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Schreiner et al.

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[54] **METHOD OF PRODUCING TIN LAYERS OR TIN ALLOY LAYERS ON COPPER OR COPPER ALLOY WIRES BY HOT TIN PLATING**

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Related U.S. Application Data

[63] Continuation of Ser. No. 263,621, June 16, 1972, abandoned, which is a continuation of Ser. No. 88,286, Nov. 10, 1970.

[30] **Foreign Application Priority Data**

Nov. 13, 1969 Germany 1957032

[52] **U.S. Cl.** ..... **117/102 M,** 117/114 B, 118/125, 118/420

[51] **Int. Cl.** **B05c 11/10**

[58] **Field of Search** ..... 118/DIG. 19, DIG. 20, 125, 118/420, DIG. 22; 117/102 L, 102 M, 114 R, 114 A, 114 B, 114 C, 115, 128

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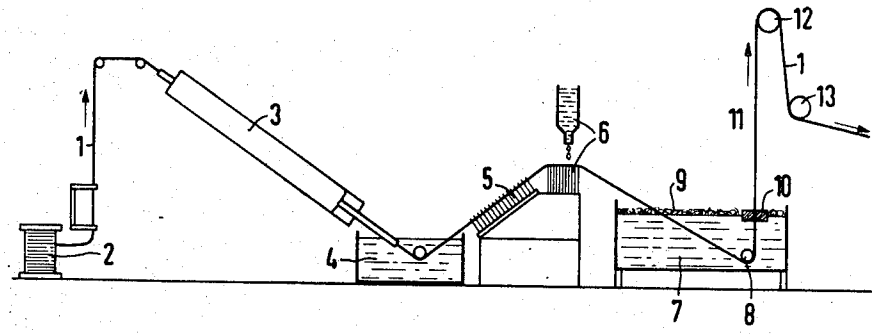
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[57] **ABSTRACT**

The invention relates to a method and a device for tin plating copper jump wires. The copper wire passes through a tin bath and is guided through a stripper nozzle, whose outlet opening lies approximately in the plane of the bath surface. The bore of the stripper nozzle possesses a wave shaped cross section. For a wire diameter of 0.5 mm, .4 to 20 half waves are provided and the diameter of the bores as well as the depth of the half waves are adjusted to the diameter of the wire. The copper wires tin plated according to the invention, have a uniform tin layer with a thickness >3 μm and are extremely solderable.

8 Claims, 4 Drawing Figures



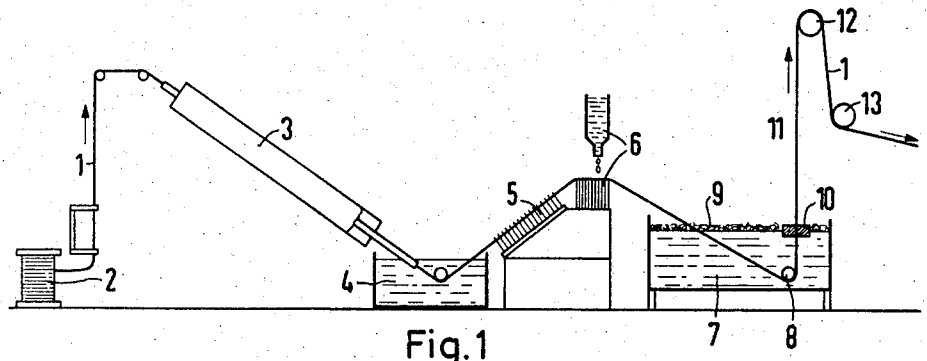


Fig. 1

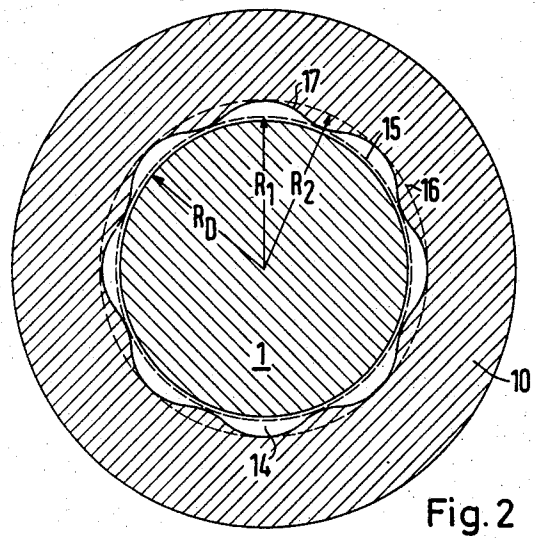


Fig. 2

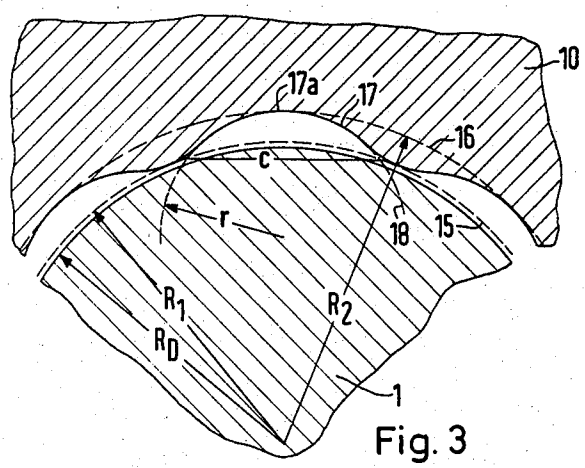


Fig. 3

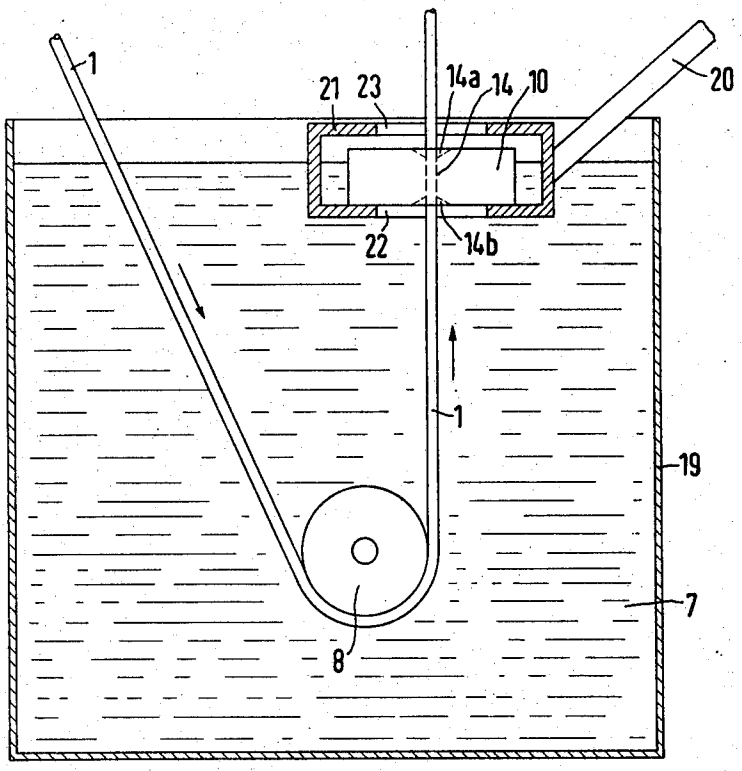


Fig.4

METHOD OF PRODUCING TIN LAYERS OR TIN ALLOY LAYERS ON COPPER OR COPPER ALLOY WIRES BY HOT TIN PLATING

This is a continuation, of application Ser. No. 263,621, filed June 16, 1972 now abandoned.

Our invention relates to a method of producing tin layer or tin alloy layers on copper or copper alloy wires having a diameter of <0.5 mm. The method is effected by hot tin plating at a uniform thickness of >3 μm across the wire circumference. The wire is then passed through a tin bath or a tin alloy bath and is guided through a profiled stripper nozzle.

For an impeccable solderability of thick tin plated copper jump wires, a minimum layer thickness of 3 μm tin or tin alloys is required for each place of the wire. Various tin plating methods for producing copper jump wires have been suggested or made known, whose aim is to provide the copper wires with adhering, uniformly thick, good solderable tin layers. To this end, the copper wire may be appropriately treated, prior to its insertion into the tin bath, as well as following its emergence from the tin bath.

It is known, for example from German Disclosure Document 1,521,487, to produce a tin layer of medium thickness, between 3 and 10 μm, on wires of copper or copper alloys. This is done by hot tin plating a tin layer placed upon a circular cross section wire during its passage through a stripper nozzle with polygonal cross section and to distribute the tin to a medium layer thickness that fluctuates across the circumference of the wire but is uniform in the sectors. It is then formed immediately thereafter into a uniform layer thickness, with a calibrating nozzle of uniform cross section.

British Pat. No. 921,755 makes known, for example, to arrange a stripper nozzle on the surface of the tin bath. This stripper nozzle possesses a bore with circular cross section. Since, in the device described in the British Pat. No. 921,755, the wire leaves the tin bath at the bottom of the bath container, the stripper nozzle is to prevent, in the first place, the running out of the tin bath.

The known method is affiliated with shortcomings with respect to continuous manufacture. Above all, fluctuations in layer thickness occur and it is difficult to adjust the layer thickness. It is an object of the invention to overcome these disadvantages.

The present invention has as its object overcoming the above disadvantages.

For a method of the afore-described type, the invention accomplishes this object by using a stripper nozzle whose outlet opening is approximately in the place of the bath surface.

The bore diameter of the stripper nozzle is bordered by a wave train, which runs between two concentric circles. The radii of the circles are adjusted to the radius of the wire and 3 to 15 half waves are provided for each millimeter of the circumference of the inner, concentric circles. A stripper nozzle may be used with 5 to 8 half waves per millimeter of the circumference.

The temperature of the stripper nozzle may be determined by the bath temperature.

The method of the invention provides tin plated copper jump wires with a tin layer of uniform thickness, across the entire circumference of the wire. The geometry of the profiled stripper nozzle prevents the Bernoulli effect, the so-called "hydrodynamic pressure",

which results in assymetrical positions of the wire within the stripper nozzle when nozzles of circular cross section are employed. The resulting formation of sicle-shaped tin layers on the copper wire is avoided thereby. The selection of the wave level, that is the selection of the distance between the two concentric circles between which the wave train proceeds the immersion depth of the nozzle below the bath level and the wire velocity, determine the layer thickness. During the adjustment of the wire radius, the tolerance limits for the wire radius may be taken into consideration. This adjustment of the tin layer thickness may also be effected for high wire velocities, that is for wire velocities above 1 m/sec. Thus the method of the invention may be applied many fold and is extremely economical. It must be emphasized that the profiled stripper nozzle is situated directly on the bath surface. Hence no tin oxides are installed into the tin layer of the wire. The tin, which is located below the inlet opening of the stripper nozzle, helps to continually renew the tin boundary layer which is being transported along by the running tin wire, since only one portion of the boundary layer enters into the nozzle. Therefore, it is not necessary to use organic substances, for example oil, as a cover for the tin bath, as is customary in the known methods. The remaining tin bath surface may be covered with iron sheets. A portion of the exposed tin bath surface, which is situated in the region where the wire enters into the tin bath, is covered with charcoal. This limits the free tin layer which reacts with the air to a minimum. We should also stress that no cracking products occur since organic substances, such as for example oil, are being avoided. Such cracking products lead frequently to a disturbance in the tin layer. It is also advantageous that the stripper nozzle must not be separately preheated. The stripper nozzle is heated directly by the tin bath and the temperature of the stripper nozzle is in a state of equilibrium, close to that of the tin bath.

The solderability of the copper wires tin plated according to the invention, may be tested according to the solder ball test. Testing conditions for a wire diameter of 0.5 mm, are a solder ball weight of 75 mg when SnPb 40 is used as solder and a testing temperature of 235° C. The clamped wire is dipped into a liquid solder pearl and the time which elapses until the solder drop encloses the entire wire is measured. in wires which are tin plated according to the invention the solder periods are considerably below a second, even if changes have taken place for many days, for example by tempering. Due to this good solderability, the copper wires tin plated according to the invention are also suitable for automatic soldering processes such as for example sonic or immersion welding.

A preferred device for performing the method of the invention is provided with a stripping nozzle, where the radius of the inner-one of the concentric circles, wherebetween the wave train proceeds, is 1 to 10 μm, preferably 2.5 to 5 μm larger than the upper tolerance limit for the radius of the wire. Preferably, a stripper nozzle is provided where the difference between the radii of the inner and the outer one of the concentric circles, wherebetween the wave train proceeds, is 20 to 80 μm, preferably 40 to 60 μm.

The half waves of the wave train which contact the outer of the concentric circles may be shaped at least nearly as a circular arc. The stripper nozzle may consist of diamond, ruby, hard metal or stainless steel. The

stripper nozzle may be situated in a holder, which is so designed that the stripper nozzle is movable in the plane of the bath surface and in pulling direction and opposite the pulling direction of the wire. By arranging the stripper nozzle in a holder on the bath surface assures a comfortable servicing and handling during the rethreading of the wire, for example when exchanging the roller or possibly when the wire tears within the roller.

FIG. **1** is a schematic illustration of a thick tin plating installation;

FIG. **2** is a stripper nozzle;

FIG. **3** is an enlarged section of the stripper nozzle of FIG. 2; and

FIG. **4** schematically illustrates the tin bath with the stripper nozzle on the surface.

The invention will further be described with reference to FIGS. **1** to **4.**

FIG. **1** schematically illustrates a thick tin plating installation. The copper jump wire **1** is removed from reel **2,** in the direction shown by the arrows. After two deflection rollers, the wire passes first in an annealing furnace **3,** through a water vapor atmosphere, at 800° to 900° C, where its surface is purified. The required stretching values of 27 to 30 percent are further adjusted by annealing. Thereafter, the annealed wire **1** enters a water vath **4.** Following the water bath, the water is stripped off the wire surface with the aid of a drying brush **5.** The copper wire passes through an etchant solution section (HCl acid) **6** to remove surface layers, and enters the tin bath **7.** The HCl etchant section consists of a dropping vessel, filled with hydrochloric acid. The dropping vessel is situated above strippers which may be produced of felt. The felt strips are saturated with hydrochloric acid, with the aid of the dropping vessel.

In the tin bath **7,** the wire **1** is deflected with a deflection roller **8** and leaves the tin bath **7** at least nearly vertical. The tin bath **7** is covered with charcoal **9,** at least in the region of the inlet point of the wire **1,** in order to prevent contamination of the tin bath **7,** for example, an oxidation of the tin surface.

The copper wire **1,** which emerges from the tin bath **7,** is guided through a stripper nozzle **10,** which dips into the tin bath **7** and whose outlet opening is situated in the plane of the surface of the tin bath **7.** The advantages of said device, particularly the lack of contamination through oxidation products in the vicinity of the outlet point of the wire **1,** have previously been pointed out. After passing a cooling path **12,** where the wire **1** is cooled by air, the wire is deflected via rollers **12** and **13** and guided to a take up device, not illustrated in FIG. **1.**

The stripper nozzle has a bore with a wave profile. The inner diameter of the bore and the depth of the waves are adjusted to the diameter of the copper wire. This adjustment will be derived from subsequent descriptions of the Figures. The stripper nozzle is heated by the tin bath up to almost the temperature of the tin bath.

FIG. **2** illustrates a section through a stripper nozzle **10,** with a copper wire **1** also shown in section in the bore **15** of the stripper nozzle. The bore **14** of the stripper nozzle **10** has a wave profile. In FIG. **2,** two concentric circles **16** and **17** are shown with radii R_1 and R_2. The closed wave train **18** runs between the concentric circles **16** and **17.** The wave train **18** has between 3 and 15, and preferably 5 to 8 half waves, per millimeter of the circumference of the inner circle **16.** FIG. **2** shows a nozzle for a wire radius R_D of 0.25 mm. A closed wave train with 8 half waves is provided, this corresponds to at least 5 half waves relative to a unit length. The radii R_1 and R_2 and thus the depth ($R_2 - R_1$) of the half waves of the wave train **18** are adjusted to the radius R_D of the wire. Determining this adjustment are the tolerance limits for the wire radius R_D and the desired layer thickness for the tin plating. The tolerance limits for the wire diameter R_D enter essentially in the radius R_1 of the interior concentric circle **16.** This radius must be selected at least large enough so as to prevent, during the passage of the wire **1,** the wave profile from being embedded in the wire surface. It is preferred that R_1 is between 1 and 10, preferably 2.5 to 5 μm greater than the upper tolerance limit for the wire radius R_D. The layer thickness is essentially determined by the depth $R_2 - R_1$ of the individual waves and by the distance between the wave maximum and minimum, that is the number of half waves per millimeter of the circumference.

FIG. **3** illustrates an enlarged section of the stripper nozzle **10** according to FIG. **2** and shows that the half waves **17a,** which touch the outer concentric circle **16,** are preferably shaped at least nearly as a semicircle. The radius *r* of a circle **18** drawn into a half wave **17***a* and the chord c which is defined by the intersecting points of the circle **19** with the inner concentric circle **16,** are decisive for the layer thickness, next to the difference between the diameters R_1 and R_2 of the concentric circles **15** and **16.** The radius r or the length of the chord c is determined by the number of half waves of the wave train **18.** It was found that for a layer thickness which ranges between 3 μm and about 7 μm, the number of half waves per millimeter of the circumference R_1 of the circle **15,** must be between **3** and **15.** The difference $R_2 - R_1$ between the radii R_1 and R_2 of the concentric circles **16** and **17** may vary between 20 and 80 μm, preferably from 40 to 60 μm. The tin layer adhering to the wire is profiled with a thus dimensioned stripper nozzle. The subsequent smoothening is effected by itself through the surface tension of the profiled tin layer, whereby the form of profiling provides a uniform, average layer thickness of at least almost constant size, over the entire wire circumference. This provides the aforedescribed advantages and the excellent solder characteristics of the copper jump wire tin plated in accordance with the method of the invention.

Stripper nozzle **10** is made of diamond, ruby, hard metal or stainless steel, in order to obtain the best possible stability therefor. The production process begins with a stripper nozzle with a circular bore whose diameter **2** is R_1. To produce a stripper nozzle according to FIG. **2** with 8 half waves for a wire radius R_D of 0.25 mm, the nozzle is clamped into an octagonal holder and a tungsten wire with diameter *r* is threaded through the bore of the nozzle and moved back and forth in exact guidance. The grinding material may be a diamond board. The processing is carried out in steps and the wave depth is measured by microscope. After a half wave is ground out, the clamping device is placed upon the next polygonal surface so that one by one, all half waves shaped in a circular arc are worked in. The sharp edges are subsequently rounded off by after-polishing. For instance, when a 0.500 mm thick copper wire with tolerance limits between 0.497 to 0.508 mm is to be tin

plated, the profiled nozzle **10** having 8 half waves is dimensioned as follows: radius R_1 0.259 mm; radius R_2 0.299 mm. The copper jump wire had a pay out velocity of 1 m/sec. A uniform tin layer thickness of 5 μm was obtained over the entire wire circumference and the wire length. The uniformity of the tin layer thickness along the wire circumference was determined at ground cross sections of the tin plated wire, with the aid of light optics.

FIG. **4** shows the tin bath of FIG. **1**, in enlarged illustration. The tin bath **7** is placed into a container **20** and may be heated. A heating device is not shown in FIG. **4** in order to preserve the clarity. Also, not found in FIG. **4** is the charcoal covering **9**, which is shown in FIG. **1**. The copper wire **1** entering the tin bath **7** is deflected with deflection roller **8**, and leaves the tin bath at least almost perpendicularly.

The stripper nozzle **10** is so arranged that the outlet opening **14***a* of the bore **14** is situated at approximately the same height as the surface of the tin bath **7**. Thus, the inlet opening **14***b* is located below the bath surfaces.

FIG. **4** shows a holder which comprises an arm **20** and a round box **21**. The arm **20** is affixed to a structure not shown in the drawing. The bottom and the cover of the round box is provided with openings **22** and **23**, whose diameter is essentially smaller than the width of the stripper nozzle **10**. The stripper nozzle **10** lies inside the round box **21**, bearing upon the bottom and is thus movable in the plane of the bath surface, in all directions. Since the distance from the bottom to the cover of the round box **21** is greater than the thickness of the stripper nozzle **10**, the stripper nozzle is also kept mobile in pulling direction of the wire **1**. During the operation of the device, the nozzle **10** will be somewhat raised up from the bottom of the round box **21**, due to the pressure to which it is subjected, at its inlet opening **14**b. During sudden disturbances, the stripper nozzle **10** is thus slightly movable also in opposite direction of the wire **1**.

The advantages of said holder have previously been explained. It should be stressed, however, that the mobility of the stripper nozzle **10** prevents, to a large extent, the tearing of the wire.

German Disclosure Document 1,521,487, corresponds to United States Application 605,743.

We claim:

1. A method of producing tin layers or tin alloy layers on wires comprising copper or copper alloys by means of hot tin plating, with a uniform thickness of >3 μm, wherein the wire passes a tin bath or a tin alloy bath and is guided through a profiled stripper nozzle, said stripper nozzle having an outlet opening, said outlet opening being approximately on the level of the bath surface, said stripper nozzle having a bore diameter defined by a wave train, which runs between two concentric circles, the radii of said circles are adjusted to the radius of the wire to be processed therethrough, the radius of the inner of said concentric circles being from 1 to 10μ greater than the outer tolerance of the given radius of the wire, the difference between the radii of the inner and the outer of the two concentric circles being from 20 to 80μ, and 3 to 15 half waves are provided for every millimeter of circumference of the inner of said concentric circles.

2. The process of claim **1**, wherein the stripper nozzle has from 5 to 8 half waves per millimeter of circumference.

3. The process of claim **1**, wherein the temperature of the stripper nozzle is determined by the bath temperature.

4. Apparatus for producing a tin or a tin alloy layer on a wire of given radius formed of copper or copper alloy by hot tin plating the wire with a uniform thickness of >3μ, comprising means containing a bath of metal selected from the group consisting of tin and tin alloy, a stripper nozzle having an outlet opening approximately on the level of the bath and being formed with a bore having a periphery in the shape of a wave train running between two concentric circles having radii that are adapted to the radius of the wire to be hot tin plated, the radius of the inner of said concentric circles being from 1 to 10μ greater than the outer tolerance of the given radius of the wire, the difference between the radii of the inner and the outer of the two concentric circles being from 20 to 80μ, 3 to 15 half waves of the wave train being provided for every millimeter of circumference of the inner of said concentric circles, and means for passing the wire through said bath containing means and said stripper nozzle.

5. Apparatus according to claim **4**, wherein the radius of the inner circle is 2.5 to 5 μm greater than the outer tolerance of the radius of the wire to be hot tin plated.

6. Apparatus according to claim **4**, wherein the outer of the concentric circle through which the wave train runs is at least of a circular arc.

7. Apparatus according to claim **4**, wherein the stripper nozzle is of diamond, ruby, hard metal or stainless steel.

8. Apparatus according to claim **4**, wherein the stripper nozzle is arrayed in a holder formed so that the stripper nozzle is parallel to the surface of the bath and is movable in the direction and opposite direction of the wire.

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