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2,429,222

METHODS OF MAKING CONTACT WIRES

Filed June 5, 1943

2. Sheets-Sheet 1



FIG. 1

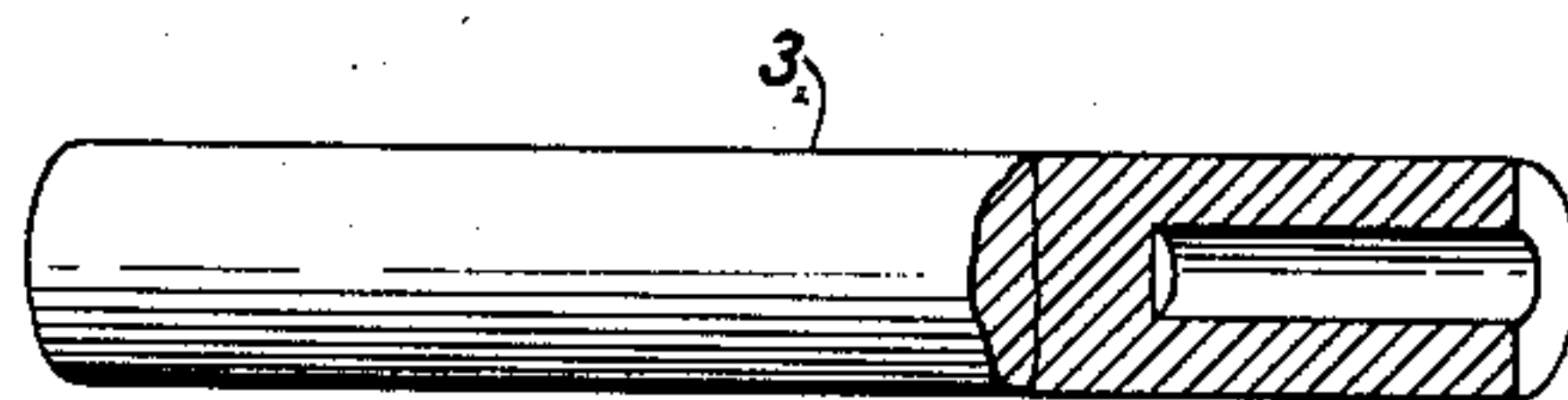


FIG. 2

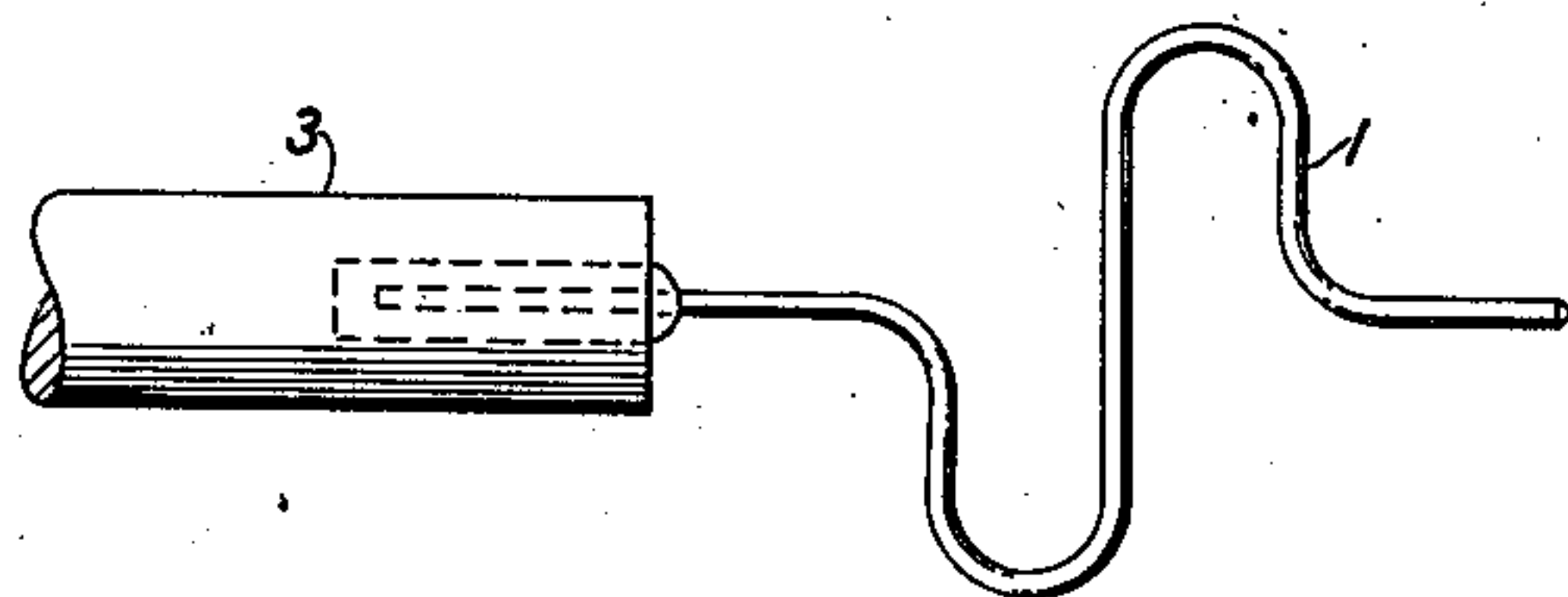


FIG. 3

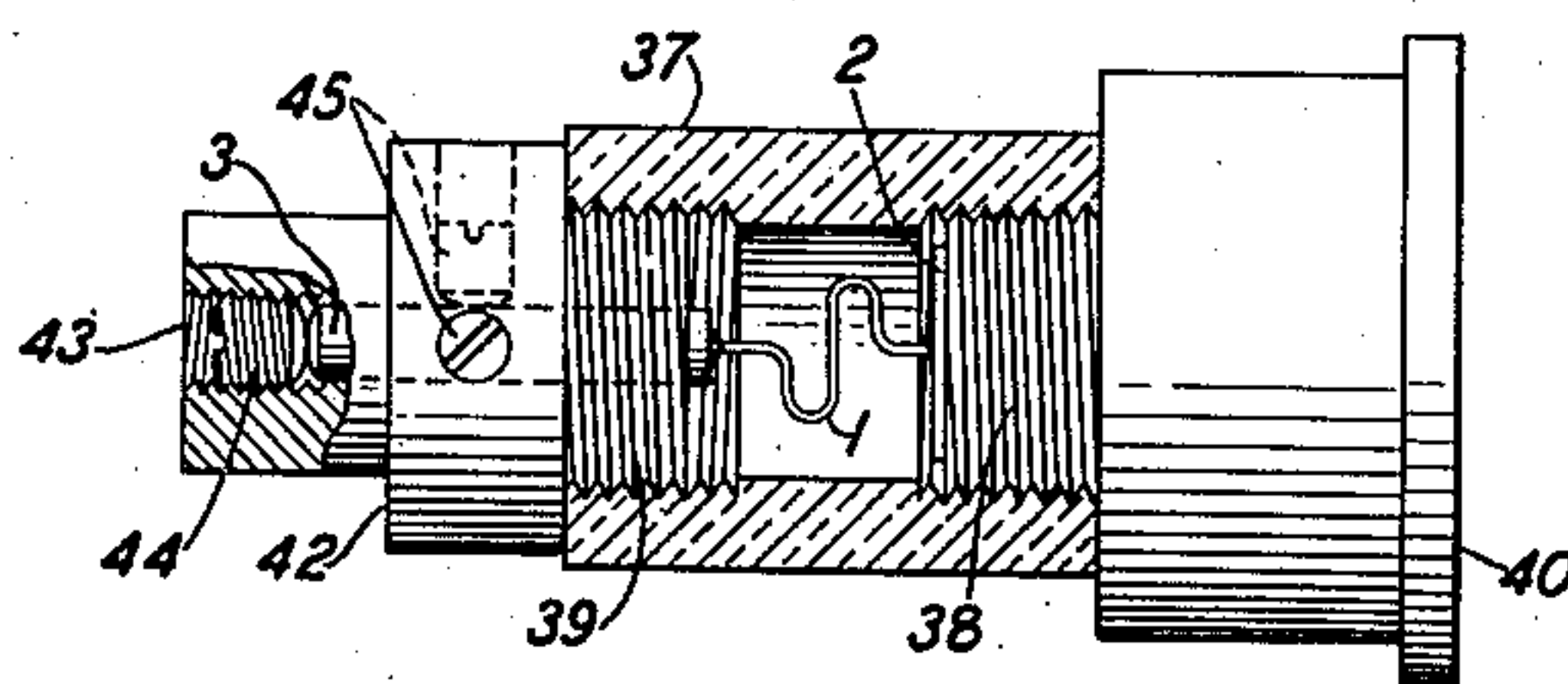


FIG. 4

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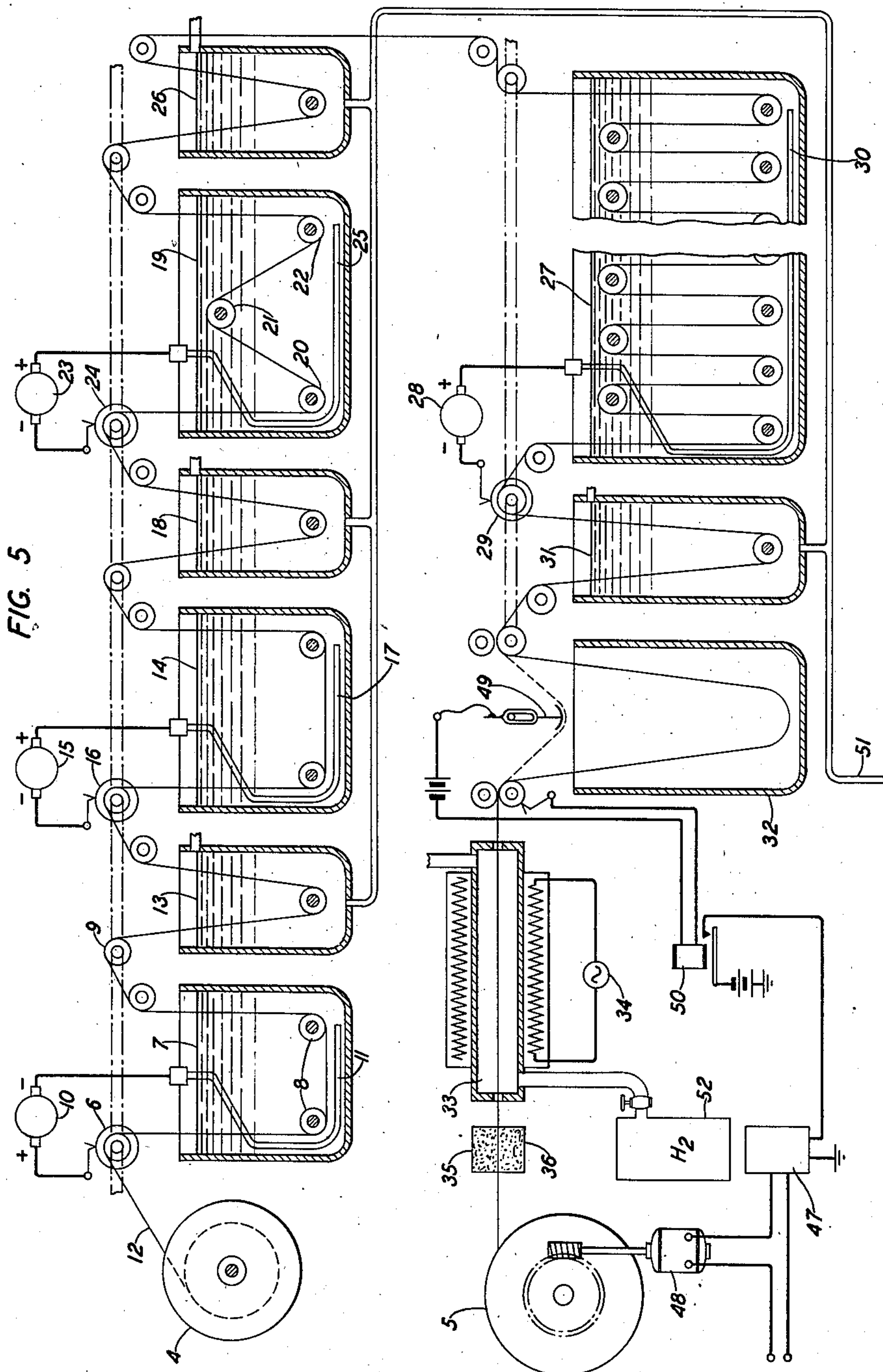
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2 Sheets-Sheet 2



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METHOD OF MAKING CONTACT WIRES

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5 Claims. (Cl. 204—28)

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This invention relates to translating materials and devices and particularly to methods of making them.

The objects are to reduce the cost of manufacturing contact wires for translators; to improve the electrical contact between the contact wire and its supporting member in the assembly; to facilitate the joinder of this wire and the supporting member by soldering or otherwise; to facilitate the forming of the wire into the requisite shapes; and in other respects to improve these devices and the methods of making them.

The successful extension of radio signaling into the range of ultra-high frequencies, corresponding in some cases to wavelengths of only a few centimeters, has depended in large measure upon the development of a suitable device for detecting, converting, translating, or otherwise utilizing the signal waves at these extreme frequencies. For this purpose the translating device most commonly used is one of the point-contact type in which the free end of a fine contact wire of some material such as tungsten makes a point contact with the surface of a rectifying element such as a silicon crystal. The other end of this wire is generally soldered to a metal support or holder forming a part of the translator assembly, and the minute character of the currents flowing in the wire makes it imperative that the joint it forms with the holder shall be substantially perfect. This is true for two reasons: any imperfection in the joint introduces a loss in the working current, which is serious in view of its small magnitude; and a faulty joint also gives rise to noise currents, which are likewise objectionable. Since the fine tungsten wire cannot be soldered readily to the metallic holder, the present practice is to coat one end of the contact wire by dipping it in a hot bath of contact metal before performing the soldering operation. This method is slow and expensive and is very unsatisfactory where quantity production is required. Moreover, the adherence between the tungsten wire and the coating is not sufficient to give an adequate electrical contact.

In accordance with the present invention the objections above mentioned are overcome and an improved contact wire and joint are obtained by a new method of preparing, plating, and treating the wire before it is soldered or otherwise secured to the metal holder. More specifically, this new method comprises a series of steps which are so arranged sequentially that the wire stock may be run continuously from the beginning to the end of the process. The first step is to subject the

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tungsten wire to a cleaning operation, following which it is given a strike coating of nickel in a special bath. Following the strike coating the wire is given a heavier plating of nickel in an electroplating bath of suitable materials. Thereafter the wire proceeds through a final electrolytic bath in which it is given a coating of precious metal, such as gold. The next step is to run the plated wire through a heating chamber to cause a partial diffusion between the nickel and tungsten and between the nickel and gold. Thereafter the prepared wire is cleaned and is then ready for use in the rectifier assemblies.

In addition to the manufacturing advantage realized from this improved process the contact wires prepared in this way also have distinct electrical advantages. The layer of nickel adheres to the tungsten surface and forms a base for the outer layer of gold, which cannot be made to adhere directly to the tungsten surface, and the heat treatment then forms an intimate union by alloying a part of the nickel with the tungsten and also by alloying a part of the nickel with the gold. Thus a substantially perfect electrical joint is formed between the tungsten wire and the outer plating to which the soldered connection is made. Moreover, the outer layer of gold, which is highly resistant to oxidation, affords a superior surface to which a soldered joint having the requisite electrical and mechanical characteristics can be made. Another advantage of this method is that the strong adherence between the coating and the tungsten, resulting from the diffusion of the metals during the heat treatment, makes it possible to bend and form the wire into desired shapes without causing the coating to flake or peel. The formation of a completely adherent coat is essential not only at the end of the wire where it is soldered to the holder but also in the intermediate section which must be formed and shaped to give the required resilience to the point contact. Any loosening of the coating on the tungsten surface due to bending results in electrical disturbances in the working circuits.

These and other features of the invention will be discussed more fully in the following detailed specification.

In the drawings accompanying the specification:

Fig. 1 illustrates a length of tungsten wire (greatly enlarged) used as a point-contact element in a rectifier;

Fig. 2 shows a metallic cylinder of brass or other suitable metal which serves as a holder for the contact wire;

Fig. 3 shows the contact wire fixed in position in the metal holder;

Fig. 4 illustrates one of the rectifier assemblies; and

Fig. 5 shows the apparatus for performing the plating and heat-treatment operations on the contact wire.

A better understanding of the problem with which applicants' invention is concerned may be had by considering the small dimensions of some of the component parts of these point-contact rectifiers and the minute current which they conduct. The contact wire 1, the free end of which makes a minute point contact with the surface of a silicon crystal 2 is about .203 inch in length and is as small as .005 inch in diameter. The silicon crystal 2 is about .090 inch in diameter and has a thickness of .015 inch. The free end of the wire 1 is ground to a point in order to reduce the area of the rectifying engagement between the wire and the crystal surface. In view of the minute size and delicate character of the point contact thus formed only currents of very small amplitude flow through the contact wire to the associated parts of the rectifier assembly.

The contact wire 1 is supported by a cylindrical holder 3, preferably of brass, to which it is attached by means of a soldered joint as illustrated in Fig. 3. As mentioned above, the difficulty in the manufacture of these devices is to obtain a joint between the wire 1 and the holder 3 which is strong mechanically, free from noise sources, and offers substantially no resistance to the flow of the minute currents between the wire and the holder. Moreover, it is necessary to obtain such a joint without interfering with the ability of the wire to undergo flexing and bending in order that the resilient formation shown in Fig. 3 may be attained. The process of preparing a contact wire which meets all of these requirements will now be described in detail.

Referring to Fig. 5, the tungsten wire stock is taken from a supply reel 4 and advanced in a continuous movement at a uniform rate of speed by any suitable driving means through a succession of electrolytic baths and finally through a heat-treating apparatus from which it is delivered to a storage reel 5. The linear speed of the moving wire 12 may be chosen at any desired value, but it has been found that a speed of 2.5 feet per minute gives good results. After the wire leaves the supply reel 4 it passes over a pulley 6 into a cleaning bath 7 around pulleys 8 and thence out of the cleaning bath to the pulley 9. The bath 7 comprises a twenty per cent solution of sodium hydroxide, and its purpose is to give the wire a preliminary cleaning. To this end the moving wire is made the anode of the electrolytic cell by connecting the positive pole of generator 10 to the metal pulley 6 and by connecting the negative pole of the generator to the submerged cathode 11. The proportions of the bath 7 relative to the speed of the moving wire may be chosen to give the desired time interval of exposure. Applicants have found that an interval of about twenty-seconds at a current density of 190 amperes per square foot is sufficient for the initial cleaning step. On emerging from the cleaning bath 7 the wire passes over the pulley 9 and into a rinsing bath 13.

From the rinsing bath 13 the wire passes through the initial plating bath 14. This bath comprises a special solution of nickel chloride and hydrochloric acid in the following proportions:

NiCl₂·6H₂O ----- ounces per gallon--- 32
HCl ----- fluid ounces per gallon--- 16

The moving wire is made the cathode by connecting the negative pole of the generator 15 to the metal pulley 16, and the positive pole of the generator is connected to the immersed anode 17. This bath is highly acid and exerts a cleaning influence on the tungsten due to the copious evolution of hydrogen. In this manner all traces of oxide or other impurities are removed from the surface of the wire, exposing the clean tungsten to the bath. The interval of immersion is relatively brief, preferably of the order of twenty-five seconds, but during this time the cleaning action takes place and a strike coating of nickel is deposited on the cleaned surface of the wire. A current density of 720 amperes per square foot during the twenty-five second exposure is found to give excellent results. The main purpose of this initial plating step is to lay a primary coat of nickel on the clean tungsten surface as a base for the deposit of succeeding and heavier plates. After leaving the striking bath 14 the wire is again rinsed in a cleaning bath 18.

From the cleaning bath 18 the wire proceeds into the nickel-plating bath 19 for the purpose of depositing a plate of nickel of substantial thickness. To this end the size of the bath 19 is chosen with reference to the speed of the wire to give a time interval exposure of about sixty seconds. One method of accomplishing this longer exposure is to loop the moving wire over a number of pulleys 20, 21, 22. The bath 19 may consist of any suitable and well-known nickel-plating solution such as those including nickel chloride, nickel sulphate and boric acid. The current density in the bath 19 is maintained at 7 amperes per square foot by the generator 23, which has its negative pole connected to the metal pulley 24 in contact with the wire and its positive pole connected to the submerged anode 25. From the plating bath 19 the wire is guided into another cleaning bath 26.

From the cleaning bath 26 the wire is led into a gold-plating bath 27 for depositing a final plate of gold. It is desired to have the thickness of the gold plate considerably greater than that of the preceding nickel plate, and for this purpose the bath 27 is designed to expose the moving wire to the solution for an interval of about two hundred and forty seconds. Any suitable and well-known gold plating solution may be employed such as the following:

Ounces per gallon
NaAuCN₂ ----- 1
NaCN ----- 1
Na₂HPO₄ ----- 1

The current density of the bath is maintained at 15 amperes per square foot by means of the generator 28, the negative pole of which is connected to the moving wire through the medium of pulley 29 and the positive pole of which is connected to the submerged anode 30. Following the gold-plating bath the wire is cleaned in a bath 31 whereupon it is delivered to a temporary storage receptacle 32.

The final heat treatment step of the process is performed by running the plated wire 12 through a chamber 33 containing purified hydrogen supplied from a tank 52. The chamber 33 is heated from a suitable source 34 and is closely regulated to the desired temperature, which may be about 710° C. The movement of the wire through the hydrogen atmosphere is preferably at a con-

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siderably higher speed, about fourteen or fifteen feet per minute. This difference in speed between the movement of the wire through the successive baths and through the heat-treating chamber makes it necessary to introduce the storage receptacle 32 for storing a quantity of the plated wire before the heat treatment is applied. If desirable a timing switch 47 may be arranged to start the motor after the plating mechanism has run long enough to accumulate a quantity of the plated wire. As soon as nearly all the plated wire has been removed from receptacle 32 it engages the swivel contact 49 and closes a circuit for relay 50, which stops the motor 48 to allow a new supply of wire to accumulate.

After the treated wire passes from the chamber 33 it is subjected to the friction of cloth pads 35 and 36 which are pressed together by a force of approximately 16½ pounds. As the wire leaves the pressure pads 35 and 36 it is received and wound on the storage reel 5.

It will be understood that any suitable means may be employed for moving the wire through the successive baths and through the heat-treating chamber. A number of pulleys have been illustrated conventionally, any of which may serve as the driving member for moving the wire along its course. A common supply pipe has been shown for the rinsing baths, but it will be understood that separate supply sources may be provided if desirable.

To review the effects of the different steps in the process briefly, it will be recalled that the purpose of bath 14 is to free the tungsten wire from its oxides and other surface impurities and to deposit thereon a very thin adherent coating of nickel. This thin flash coating is applied while the wire is in a clean condition and lays the basis for the subsequent deposit of the heavier nickel plate. This heavier plate is laid on during the next step while the wire is passing through the bath 19. For the values given it is estimated that the nickel plate deposited in the bath 19 is about 0.00001 inch in thickness. The purpose of using nickel for the initial plate is that it is one of the very few metals that adheres to tungsten. On the other hand, nickel tarnishes when exposed to oxygen and will not, therefore, meet the requirements of the rectifier contact wire if used as a soldering surface. Hence the next step in the process is to apply a relatively thick plating of gold over the nickel plate. Gold was selected for two controlling reasons. In the first place it is highly resistant to oxidation and affords an excellent surface for making the soldered joint between the contact wire and the metal holder of the rectifier. In the second place, gold alloys or diffuses with nickel at a temperature sufficiently low to permit the heat treatment without injury to the tungsten wire. Finally the plated tungsten wire is given the heat treatment described, which results in a partial diffusion of the nickel plate into the body of the tungsten and a partial diffusion of the nickel plate into the outer plating of gold. The result, therefore, is an intimate adherent coating on the tungsten wire which satisfies the exacting requirements of these translating devices and which is capable of being formed into the necessary shapes without flaking or peeling.

Although specific values are given herein for the rates of movement of the wire through the various steps of the process and for the time intervals of immersion, it will be understood that

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these values may be varied somewhat without departing from the invention.

After the tungsten wire is prepared as above described, a length 1 is cut therefrom and soldered into the bore in the end of the brass cylindrical holder 3. The wire 1 is then shaped as illustrated in Fig. 3, and the unit is now ready to be included in the assembly shown in Fig. 4. The rectifier assembly includes a ceramic cylinder 37, the interior of which is threaded to receive threaded studs 38 and 39. Stud 38 is an integral part of the metal base 40 which closes one end of the hollow cylinder 37. The stud 38 also serves as a mounting for the thin crystal wafer 2 of silicon. The other stud 39 is an integral part of the metal cap 42, which contains a central bore 43 for receiving the holder 3. The holder 3 is slipped into the bore 43 and adjusted by means of a set screw 44 until the tip end of the contact wire 1 engages the surface of the crystal 2 with the requisite degree of force. The cylinder 3 is then seized by the set screws 45.

What is claimed is:

1. The method of preparing contact wire for point-contact translators which comprises moving an indefinite length of tungsten wire continuously at a uniform rate, immersing the wire in an electrically energizing bath containing an etching agent for the wire, said wire being made the anode in the bath, immersing the moving wire for a predetermined interval in an electrolytic bath including a nickel compound and an acid for cleaning the wire and giving it a thin initial adherent plating of nickel, said wire being made the cathode in said electrolytic bath, immersing said initially plated moving wire for a predetermined longer interval in an electrolytic nickel plating bath for depositing thereon a plating of nickel of substantial thickness, immersing said moving wire for a still longer predetermined interval in an electrolytic gold plating bath for depositing on said nickel plating a plating of gold of substantial thickness, and subjecting said plated wire to a heat treatment sufficient to cause a diffusion of the initial nickel plating into the tungsten body of the wire and only a partial diffusion between the outer plating of gold and the plating of nickel.

2. The method of preparing contact wire for rectifiers which comprises moving an indefinite length of tungsten wire at a predetermined rate through an electrically energized cleaning bath containing an agent suitable for cleaning and etching the wire, said wire being made the anode in the cleaning bath, rinsing said wire, moving said wire through an electrolytic bath including a nickel salt and hydrochloric acid for cleaning the wire and giving it a strike coating of nickel, said wire being made the cathode in said electrolytic bath, rinsing said wire, moving said coated wire at a predetermined rate through a second electrolytic nickel plating bath for depositing on said strike coating a plating of nickel of substantial thickness, moving said plated wire at a predetermined rate through a third electrolytic bath containing gold for depositing on said nickel plating a plating of gold of substantial thickness, and subjecting the said plated wire to a heat treatment of 710° C. to cause a portion only of the nickel plating to alloy with the tungsten body of the wire and to cause a portion only of the gold plating to alloy with the nickel plating to cause a portion only of the nickel plating to alloy with the tungsten body of the wire and

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to cause a portion only of the gold plating to alloy with the nickel plating.

3. The method of preparing contact wire for point-contact rectifiers with a plating of metal which is free from flaking and peeling comprising moving an indefinite length of wire continuously, passing the wire through an electrically energized cleaning bath containing a solution of sodium hydroxide, the wire being the anode in said cleaning bath, immersing the moving wire for an interval of twenty-five seconds in an electrolytic bath including a solution of nickel salt and hydrochloric acid for cleaning the wire and giving it a strike coating of nickel, the wire being the cathode in said electrolytic bath immersing said moving wire for an interval of sixty seconds in a second electrolytic nickel plating bath for depositing on said strike coating a plating of nickel of substantial thickness, immersing said moving wire for an interval of two hundred and forty seconds in an electrolytic bath containing gold for depositing on said nickel plating a plating of gold, subjecting said plated wire to a heat treatment sufficient to establish a close adherence between the wire and the strike coating of nickel and between the platings of nickel and gold thereon, but not sufficient to make the platings of nickel and gold lose their identities, cutting said treated wire into unit lengths and bending said wire units to give them resilience when assembled in said rectifiers.

4. The method of preparing contact wire for point-contact rectifiers which comprises moving an indefinite length of tungsten wire continuously at a uniform linear speed, immersing said wire for a predetermined interval of time in a cleaning bath of sodium hydroxide, said cleaning bath being electrically energized and having a cathode and said wire being the anode, said predetermined interval of time being sufficient for cleaning and etching the tungsten wire, rinsing the cleaned and etched wire, immersing the moving wire for a second predetermined time interval in an electrolytic bath including a nickel salt and an acid for cleaning the wire, said second predetermined time interval being sufficient for further cleaning said wire and giving it a strike coating of nickel, the cleaned and etched wire being the cathode in said electrolytic bath, rinsing the strike coated wire, immersing the moving wire for a longer predetermined interval in a second electrolytic nickel plating bath for depositing on the strike coating a plating of nickel of substantial thickness, rinsing the nickel plated wire, immersing the moving wire for a still longer predetermined interval in an electrolytic gold plating bath for depositing on the plated wire a plating of gold of still greater thickness, rinsing

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the gold plated wire and heat-treating said plated wire in an atmosphere of hydrogen at a temperature only sufficient to cause a portion of said plating of nickel to diffuse into the tungsten body of the wire and another portion of the nickel to diffuse into the plating of gold but without alloying the metal on the outer surface of said plating of gold.

5. The method of preparing electrical contact wire which comprises moving an indefinite length of wire at a predetermined uniform linear speed, passing the wire as an anode through an electrically energized cleaning and etching bath containing a solution of sodium hydroxide, rinsing the wire, leading said wire as a cathode through an electrolytic bath including a solution of nickel salt and hydrochloric acid for cleaning the wire and giving it a strike coating of nickel, the nickel salt being greater than the hydrochloric acid in the proportion of about 2 to 1, rinsing the strike coated wire, leading said coated wire through a second electrolytic nickel plating bath for depositing on said strike coating a plating of nickel of substantial thickness, rinsing the plated wire, leading said plated wire through a third electrolytic bath containing gold for depositing on said nickel plating an outer plating of gold of substantial thickness, rinsing the gold plated wire, and subjecting said plated wire to a heat treatment of 710° C. to cause diffusion between a portion of the nickel plating and the tungsten body of said wire and diffusion between another portion of said nickel plating and a portion only of the gold of said outer plating to cause diffusion between a portion of the nickel plating and the tungsten body of said wire and diffusion between another portion of said nickel plating and a portion only of the gold of said outer plating.

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