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ART OF UNITING METALS

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This invention relates broadly to the art of uniting metals, and more particularly to improvements and modifications in the art of uniting metallic elements and alloys thereof which can be electroplated with mercury. It is more particularly concerned with, and has as a main object to provide certain improvements in the process set forth in my co-pending application Serial No. 90,882, filed July 16, 1936, and assigned to the same assignee as the present application, which is a continuation-in-part of aforesaid co-pending application.

Briefly described, the present invention involves electroplating mercury upon at least one of two facing surfaces of metals to be united and then applying pressure, or preferably simultaneously applying heat and pressure, to bond the metals. In the preferred embodiment of the invention excess mercury is vaporized from the surfaces during a heat and pressure treatment. My invention provides articles of manufacture, comprising metals, such as copper, silver and the like, rigidly and strongly joined together by a process that is rapid, economical and effective. The invention is especially applicable to uniting silver to copper and its alloys, hereinafter for brevity collectively designated as copper, and for bonding copper to copper.

Before the action of current on metallic solutions was known (by means of which certain metals can be plated from solutions on a given surface) amalgams were used for gilding and silvering. The article to be coated was covered by the amalgam and the excess mercury was volatilized by the application of heat, the gold or silver remaining on the surface as a strongly adhering coating. Later, it was proposed to apply heat and pressure simultaneously to the mercury-coated surfaces to form a union of the metals. Unions of lead to lead, tin to tin, lead to tin, or either lead or tin to any other metal which may be provided with a tinned surface, are old and well known.

In my aforesaid co-pending application Serial No. 90,882, I have disclosed and claimed a method of uniting metal articles the surfaces of which will form an amalgam with mercury which comprises applying a film of mercury to the clean surfaces to be united, bringing the amalgamated surfaces into intimate contact with each other to join the articles, treating the joined articles for the removal of any entrapped gas, cushioning the joined articles to compensate for any surface irregularities therein, and subjecting the cushioned articles to a simultaneous pressure and

heat treatment sufficient to remove excess mercury and firmly and permanently unite the articles without detrimentally affecting the physical properties thereof. In that co-pending application products of such process also were claimed.

The first steps of the process disclosed in my co-pending application Serial No. 90,882 are hereinafter described more fully (with particular reference, for purpose of illustration, to the bonding of silver to copper), so that the differences between the present invention and the aforesaid co-pending application may be more easily understood. The process disclosed in said co-pending application comprises the following steps:

1. The surface of the copper article, for example, a piece of flat copper, was treated to render it substantially clean, said treatment comprising, for example, acid dipping or scrubbing with, for instance, pumice. The part of the copper to which the silver was to be applied, was coated with mercury as described in the following paragraph.

2. Over an area of the copper surface a little larger than the piece of silver to be applied, a small amount of an aqueous solution of mercuric nitrate and sodium cyanide was swabbed with a pad made of chamois skin, or metallic mercury and sodium cyanide could be similarly applied, in either case subsequently rubbing the surface until the mercury was thoroughly amalgamated with the copper. In using metallic mercury, it was filtered through a chamois skin as it was applied to the copper surface. The surplus mercury and cyanide solution were removed and the article set aside to dry for about one-half hour. The resultant surface was polished with a dry pad of chamois skin. Next, fresh mercury was applied as has been described and the surplus was subsequently removed.

3. A strip of silver of the desired thickness, for example, 3 mils thick, and of the shape and size required, was brushed or wiped clean, and the cleaned silver strip was then immersed in a bath of metallic mercury until it was coated. The amalgamated silver strip was removed from the mercury bath and brushed to remove excess mercury and any particles of dirt or other foreign impurities adhering thereto.

4. The mercury-coated silver strip was now placed upon the previously marked-off spot on the mercury-coated copper surface, and pressed and fixed thereon by hand. It adhered readily to the amalgamated copper surface.

5. The assembled article, if flat, was now pressed slowly and with considerable pressure through

rubber rolls such, for instance, as those of an ordinary clothes wringer. When this was impractical due to the shape of the piece, the silver was patted down with a stiff wire brush, starting the patting operation at one end and continuing to the other end. The object of such operations was to remove any entrapped gas such as air bubbles from the joint. Such bubbles, if not removed, caused blisters to appear in the union and a consequent weakening thereof.

I have now found that any or all, as may be desired or as conditions may require, of aforedescribed steps 2, 3 and 5 can be eliminated by electroplating mercury upon either or both of the surfaces to be united, thereby simplifying the process and lessening the time required therefor, decreasing labor costs and reducing health hazards.

The process then is essentially as follows, and for illustrative purposes the bonding of metallic silver to metallic copper will be described.

The copper parts are first thoroughly cleaned in any suitable way, for example by an acid dip in the usual and well known manner, followed by rinsing to remove excess acid and foreign impurities. Cold water, for example, is a suitable rinsing fluid.

The cleaned copper surfaces are then electroplated with mercury, using any suitable mercury plating solution. For purpose of illustration I mention below a plating solution which I have used successfully, although it is to be distinctly understood that other mercury plating solutions may be employed and that the specified percentages may be varied as desired or as conditions may require:

Mercuric oxide.....	ounces.....	1 1/2
Sodium cyanide.....	do.....	4
Ammonium chloride.....	do.....	2
Water.....	gallon.....	1

A solution made in the proportions stated is put into an electroplating tank of ferrous metal such as steel, which serves as the anode. The copper parts to be mercury plated are placed in this solution, the copper articles being the cathode. Current is applied in well known manner using, for example, a current density of from about 10 to 15 amperes per square foot. A uniform coating of metallic mercury is plated on the copper in from about 3 to 5 seconds. It is simply necessary to secure complete coverage, as any excess mercury merely flows off. If desired, surfaces not to be joined to another metallic member, and which therefore it would not be necessary to mercury plate in carrying the present invention into effect, may be masked to prevent mercury plating thereof. It is more economical and less time-consuming, however, to plate the entire work, since the excess mercury may be volatilized during a subsequent operation.

After the electroplating of the mercury on the copper the piece is rinsed, for example by dipping in cold water followed by hot water, and then dried, for example by subjecting to a hot air blast for a few seconds, usually not more than about 5 seconds.

A silver strip is now placed on the mercury-plated copper surface at the point of desired permanent union. If desired, this silver strip may be electroplated with mercury or it may be amalgamated with mercury merely by rubbing with mercury or immersion in a bath of mercury. I have found that when the copper surface is electroplated with mercury it is usually not necessary

to coat the silver strip with mercury. However, under certain conditions, for example when the silver strip is not perfectly flat, it is sometimes advantageous to coat both the silver and copper surfaces with mercury.

As a matter of practical convenience in holding the silver strip temporarily in place at the point where it is to be joined to the copper, I apply a volatilizable adhesive in the general locality where the silver is to be applied. For this purpose various alcohols such as polyhydric alcohols and other viscous high-boiling organic substances may be used. More specific examples of suitable adhesives are glycerine, ethylene glycol, diethylene glycol, alkyl ethers of diethylene glycol, and the like. I have found glycerine to be particularly adapted for this purpose. Glycerine or like or equivalent substance functions mainly as an adhesive to hold the silver strip in place while the combined article is being placed in a press for subsequent treatment. Materials such as glycerine are not required as an aid to bonding the metals. Glycerine or the like, however, does have a beneficial effect as a protective coating for the mercury-plated surface in case there is unavoidable delay of, for example an hour or so, before the assembled articles are subjected to the final pressing operation.

The assembled parts are now placed in a press having heated platens. Sufficient work is spread on the platen so that the pressure will be uniformly distributed and will not crush the copper parts. Steel spacers are used at the sides of the pieces to prevent crushing, that is, deforming, the copper. Advantageously a cushion of compressible material, for example, a sheet of aluminum, pressboard (about 1/64 inch thick), or heavy paper, is placed over the entire area of the assembled parts. If desired, small individual pieces of such compressible material sufficiently large to cover the silver, at the point where it is to be firmly united to the copper, may be used. Such a cushion compensates for irregularities in the copper surface and insures intimate contact of the copper and silver throughout their entire adjoining surface areas. Without a cushion of the kind described, the copper might have to be compressed to its flow point to get uniform contact with the silver. For most purposes, such deformation of the copper is undesirable. For economic and other reasons a pressure no higher than necessary to obtain a strong bond is preferred.

The temperature of the platens is maintained below about 290° C., advantageously between about 175° and 250° C., by any suitable means, for instance, by electric heating units. Temperatures above about 290° C. have a harmful effect upon the copper, for example, detrimentally affecting its hardness. The purpose of applying heat is to remove excess mercury and to assist in the formation of a strong union between the silver and the copper. Although the use of simultaneous heat and pressure is preferred, recent observations have led me to believe that a union may be obtained by the use of pressure alone in bonding the mercury-coated surfaces, in which case the work advantageously may be "aged" at room temperature for at least a day prior to use. For most purposes, however, it is desirable that the work be heated to a temperature between about 100° C. and 290° C. while simultaneously applying pressure thereto.

The particular pressure employed depends upon the surface irregularities of the copper and the

resistance of particular pieces to displacement, that is, to effecting intimate contact. Too little pressure gives a weak joint. Too high a pressure may set up strains within a metal such as copper sufficient to weaken it materially. Depending upon the size of the article and other influencing factors the pressures used may vary widely, for example, between about 500 and 40,000 pounds per square inch, the lower limit in most cases being about 1000 pounds. Pressures ranging between about 1,000 and 4,000 pounds per square inch, for example about 3,000 pounds per square inch, in most cases are effective in producing the desired results and are generally satisfactory in bonding silver to copper by the above-described process. The period of time the united parts are subjected to pressure depends to a large extent upon the size of the individual pieces. For the same size and kind of work, the time the work is under pressure is substantially less when the procedure described in the present application is followed as compared with the process set forth in my co-pending application Serial No. 90,882. Usually it is necessary to leave the work in the press merely long enough to bring the work to a point within the preferred temperature range. Of course if no heat is employed during the pressure treatment, it may be necessary to subject the work to pressure for a longer period of time. To decrease the health hazard, the press should be provided with suction orifices at both sides thereof and in front for withdrawing mercury as it is vaporized from between the joint.

After pressing, the bonded pieces are removed from the press. In a process such as described in my co-pending application Serial No. 90,882, it is usually desirable to place the work, after the pressing operation, in an oven and therein heat it at a temperature of at least about 190° C. for 20 minutes or longer in order to remove excess mercury. Such heat treatment after a compression treatment is not necessary when the mercury is electroplated upon the surface of a metal to be united, as herein described, to another metal since, for one reason, the mercury film which is electrolytically deposited on the metal surface is so thin that the excess mercury is readily distilled off during the simultaneous heat and pressure treatment. The plating operation, which is an essential step in carrying the present invention into effect, provides a more uniform coverage of mercury on the work than otherwise may be obtained. In addition, the mercury probably penetrates further within the surface layers of the work. It has been demonstrated under practical conditions of operation that an electrolytically applied coating or film of mercury on a metal surface better protects such surface from oxygen (air), dust, lint and other foreign impurities than a mercury coating produced on metal by rubbing with, or immersion in, for example metallic mercury. Such contaminants, when present between facing surfaces of the metals being united, are a cause of blister formation in the finished joint and of defective work.

From the foregoing it will be noted that an electrolytically deposited coating of mercury has properties different from, or in addition to, mercury coatings, obtained by merely rubbing an amalgamatable metal with, or immersion of such metal in, mercury. A mercury-plated surface therefore is neither the same as, nor the equivalent of, amalgamated metallic surfaces otherwise produced.

Another embodiment of my invention com-

prises electroplating mercury on a thin sheet or strip of metal capable of being so electroplated, for example a silver sheet or strip about 3 mils thick, and inserting the mercury electroplated strip between the pieces of metal to be joined, for instance between two pieces of copper. In addition to, or in lieu of, electroplating the intermediate metallic layer with mercury, the metals to be joined may be so electroplated. In all cases the metals to be united must be capable of being electroplated by, or of amalgamating with, mercury. By means of pressure, preferably pressure and heat, a bond is formed which varies in strength with the metals other than mercury which are employed.

Lead, tin, silver, gold, copper, cadmium, and alloys thereof, are mentioned as examples of metals which may be electroplated with mercury and the mercury-plated metal then used to bond the same or other mercury-plated, or amalgamated (by rubbing with, or immersing in, mercury), or non-mercury-covered articles, with varying strength of the resultant bonds. For uniting copper articles, sheet silver is a preferred bonding metal because of the high tensile strength of the resultant bond.

Unions or joints produced in accordance with the present invention are practically as strong, and of the same general physical structure as joints made as described in my aforesaid co-pending application. The process herein described, however, is simpler, requires less time and involves less labor cost. It also comprises less health hazard to workmen since hand application of mercury to the metal surfaces is eliminated.

The terms "metal", "metals", and "metallic" as used hereinbefore, and in claims which follow, include both substantially pure metal of the particular genus or species stated, and alloys thereof.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A method of uniting metals having surfaces that can be electroplated with mercury which comprises applying electrolytically a coating of mercury upon a clean surface of at least one of such metals at the point where it is subsequently to be united to the other, assembling the metals in the position of ultimate rigid union to bring facing surfaces in intimate contact with each other, and subjecting the resultant assembly to pressure sufficient to form a firm and permanent union of said metals.

2. A method of uniting metals having surfaces that can be electroplated with mercury which comprises applying electrolytically a coating of mercury upon a clean surface of at least one of such metals at the point where it is subsequently to be united to the other, assembling the metals in the position of ultimate rigid union to bring facing surfaces in intimate contact with each other, and subjecting the resultant assembly to a simultaneous pressure and heat treatment sufficient to remove excess mercury and to form a firm and permanent union of said metals.

3. A method of uniting metallic copper members which comprises electrolytically depositing a film of mercury upon clean surfaces of said members where subsequently united, bringing a thin sheet of metallic silver into contact with the mercury-plated surfaces of the copper members at the point of ultimate rigid union, and subjecting the resultant assembly to pressure.

4. A method of uniting metallic copper members which comprises applying electrolytically a

film of mercury upon clean surfaces of said members where subsequently united, placing a thin mercury-coated sheet of metallic silver between and in contact with the mercury-plated surfaces of the copper members at the point of ultimate rigid union, and subjecting the resultant assembly to a simultaneous pressure and heat treatment sufficient to remove excess mercury and to form a strong, permanent union between the copper members.

5. A method of uniting metallic silver and copper members which comprises applying an electrolytic coating of mercury upon a clean surface of a copper member, bringing a silver member into contact with the mercury-plated surface of the copper member, and subjecting the resultant assembly to compression between about 1,000 and 40,000 pounds per square inch.

6. A method of uniting silver and copper articles which comprises providing a surface of a copper article, at the point of subsequent rigid union with a silver article, with an electrolytic coating of mercury, bringing the silver article into contact with the mercury-plated surface of the copper article, cushioning the assembled articles with a compressible material to compensate for any surface irregularities therein, and subjecting the assembly to a simultaneous pressure and heat treatment, said pressure being between about 1,000 and 40,000 pounds per square inch and said heat being between about 100° and 290° C.

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