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December 28, 1950

Berkeley, California

# SILVER PLATING ON INCONEL

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## Abstract

A method of electroplating silver onto Inconel is described. The deposits produced by this method have excellent adherence and are very fine grained. Films as thin as 0.0002 in. have been produced with an electrical conductivity of the order of 95 percent of the value for pure bulk silver.[1]

## Introduction

In the production of components for high frequency electrical equipment there are many applications for silver plating where it is essential that the surface have the highest possible electrical conductivity. This requirement is easily satisfied with plating thicknesses greater than about 0.001 in. on most common base metals. However, in all cases which have come to our attention, attempts to obtain high electrical conductivity in thinner films on such base metals as Inconel and stainless steel have been unsuccessful. In these earlier studies a number of rather unusual techniques were employed, including; preliminary buffing of the base metal, buffing of the finished plating, electrolytic passivation of the base metal, periodic reversals of the plating current, and the addition of various brightening agents to the plating bath. None of these techniques led to conductivities higher than about 55 percent.

The present investigation was concerned with the plating of silver, 0.0002 in. thick onto Inconel tubing, 3/8 in. in diameter. This tubing was then

[1] The electrical resistivity of pure silver, melted and annealed <u>in vacuo</u> is taken as $1.59 \times 10^{-6}$ ohm-cm at $20^{o}C$. All relative conductivities given in the text are based on this value.

to be used as the center conductor of a coaxial cable and in order that the cable have the desired frequency characteristics it was necessary for the silver plating to have a conductivity of at least 90 percent. The technique described here has consistently produced conductivities of the order of 95 percent in films 0.0002 in. thick and employs only conventional electroplating techniques.

The Process. The operations are listed in the order in which they were performed. The whole process was carried out continuously. If the work was allowed to dry at any stage the quality of the finished plating was impaired.

Preliminary Cleaning. In the laboratory tests, satisfactory results were obtained by cleaning with soap and water or with organic solvents. In production, it was found more convenient to clean cathodically in a proprietary alkaline cleaner at 20 amperes per square foot for 1 minute. This was followed by rinsing in water.

Electrolytic Pickling. The purpose of this step was to remove the passive chromium oxide and nickel oxide films, and to produce a surface structure fine in comparison with the thickness of the silver film to be plated. This is apparently the most critical step in the procedure, and it was controlled by observation of the pickled surface with a metallurgical microxcope at 500X. The pickling was done anodically in 10 percent hydrochloric acid. A typical treatment was 35 amperes per square foot for 3 minutes. The loosely adhering oxide was then conveniently removed by rubbing with a cotton cloth, followed by thorough rinsing in water.

The optimum current density and time varied over wide limits, depending on the condition of the alloy. A treatment which was too mild to strip the oxide on one batch of Inconel was so severe on another that it produced pits of the order of 0.005 in. in diameter. This effect is commonly observed in the demonstration of cold-work by electrolytic etching.

Nickel Strike. Adherence was promoted by plating at 75 amperes per square foot for 10 minutes in a high chloride nickel strike bath. This was followed by a thorough rinse in water.

Silver Strike. The work was struck at 20 amperes per square foot for 30 seconds in a bath with the following composition:[2]

| | | |
|---|---|---|
| AgCN | 0.9 | oz/gal |
| KCN | 10 | oz/gal |
| $K_2CO_3$ | 2 | oz/gal |

It was observed that in all cases where high-conductivity silver resulted, the strike was immediate and uniform, whereas in other cases it appeared more slowly and with some irregularity.

Silver Plating. The work was plated at 6 amperes per square foot for 10 minutes in a plating bath with the following composition:

| | | |
|---|---|---|
| AgCN | 4.8 | oz/gal |
| KCN | 8.0 | oz/gal |
| $K_2CO_3$ | 6.0 | oz/gal |

The silver strike bath and the silver plating bath were made up with C.P. grade chemicals and distilled water. It should be noted that no brightener was used. It was observed that when a brightener was used in a bath compounded with NaCN instead of KCN it did not really refine the grain, but merely produced a smoothing of the coarse grains.

## Conductivity Measurement

The electrical conductivity of the deposit was determined by measuring the ~~resistance~~ conductance of a 4-in. length of tubing before and after plating. Taking the difference as the ~~resistance~~ conductance of the silver plate, the conductivity of the silver is calculated from the geometry of the film. The ~~resistance~~ conductance of the tube

[2] The silver bath formulae are given by William Blum and George B. Hogaboom, "Principles of Electroplating and Electroforming", McGraw-Hill Book Company, Inc., New York.

was measured with a Kelvin double bridge. In order to determine the thickness of the deposit, plated specimens were mounted in bakelite moulding compound, prepared by the usual technique for finishing metallographic specimens, and measured with a microscope at 500X. The simpler technique of measuring the resistance of a stripped film was not applicable, because in order to strip the film it was necessary to passivate the surface of the base metal. The conductivity of such films was always less than 60 percent.

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