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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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Nov. 13, 1969 Germany .... P 19 57 034.4

[52] **U.S. Cl.** **72/47**

[51] **Int. Cl.** **B21c 37/04,** B21f 19/00

[58] **Field of Search** .... 29/527.2; 72/46, 72/47; 117/7, 64, 102 M, 114 B

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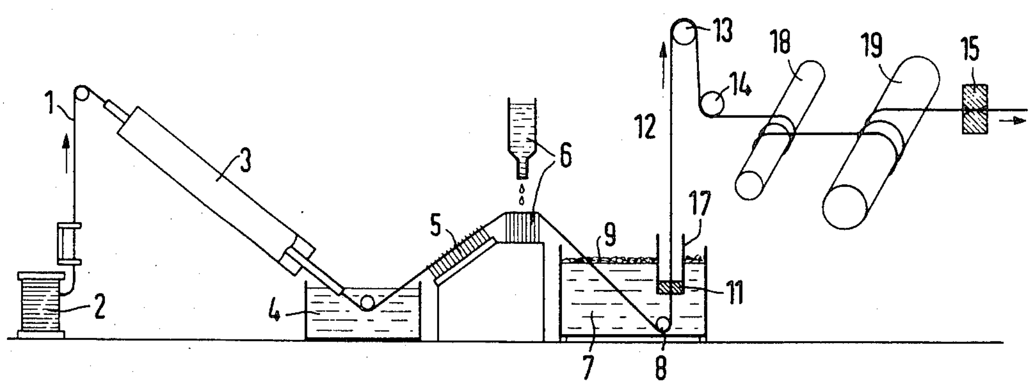
[57] **ABSTRACT**

The invention relates to a method and a device for tin plating copper jump wires. The copper wire passes a tin bath and is guided through a profiled stripping nozzle. Following the tin plating, the copper wire is passed through at least one stretching stage wherein the diameter of the copper wire is reduced by pulling. This method affords a simple way of producing tin plated wires of small diameter. The tearing of wires with small diameter during the tin plating process is eliminated and the expensive production of profiled stripping nozzles with small bore diameters is avoided. The copper wires which are tin plated according toe the present invention have a uniform tin layer of a thickness >3 μm and are extremely solderable.

2 Claims, 8 Drawing Figures



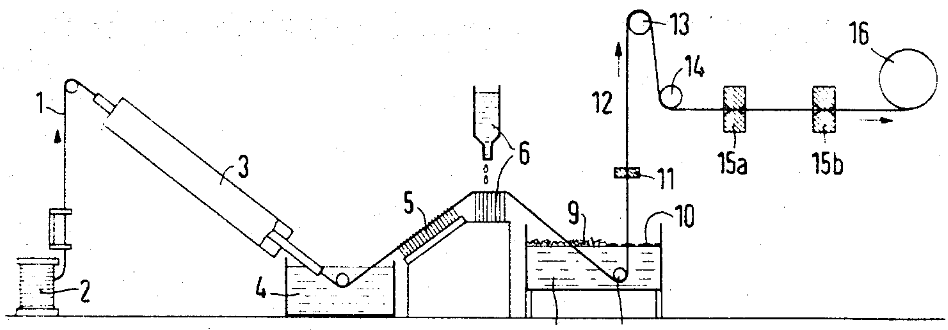


Fig.1

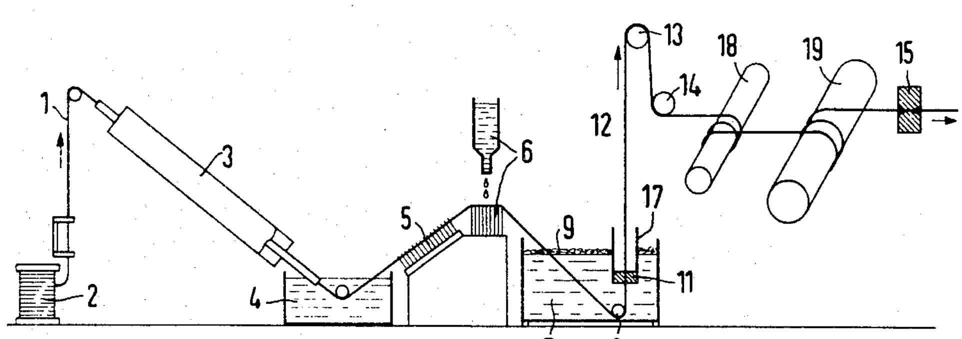


Fig.2

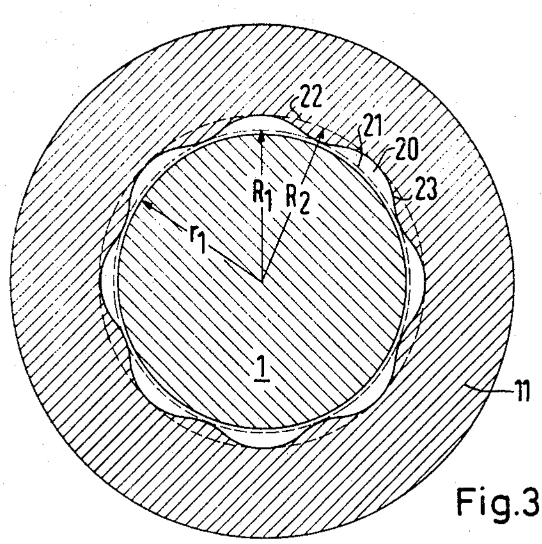


Fig.3

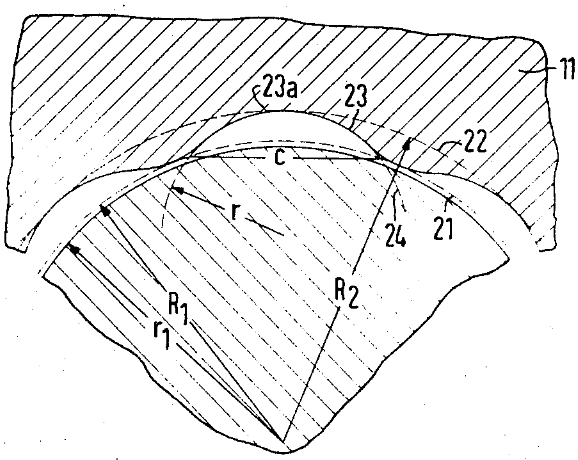


Fig.4

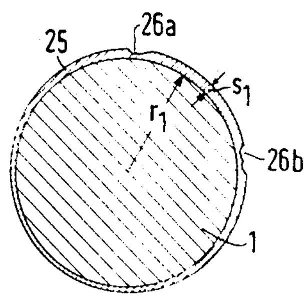


Fig.5a

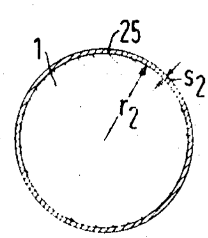


Fig.5b

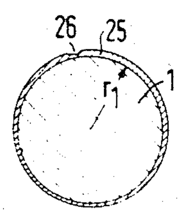


Fig.6a

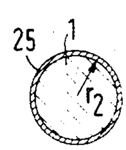


Fig.6b

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

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 No. 1,521,487, which corresponds to U.S. Pat. application Ser. No. 605,743, filed Dec. 29, 1966, now abandoned. 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 the 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.

When using this method of hot tin plating, employing a profiled stripper nozzle, each wire diameter must be provided with a fitting profiled nozzle. Such profiled nozzles may be provided without difficulty down to a diameter of the copper wire of 0.5 mm. When the diameter of the copper wire is smaller than 0.5 mm, a higher economical expenditure is necessary for producing an appropriately profiled stripper nozzle. Also, the copper jump wires, whose diameter is less than 0.5 mm, are more vulnerable to the danger of tearing during hot tin plating, e.g. due to pull fluctuations. This results in greater down time with a much greater demand placed upon the servicing personnel. It should also be mentioned that the insertion of the wire, primarily into the stripper nozzle, is more difficult with small diameter wires than with larger ones.

The object of the present invention is to solve the problem of tin plating wires, whose diameters are below 0.5 mm, without encountering the afore-described disadvantages. The solution to the problem, according to the invention, is to pass the copper wire, following the tin plating, through at least one stretching stage and to reduce the diameter of the copper wire by means of pulling.

The present invention makes it possible to produce hot tin plated wires of small diameter, such as for example, diameters between 0.1 and 0.5 mm, in a simple manner. The wire diameter is reduced to the desired value only after the hot tin plating. This obviates the danger of the afore-described operational interferences. Also, stripper nozzles with standard bore diameters may be used, such as stripper nozzles with diameters of 1 mm, 0.8 mm and 0.5 mm. Within these bore diameters are the wire diameters, and smaller wire diameters may be obtained by pulling. The production of stripper nozzles is considerably facilitated and the economy of the tin plating method is improved.

It is known as such to stretch the wires in stretching stages in order to reduce their diameter. This method was not used up to now, in tin plated wires. It is surprising for the average person skilled in the art to find that the surface quality of the tin layer is improved by the pulling, for example through smearing of pitted localities to yield a more uniform tin layer thickness. It is surprising, as well, that the pulling makes it possible to maintain considerably narrower diameter tolerances in previously tin plated copper wires as compared to the copper wires produced with conventional technique, where the wires pulled to the desired degree, are thereafter hot tin plated according to a known method.

The solderability of the copper wires tin plated in accordance with the invention and subsequently stretched, can be tested according to the solder ball test. Testing requirements for a wire diameter of 0.5 mm are a solder ball weighing 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 diameter, is measured. These solder times in wires tin plated according to the invention are essentially below one second, even when following several days of changes, for example by tempering, which indicates an excellent solderability. Due to the good solderability, the copper wires tin plated according to the invention, are suitable as jump wires also for automatic soldering processes such as for example, sonic or immersion soldering.

FIG. 1 schematically illustrates a hot thick tin plating installation as modified by our invention;

FIG. 2 schematically illustrates another embodiment according to our invention;

FIG. 3 shows a stripper nozzle in section;

FIG. 4 is an enlarged section of the stripper nozzle of **FIG. 3**; and

FIGS. 5 and **6** illustrate in ***5a*** and ***5b*** and ***6a*** and ***6b***, respectively, embodiment examples.

The method of the invention will be illustrated in greater detail with reference to Examples, shown in **FIGS. 1** to **6.**

In FIG. **1**, the copper jump wire **1**, which may have a diameter of 1 mm, is removed from reel **2**, in the direction indicated by arrows, Following two deflection rollers, the wire passes first through a steam atmosphere in an annealing furnace **3**, at 800° to 900°C wherein the wire surface is purified. Thereafter, the annealed wire **1** enters water bath **4.** The water, following the water bath **4**, is stripped off from the surface of the wire **1** by drying brush **5**. The copper jump with **1** passes through an HCl etching acid **6**, for removing the surface layers, and thereafter enters a tin bath **7.** The HCl etchant section comprises a dropping vessel, filled with hydrochloric acid, said dropping vessel being situated above strippers which may consist of felt. The felt strips of the stripper are saturated with hydrochloric acid from the dropping device.

In the tin bath **7**, the wire **1** is deflected with a deflection roller **8** and leaves the tin bath **7**, at least almost perpendicularly. The tin bath may be pure tin or a tin alloy such as SnPb 40. The tin bath **7** is covered with charcoal **9**, at least in the region where the wire **1** enters, in order to avoid contamination of the tin bath **7**, for example, even an oxidation of the surface. An oil layer 10 is located on the surface of tin bath 7, in the region where the wire 1 emerges from the tin bath 7.

The copper jump wire 1 emerging from the tin bath 7, is guided through a stripper nozzle 11 which is located above the surface of the tin bath 7. The excess tin, which is carried along by the wire 1, is stripped off by the stripper nozzle 11 and after passing a cooling path 12, the wire is deflected via rollers 13 and 14 and directed to a pulling device. In the embodiment shown in FIG. 1, the pulling device comprises two stretching stages, whereby each of the stretching stages is provided with a stretching or pulling blocks 15*a* and 15*b*. After the wire 1 runs through the pulling blocks, it is wound upon take up roller 16.

The diameter of the copper jump wires is reduced in a known manner, during its passage through the pulling or stretching blocks. Thus, the initial diameter of 1 mm for the copper wire may be reduced by 0.6 mm, during its passage of pulling blocks 15*a* and 15*b* of FIG. 1. A suitable material for the pulling blocks is steel or a hard metal.

It should also be pointed out that in FIG. 1, the distance between the stripper nozzle 11 and the surface of the tin bath 10, is preferably such that the stripper nozzle 11 is situated within the solidification range of the tin or the tin alloy of the bath 7. The profiling of the stripper nozzle 11 and its influence upon the thickness of the tin layer of the tin plated wire, will be described further hereinbelow.

In FIG. 2, the stripper nozzle 11 is situated so that its outlet nozzle lies beneath the surface of the tin bath 7. The stripper nozzle 11 is set into a tube 16 and is pressed with the same, beneath the surface of the tin bath 7. The immersed stripper nozzle 11 prevents impurities such as oxidation products which are present at the surface of the tin bath 7, from contaminating the tin layer of the wire 1. This may be done with a stripper nozzle 11, Which deviating from FIG. 2, dips into the tin bath 7, with its inlet opening. Beyond this, the stripper nozzle 11, whose outlet opening is situated below the tin bath surface, affects in a beneficial manner, the hydrodynamic and hydrostatic pressure in the tin bath, in the region of the inlet opening of the stripper nozzle 11.

The stretching or pulling device according to FIG. 2, again contains two stretching stages. In the first of the stretching stages, the wire runs across two rollers 18 and 19. The diameter of the second roller 19 is larger than the diameter of the first roller 18. Both rollers 18 and 19 rotate, and the rotation speed of the second roller 19 is higher than that of the first roller 18. The rollers 18 and 19 exert variable circumferential forces upon the copper wire 1 whereby roller 19 exerts a greater peripheral force than does roller 18. Due to these different peripheral forces, the copper jump wire 1 is stretched in a very uniform manner. After the two rollers, the copper wire 1 is led in a second stretching stage, through a pulling block 15, where the surface of the tin plated copper wire 1 is smoothened and the diameter of the copper wire is further reduced. After passing the pulling block 15, the wire is delivered, as in FIG. 1, to a take up roller. This take up roller, which corresponds to 16 of FIG. 1, is not shown in FIG. 2.

In the embodiment examples according to FIGS. 1 and 2, the copper wire 1 is guided, immediately following the tin plating, into the pulling installation and the heating of the wire in the tin bath 7 is utilized for stretching. Additional heating may become necessary during the pulling and may be provided by resistance heating. To this end, sliding contacts should be applied to the copper wire 1. These contacts are not shown in FIGS. 1 and 2. If necessary, the stretching device may be separated from the tin plating installation. The completely cooled tin plated wire may be inserted into the stretching device, following a lengthy storage, and be heated and stretched therein. The quality of the tin plated copper wire, stretched to the final degree, is not influenced by the interruption in its manufacturing process.

The pulling effected in the stretching stages of FIG. 1 or of FIG. 2, reduces not only the wire diameter but also the thickness of the tin layer. Since the finished copper wire should have a tin layer which must not be below 3 μm, and if possible, must not exceed 10 μm, as the consumption of tin would otherwise prove uneconomical, the tin layer which is placed upon the copper wire in the thick tin plating installation, must be adjusted to the final dimension of the stretched, tin plated wire. This adjustment is easy to achieve, with the aid of equation:

$$(r_1/r_2) = (s_1/s_2)$$

wherein r_1 is the original wire radius, r_2 the radius of the copper wire after pulling and s_1 and s_2 are the thicknesses of the tin layer prior to and following the stretching, respectively. This equation is obtained on simple considerations based on the fact that the volume of the copper wire, as well as the volume of the applied tin layer, must be equal prior to and following the stretching. The problem of producing a uniform tin layer of definite thickness upon the copper wire, during the stretching of the tin plated copper wire, thus goes back to the problem to produce a tin layer of defined thickness during the tin plating itself. This is achieved with the aid of the profiled stripper nozzle, whereby the bore diameter of the nozzle and the profiling of the nozzle must be adjusted to the radius of the copper wire as well as to the desired layer thickness.

It was found very favorable to adjust the layer thickness with the aid of a stripper nozzle 11, whose bore has a wave profile. FIG. 3 depicts such a stripper nozzle 11, in section with a copper wire 1, also shown in section, in the bore 20 of the stripper nozzle 11. The bore 20 has a wave profile. In FIG. 3, two concentric circles 21 and 22 are shown with radii R_1 and R_2. The wave train 23 passes between these concentric circles 21 and 22. The wave train 23 possesses between 3 and 15, and preferably 5 and 8 half walves, per millimeter of the circumference of the inner circle 21.

FIG. 3 shows a nozzle for a wire radius r_1 of 0.25 mm. A closed wave train with 8 half waves is provided, which corresponds to about 5 half waves, relative to the unit of length.

The radii R_1 and R_2 and thus the depths $(R_1 - R_2)$ of the half waves of the wave train 23, are adjusted to the radius r_1 of the wire. Decisive for this adjustment are the tolerance limits for the wire radius r_1 and the desired layer thickness for the tin plating. The tolerance limits for the wire radius r_1 enter essentially into the radius R_1 of the inner concentric circle 16. This radius must be selected at least so large as to prevent, during the passage of the wire 1, the wave profile from being cut into the wire surface. It is preferable that R_1 be between 1 and 20 μm greater than the upper tolerance limit for the wire radius r_1. The layer thickness is being essentially determined through the spacing between the wave maximum and minimum, that is the number of half waves per millimeter of the circumference.

FIG. 4 shows that the half waves **23a**, which contact the outer concentric circle **22**, are preferably shaped at least almost as a semicircle. The radius r or circle **24**, which is drawn into a half wave **23a**, and the chord c, defined by the intersecting points of the circld **24**, with the inside concentric circle **21**, are decisive for the layer thickness next to the difference between the diameters r_1 and r_2 of concentric circles **21** and **22**. The radius r or the length of the chord c, is determined by the number of half waves of the wave train **23**. It was found that for a layer thickness of around 7 μm, the number of half waves per millimeter of the circumference R_1 of the circle **21**, must be between **3** and **15**. The difference $R_2 - R_1$ between the radii R_1 and R_2 of the concentric circles **21** and **22** may vary from 10 to approximately 100 μm. The tin layer adhering to the wire is profiled with a thus dimensioned stripper nozzle **11**. The subsequent smoothening is effected by itself through the surface tension of the profiled tin layer, whereby the form of the profiling helps to attain a uniform average layer thickness of at least nearly constant size, over the entire wire circumference.

Starting with these layer thicknesses, a thin wire can be obtained with this stretching method. This wire, too, is provided with a uniform tin layer of at least nearly constant layer thickness, over the entire wire circumference. It was previously pointed out that by stretching the tin plated copper jump wire, the surface quality is improved, especially through the smearing of pitted locations in the tin layer and making uniform the tin layer thickness. Thus, thick tin plated copper wires may be produced with very narrow tolerances with respect to the wire diameter and the layer thickness, as required for some usage.

FIG. **5a** shows, in enlarged illustration, a hot thick tin plated copper wire **1**, whose radius r_1 is 0.4 mm. The thickness s_1 of the applied tin layer is 6.6 μm. Pits **26a** and **26b** occur at some places in the tin layer **25**.

FIG. **5b** shows the hot tin plated copper jump wire of FIG. **5a**, following the stretching on a radius r_2 of 0.3 mm. The thickness s_2 of the tin layer now amounts to 5 μm. The stretching process frees the tin layer **25** of pits and as shown in the drawing, makes it more uniform than in FIG. **5a**, prior to pulling.

Another example of a copper jump wire with a diameter r_1 of 0.25 mm, prior to stretching, is illustrated in FIG. **6a**. A layer of SnPb 40 is placed upon the copper wire **1**. The layer thickness s_2 of tin layer **25**, prior to stretching, is approximately 9 μm. Note pit **26**.

FIG. **6b** shows the wire according to FIG. **6a**, following the stretching. The wire **1** was stretched to a radius r_2 of 0.15 mm. The layer thickness of the SnPb 40 again amounts to 5 μm, following the stretching. FIG. **6b** shows also that the SnPb layer is more uniform in thickness and free of pits.

Another feature of the method according to the present invention should be added. During the passage of the wire through the tin bath whose temperature is around 250°C, the hardness of the copper jump wire is reduced. The subsequent stretching increases the hardness. If a soft thick tin plated copper jump wire with a diameter <0.5 mm is to be produced, the copper jump wire, which has hardened during the stretching process, must be subjected to a heat treatment at temperatures between 200° and 220°C. This softening of the copper wire may also be effected by passage through with a resistance heater. The copper wire is being supplied thereby with electric current, via two contact rollers. During the passage, softening is achieved in a considerably shorter time, since wire temperatures above 220°C may be used. The wire temperature must not be selected to be so high as to cause much deformation of the tin layer or promote the formation of diffusion layers for the short period during which the wire is heated.

We claim:

1. Method of producing tin containing layers on copper or copper alloy wires, with a diameter less than 0.5 mm, by means of hot tin plating with a uniform thickness across the wire diameter of greater than 3 μm, which comprises passing a copper wire having a diameter greater than 0.5 mm through a tin containing bath and thereafter guiding the wire through a profiled stripper nozzle, subsequently passing the coated copper wire through at least one stretching stage wherein the coated copper jump wire is pulled over two rollers, the first roller exerts a smaller circumferential force than the second roller on the copper wire thereby reducing the diameter of the copper wire and the thickness of the tin coating by stretching, whereby the uniformity of the tin coating is improved during said stretching.

2. The process of claim **1**, wherein the copper wire immediately after the tin containing bath is drawn through the stretching stage.

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