ethyl Cyanide (Propionitrile). Formonitrile. Methyl Cyanide (Acetonitrile). Potassium Cyanide. Sodium Cyanide.

Occupational Exposure:

Organic synthesis. Fertilizers. Metal Cleaning. Electroplating. Photography. Tanneries. Fumigation. Gold extraction. Pigments.

Threshold Limit Value: 5 mg/cu m of air

Toxicity:

Absorption:

Inhalation. Ingestion. Percutaneous

Pathology: Cytotoxic anoxia

Signs and Symptoms:

Acute:

Headache. Dizziness. Hyperpnea. Rapid pulse. Nausea and vomiting. Unconsciousness. Convulsions. Death.

Chronic:

Headache. Anorexia. Dizziness. Weakness. Macular, papular, or vesicular dermatitis

Diagnostic Tests:

Cyanide in blood

Increased excretion of thiocyanate in urine (smokers may have up to 30 mg/liter of thio-cyanates in urine)

Treatment:

Remove from exposure

Irrigate eyes with water

Wash contaminated areas of body with soap and water

Artificial respiration and oxygen

Amyl nitrite pearls by inhalation, every 5 minutes

10cc of 3% sodium nitrite intravenously over a period of 2 minutes

Then 50cc of 25% sodium thiosulfate intravenously

Hospitalize

Repeat injections at hourly intervals as necessary

If patient swallows cyanide, induce vomiting, administer 1% sodium thiosulfate orally and proceed as above

Symptomatic and supportive

Disability:

Possible damage to central nervous system from prolonged anoxia

Preventive Measures:

Adequate ventilation. Chemical goggles. Chemical cartridge respirator of cyanide type. Rubber gloves and aprons.

No food or smoking in work area

Ear plugs for employees with perforated ear drums

Employees should not work alone

Preclude from exposure those individuals with diseases of central nervous system, heart and lungs

EMERGENCY KIT

For the treatment of certain cyano compounds, the following supplies should be readily available:

CYANIDE POISON ANTIDOTE KIT
(Lilly)

- 2 dozen amyl nitrite pearls
- 2 ampoules sodium nitrite solution (10cc, 3% solution)
- 2 ampoules sodium thiosulfate solution (50cc, 25% solution)
- 1 10cc and 1 50cc syringe with needles
- Tourniquet
- Cotton balls
- 1 bottle 70% alcohol
- 2 one pint bottles of 1% sodium thiosulfate solution for oral use

[This kit is available only by prescription.]

ELECTROPLATING

For plating processes, eye goggles and rubber gloves should be worn. To protect clothing a plastic apron should be worn also. Adequate ventilation is necessary to avoid attack on the nasal passages and other irritations. A chemical cartridge respirator should also be worn. (See HYDROCHLORIC ACID, SULFURIC ACID)

ETCHING

Hydrofluoric acid is used in etching glass, usually in a 1:3 ratio to water. This acid should be stored in plastic bottles as it will attack any glass containers. Care should be taken when mixing hydrofluoric acid or any other acid. Always pour acid into water, slowly. Never pour the water into the acid. Wear safety glasses and protective clothing (preferably plastic) when working with acids. Wear Neoprene gloves when working with hydrofluoric acid and only use with adequate ventilation. Hydrofluoric acid is one of the most dangerous of the acids to use. (See HYDROFLUORIC ACID)

*FORMALDEHYDESynonyms:

Formalin. Formic Aldehyde. Methanal. Methyl Aldehyde.
Oxymethylene. Paraform. Paraformaldehyde.

Description:

Colorless gas; pungent odor.

Occupational Exposure:

Disinfectant. Glass etching. Agriculture. Textiles. Laquers.
Dyes. Tanning. Rubber. Plastics. Brewing. Paper. Inks.

Threshold Limit Value: 5 ppm of air

Toxicity:

Absorption:

Inhalation. Ingestion

Pathology:

Irritant. Local necrosis

Signs and Symptoms:

Local:

Conjunctivitis. Corneal burns. Brownish discolorations
of the skin. Dermatitis; Urticaria. Pustulovesicular
eruption.

Inhalation:

Rhinitis and anosmia. Pharyngitis. Laryngospasm.
Tracheitis and bronchitis. Pulmonary edema. Cough.
Constriction in chest. Dyspnea. Headache. Weakness.
Palpitation. Gastroenteritis.

Ingestion:

Burning in mouth and esophagus. Nausea and vomiting.
Abdominal pain. Diarrhea. Vertigo. Unconsciousness.
Jaundice. Albuminuria, hematuria, anuria, Acidosis.
Convulsions.

Diagnostic Tests:

Formaldehyde in expired air or urine

Treatment:

Irrigate eyes with water
Wash contaminated areas of body with soap and water
Gastric lavage, if ingested, using 1% ammonium carbonate
and followed by saline catharsis
Oxygen, if indicated
Symptomatic and supportive

Disability: No permanent effects reported

Preventive Measures:

Adequate ventilation. Chemical goggles. Chemical cartridge respirator
or airline mask. Rubber protective clothing.

*GRAPHITE

Synonyms:

Black Lead. Mineral Carbon. Plumbago

Description: Soft black scales

Occupational Exposure:

Foundries. Metallurgy. Pencils. Lubricants. Electrodes.
Dynamo brushes. Dry batteries.

Threshold Limit Value: None established

Toxicity:

Absorption: Inhalation

Pathology:

Pneumocomiosis--"graphosis". Some graphites contain silica
and may therefore produce silicosis

Signs and Symptoms:

Cough. Shortness of breath. Bronchitis

Diagnostic Tests:

X-ray may show scattered nodular shadows and occasionally
cyst-like formations

Treatment: Symptomatic and supportive

Disability: No permanent effects reported

Preventive Measures:

Adequate ventilation. Mechanical filter respirator

*HYDROCHLORIC ACID

Synonyms: Chlorohydric Acid. Hydrogen Chloride. Muriatic Acid.

Description: Clear, colorless gas, or yellowish liquid.

Occupational Exposure: Metal pickling. Cane sugar refining. Acid cleaning. Electroplating. Engraving. Rubber. Plastics. Textiles. Etching.

Threshold Limit Value: 5 ppm of air (suggested)

Toxicity:

Absorption: Inhalation. Ingestion

Pathology: Forms acid proteiates

Signs and Symptoms:

Local:

Conjunctivitis. Corneal necrosis. Dermal burns.

Inhalation:

Rhinitis. Perforation of nasal septum. Dental erosion.

Laryngitis. Bronchitis. Pneumonia. Headache.

Palpitation.

Ingestion:

Burning in mouth, pharynx, esophagus, stomach. Salivation.

Nausea, vomiting, hematemesis. Perforation of intestinal

tract. Chills and fever. Anxiety. Shock. Nephritis.

Diagnostic Tests: None established

Treatment:

Irrigate eyes with water

Wash contaminated areas of body with soap and water

Treat burns as usual

Gastric lavage, if ingested, with 5% sodium bicarbonate solution followed by instillation of aluminum hydroxide gel. Care must be exercised in passing the lavage tube and alkalies should be used carefully because of formation of gas.

Oxygen, with use of intermittent positive-pressure breathing apparatus: 5% sodium bicarbonate solution as an aerosol may be used, as well as bronchodilators and decongestants.

Disability: No permanent effects reported

Preventive Measures:

Adequate ventilation. Chemical goggles. Chemical cartridge respirator. Rubber gloves and protective clothing.

*HYDROFLUORIC ACIDSynonyms: Hydrogen FluorideDescription: Colorless, fuming, corrosive liquidOccupational Exposure: Processing nuclear fuels. Chemical synthesis. Pharmaceuticals. Glass etching. Catalyst. Ceramics. Plastics. Petroleum.Threshold Limit Value: 3 ppm of airToxicity:

Absorption: Inhalation. Ingestion

Pathology: Irritant. Corrosive. Pulmonary edema. Nephritis.

Degenerative changes in liver

Signs and Symptoms:

Conjunctivitis and corneal burns. Severe skin burns with ulceration. Retrosternal pain. Cough and hemoptysis. Dyspnea. Bronchopneumonia. Cyanosis. Shock. Muscle spasms and convulsions. Paresthesias. Jaundice. Oliguria, albuminuria, hematuria

Nausea, vomiting, abdominal pain, diarrhea

Burns and corrosion of mouth, esophagus, stomach, and small bowel

Diagnostic Tests: Fluorine in blood and urine

Treatment:

Local:

Irrigate eyes with water

Wash contaminated areas of body with saturated solution of sodium carbonate or 4% solution of aqueous ammonia

Massage a paste of 20% magnesium oxide in glycerol into burned areas; (This has also been used in the eyes)

Inject 2-5cc of 10% solution of calcium gluconate beneath and around the burned areas

Nails may be split or removed if necessary for adequate treatment

General:

Gastric lavage, if ingested, using a 5% solution of calcium chloride followed by saline catharsis

Calcium gluconate intravenously and calcium lactate orally

Barbiturates for convulsions

Oxygen

Use of intermittent positive-pressure breathing apparatus with an aerosol of 1% calcium chloride has been used

High calcium diet

Symptomatic and supportive

Disability: Burns may produce permanent damage

Preventive Measures:

Adequate ventilation. Chemical goggles or full face shield. Chemical cartridge respirator or airline masks. Neoprene gloves, aprons, boots

IRIDIZING OR FUMING

(From Glassblowing, by Frank Kulasiewicz, p. 162)

Of prime consideration is the poisonous nature of the chemicals used and the released caustic fumes, so selection of equipment is important. Spraying is an effective way of iridizing, but the chemicals attack most metals. Do not use a commercial paint spray gun because most will literally be dissolved by the chemicals.

Stannous chloride, when heated, releases chlorine gas; therefore, great care must be taken when performing fuming operations. Fuming should be done under a hood attached to an exhaust system to carry away the fumes. The components of the area should be preferably made of plastics, since the metal parts, such as blowers and motors will be eaten up by the fumes.

(See TIN OXIDE, CHLORINE)

METAL POWDER PROCESS

With the metal powder process, great care should be taken with the silver immersion coating. This coating contains cyanides which can cause death in a matter of minutes. Cyanides should never be allowed to come in contact with acids as they will produce hydrocyanic acid gas which is fatal.

(From Special Report No. 14, "The Hazards of Cyanides in the Jewelry and Silverware Industries," by P. E. Gainsbury.)

Cyanides and hydrocyanic acid are what are known as "True protoplasmic poisons". That is, they interfere with the mechanism by which oxygen enters the tissues and cause death by asphyxiation. Poisoning can not only occur by breathing cyanide vapours or ingesting solid cyanides or solutions, fatal doses of hydrocyanic acid may be rapidly absorbed through unbroken skin

Inhalation of hydrocyanic acid gas or dust or vapour from solid cyanides may cause dizziness, rapid heart action, shortness of breath and nausea, followed by unconsciousness and death. Taking of cyanides by mouth first gives rapid respiration followed by slow and gasping breathing and again unconsciousness and death

Needless to say, the utmost speed in treatment is absolutely essential and the necessary materials to counter cyanide poisoning should always be kept immediately available where these substances are used.

(See CYANOGEN-CYANIDES)

MIRRORING PROCESS

(From "Preparing Non-Conductors for Electroplating," by H. L. Pinkerton, pp. 609-610.)

Modern silvering practice avoids dangerous and wasteful processes like the Brashear (cane sugar), Rochelle salt, and formaldehyde processes. The danger of these processes resides in the fact that in each the silver is reduced from a silver ammine-nitrate solution which contains no ammonium hydroxide in excess of that required to redissolve the precipitate formed when ammonium hydroxide is added to a silver nitrate solution. Such a solution is capable of forming fulminating silver if the solution is heated or dries upon a surface, or may even form spontaneously in the solution on standing 24 hr. In addition, the first two methods named before use silver solutions that as well as the ammonia also contain small amounts of alkali metal hydroxides to catalyze the reduction of silver. Unfortunately, this addition also promotes the tendency towards formation of fulminating silver.

The more modern processes use reducing agents which are capable of reducing silver from a solution in which there is an excess of ammonium hydroxide. The alkali metal hydroxide accelerator, if used, is hydrazine sulfate, nitrate, or hydroxide. Glyoxal has also been used. This procedure avoids the explosion hazard and, further, is economical of silver, because if all the silver ammonio-nitrate solution which has been prepared is not used at once, it may be kept safely; with the older processes the interests of safety required that all such solutions, used or unused, be destroyed within a few hours of preparation. In the newer processes, only used solutions are destroyed, usually by the addition of hydrochloric acid for the recovery of silver chloride.

(From "Metalizing Non-Conductors," by Charles Davidoff, p. 488.)

CAUTION: To avoid formation of explosive fulminates, the silver salt, caustic, and ammonia should never be mixed in concentrated form, but should be diluted with water first. Containers which have held this fulminate solution should be washed carefully and never allowed to dry with any residual material. Dry, this material is explosive.

Rubber gloves should be worn for this procedure. Use in a well ventilated room. (See HYDROCHLORIC ACID, HYDROFLUORIC ACID, SILVER AND COMPOUNDS, AMMONIA, and FORMALDEHYDE)

*SILVER AND COMPOUNDS

Synonyms:

Argentum. Silver Chloride. Silver Cyanide. Silver Nitrate. Silver Oxides. Silver Picrate.

Description:

Lustrous soft white metal: salts of various colors

Occupational Exposure:

Pharmaceuticals. Silver Plating. Photography. Solder and brazing alloys. Mirrors. Ceramics. Alloys. Mining.

Threshold Limit Value:

12 million particles/cu ft of air (suggested)

Toxicity:Absorption:

Inhalation. Ingestion.

Pathology:

Metal itself is unreactive

Silver precipitates in epithelial layers of skin and in elastic tissue and is then reduced by the action of light or hydrogen sulfide, resulting in argyria (bluish spots)

Signs and symptoms:

Argyrosis cornea and argyrolentis have been described

Generalized argyria ("blue men"): dark slate gray color of uniform distribution over the face, forehead, neck, hands, and forearms: fingernails may be a deep chocolate brown color; slight discoloration may be seen in the covered parts of the skin

Localized argyria occurs where the individual works with small metallic particles that penetrate the skin; in effect, tattooing

Silver salts, by ingestion, produce a severe gastroenteritis and shock

Diagnostic Tests: None established

Treatment:

Irrigate eyes with water if silver salts have contacted the tissue
Gastric lavage, if silver salts are ingested, using sodium chloride to precipitate the silver, and follow with saline catharsis

Symptomatic and supportive

Argyria does not respond to therapy

Disability:

Damage to eyes from silver nitrate can be permanent

Argyria is not disabling except through disfigurement

Preventive Measures:

Adequate ventilation. Mechanical filter respirator

No eating or smoking in work area

***SULFURIC ACID**

Synonyms: Dipping Acid. Hydrogen Sulfate. Oil of Vitriol.

Description: Heavy, corrosive oily liquid.

Occupational Exposure: Chemical synthesis. Metallurgy. Paints and pigments. Fertilizers. Petroleum. Explosives. Textiles.

Threshold Limit Value: 1 mg/cu m of air

Toxicity:

Absorption: Inhalation. Ingestion

Pathology: Corrosive

Signs and Symptoms:

Local: Conjunctivitis and corneal necrosis.

Dermatitis. Skin burns and ulceration.

Respiratory: Irritation of nose and throat. Laryngeal edema.

Bronchitis and pneumonitis. Pulmonary edema.

Gastrointestinal:

Dental erosion. Shock. Anuria.

Burning in mouth, throat, abdomen.

Nausea and vomiting of blood and eroded tissue

Perforation of gastrointestinal tract is possible

Albumin, blood, and casts in urine

Diagnostic Tests: None established

Treatment:

Irrigate eyes with water

Wash contaminated areas of body with soap and water

Gastric lavage, if ingested; care must be exercised in passing the lavage tube, and alkalies should be used carefully because of formation of gas; follow lavage with demulcents

Morphine for pain

Oxygen, with use of intermittent positive-pressure breathing apparatus; 5% solution of sodium bicarbonate as aerosol

may be used, as well as bronchodilators and decongestants

Codeine for cough

Cortisone

Symptomatic and supportive

Disability: Corneal damage may be permanent

Esophageal and gastric stenosis may occur

Preventive Measures:

Adequate ventilation. Chemical goggles. Chemical cartridge respirator. Rubber gloves and protective clothing.

*TIN OXIDES

Synonyms:

Stannic Oxide. Flowers of tin. Tin Anhydride. Stannous Oxide.
Tin Protoxide.

Description:

White crystals(-ic); beads, unstable powder(-ous)

Occupational Exposure:

Tin processing. Ceramics. Cosmetics. Alloys. Solders. Mordant
for Dyes. Chemical synthesis.

Threshold Limit Value: None established

Toxicity:

Absorption: Inhalation

Pathology:

Alveolar, perivascular, and peribronchial pigmentation
without fibrosis

Signs and symptoms:

There may be a slight cough or dyspnea

Diagnostic Tests:

X-rays for "stannosis":

Stage I: Nodules in the mid-portion of both lungs
Increased bronchovascular markings

Stage II: Extension of nodulation throughout lungs

Stage III: Predominance of denser nodulations
Gradual disappearance of bronchovascular
markings

Treatment: Symptomatic and Supportive

Disability:

No permanent effects reported

Pulmonary function is normal

Preventive Measures:

Adequate ventilation. Mechanical filter respirator.

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GLOSSARY

ACID: A substance which has a replaceable hydrogen atom, for example hydrochloric acid HCl.

ADDITION AGENT: Substance added to produce a desired change in the characteristics of a deposit. Examples include grain refiners, levelers and brighteners.

AMPERE: Unit of current. Defined as the amount of current required to deposit 0.00118 grams of silver from a solution of silver nitrate.

ANION: The ion which migrates towards the anode under the influence of an electric current.

ANODE: The electrode by which electrons leave the electrolyte, that is, the positive electrode. In common parlance one usually thinks of the anode as the electrode by which the current enters the vat. As explained in the text, however, the stream of electrons goes in the opposite direction and so the electrons actually leave the vat by the anode.

ATOM: The smallest particle of an element which can exist as such.

BASE: A substance which has a replaceable hydroxyl group OH, for example, caustic soda NaOH.

BRIGHTENER: An addition agent (or mixture of addition agents) used to produce a smooth lustrous deposit.

BURNT DEPOSIT: A term applied to an unsatisfactory deposit with a rough, dark appearance which is normally due to plating at too high a current density. Actually no heat is involved but the appearance is reminiscent of burnt or charred material.

CATION: The ion which migrates towards the cathode when an electric current passes through an electrolyte.

COVERING POWER: The ability of a plating solution to cover the surface of the article in question, that is, to produce an initial deposit.

ELECTROFORMING: An electrodeposition process whereby metal ions are transferred through an electrically conductive solution from a positive to a negative pole and deposited as atoms of plated metal. In electroforming, the mandrel is removed after the plating process is completed.

ELECTROLYTE: A conducting medium or solution in which the electric current flows by virtue of chemical changes or decomposition and where the consequent movement and discharge of ions is in accordance with Faraday's laws.

ELECTRON: The fundamental unit of negative electricity.

ELECTROPLATING: An electrodeposition process, whereby metal ions are transferred through an electrically conductive solution from a positive to a negative pole and deposited as atoms of plated metal. In electroplating, the mandrel, or form which serves as the base for the deposited atoms, remains under the plated metal.

FARADAY'S LAWS: 1. The chemical effect resulting from electrolysis is directly proportional to the quantity of electricity which is passed through the electrolyte. 2. The quantity of each substance chemically changed or liberated at an electrode by the passage of a definite quantity of electricity is directly proportional to the equivalent weight of the substance.

FREE CYANIDE: The cyanide present in a plating solution over and above that which is necessary to keep the various constituents from precipitating.

ION: An atom or group of atoms carrying an electric charge.

LEVELER: Addition agent used to produce a smoother electrodeposit.

LITRE: Volume of 1 kilogram of water at 4°C.

MANDREL: The form or mold which serves as a base for electroplating or electroforming. Mandrels may be either permanent, meaning they can be used a number of times, or expendable, meaning they are used only once.

pH: A term used to express hydrogen ion concentration.

ppm: Parts per million.

PEELING: The undesired separation of a deposit from the underlying surface.

PITS: Microscopic holes in an electrodeposit which may or may not pass through to the base metal. Usually caused by gas bubbles during deposition.

PORE: A very fine hole, usually invisible, extending through to the underlying metal.

STRIKING: The initial electrodeposition of a metal under conditions differing as regards solution or current density from those used subsequently.

STRIPPING: The removal of a deposit by chemical or electrolytic means.

THROWING POWER: A measure of the approach to uniformity in thickness of the electrodeposit obtained on a cathode of irregular shape.

VOLT: The unit of potential difference in common use, being the potential difference which, when steadily applied to a conductor having a resistance of 1 ohm, will produce a current of 1 ampere.

WATT: Practical unit of electrical power. The amount of energy expended per second by an unvarying current of 1 ampere under a voltage of 1 volt. $\text{Watts} = \text{volts} \times \text{amps}$.

WETTING AGENT: A substance, usually organic, added to reduce surface tension.