

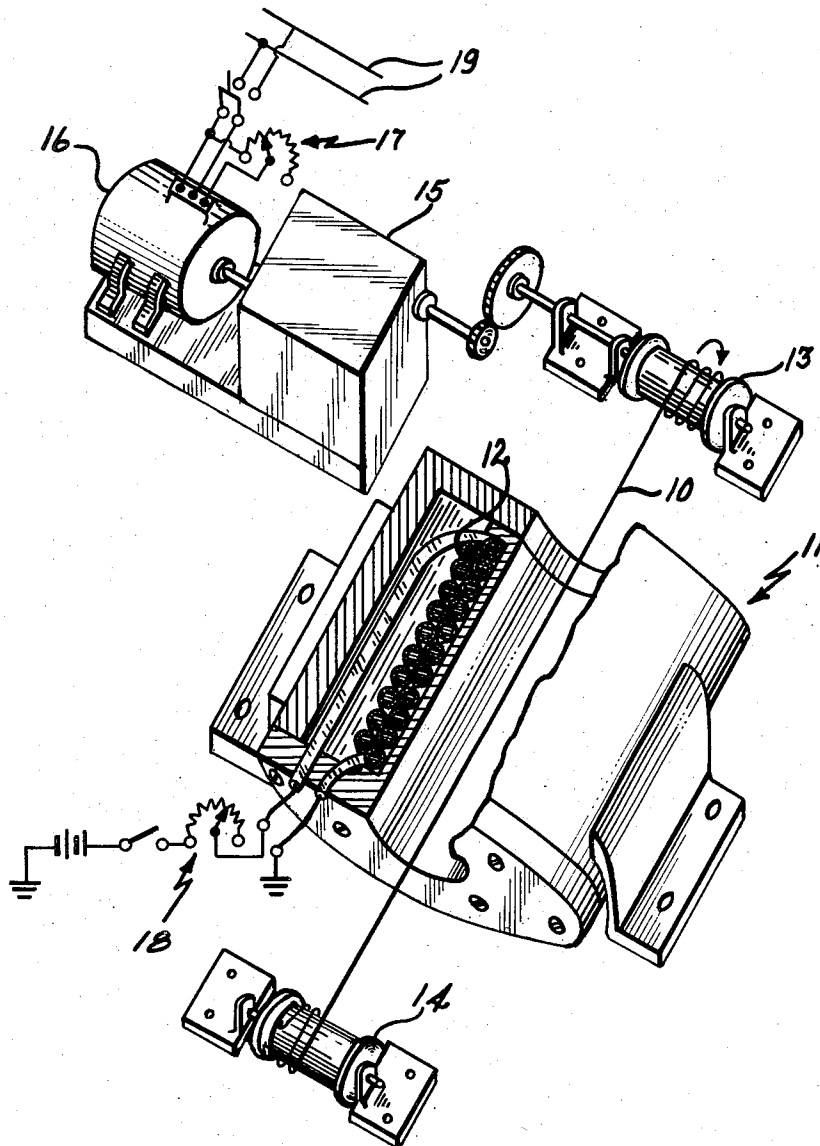
April 7, 1959

R. A. LANGEVIN

2,881,099

PREPARATION OF SEMI-CONDUCTIVE MATERIAL

Original Filed Jan. 29, 1957



INVENTOR.

ROBERT A. LANGEVIN

BY

W. A. L. Langevin
Walter F. Finney
ATTORNEYS

1

2,881,099

PREPARATION OF SEMI-CONDUCTIVE MATERIAL

Robert A. Langevin, Silver Spring, Md., assignor to the United States of America as represented by the Secretary of the Air Force

Original application January 29, 1957, Serial No. 637,052. Divided and this application November 15, 1957, Serial No. 696,893

1 Claim. (Cl. 117—227)

This invention relates to the preparation of semi-conductive material for use in signal translating devices and more particularly to methods of treating gold wire to insure optimum donor and acceptor impurity content. This application is a division of my co-pending application Serial No. 637,052, filed January 29, 1957.

It is now well established that the conductivity and certain other qualities of semi-conductor materials are determined by the characteristics of the impurities present. Donor impurities such as antimony and phosphorus tend to make a material N-conductivity type. Acceptor impurities such as gallium, boron and aluminum tend to make a material of the P-conductivity type.

An object of this invention is to provide a method for doping wire in order to introduce proper amounts of impurities necessary for its use as emitter and collector elements in transistors.

A second object is to provide a solution of novel content, for the indicated purpose.

A further object of this invention is to provide a method for reducing the impurity content of wire that has been previously doped.

These and other advantages, features and objects of the invention will become more apparent from the following description taken in connection with the illustrative embodiment in the accompanying drawing, wherein the figure is a plan view, partly in cross-section, of a dedoping furnace.

As will be clear from the drawing, a sample of wire 10, which contains an excessive amount of impurity from dip-doping at its commercial source, may be dedoped by boiling out the excessive impurity in air rather than in a vacuum. This may be accomplished by drawing the wire 10 continuously through a resistance furnace 11 heated by elements 12, the temperature of which is controlled by potentiometer 18. This operation is made continuous by driving spool 13, such that the wire is removed from supply spool 14 and passes through resistance furnace 11 at a constant rate. The driving means comprises an electric motor 16 connected to leads from a power supply 19 through potentiometer 17. This, in turn, is operatively connected to the driven spool 13 by means of a gear reduction box 15. Such a continuous type operation appears to provide good uniformity of doping level and little alteration of wire diameter contrary to previous experience in vacuum dedoping methods. Most successful results were obtained using this procedure wherein .003" diameter gold wire containing .01% antimony was employed. Typical operation of the furnace 11 involved the following parameters which were successfully fixed at the following values:

Furnace bore	2"
Furnace length	5½"
Furnace temperature at center	Approximately 900° C.
Pull rate	1.8" per hour.

The extremely slow pull rate could be obviated by modifying the above-described structure to provide for the gold wire to traverse the furnace a number of times. Another method of regulating the amount of antimony impurity in a gold wire consists of the introduction of antimony dope onto "pure" (99.99%) gold wire by

2

dipping the wire into an aqueous solution containing antimony. A solution of SbCl_3 may be used, but the results from this method tend to fail somewhat. This may be traced to the fact that SbCl_3 reacts with water to form SbOCl which, in turn, is essentially insoluble but which forms a colloidal suspension in water. Such a phenomenon causes the antimony strength of the resulting "solution" to be very dependent on the time and methods of handling. To obviate this difficulty, solutions may be prepared using antimony potassium tartrate. The latter compound forms a true solution in water and 99.99% gold wire dipped in such a solution (10 milligrams of potassium-antimony tartrate to 3 cc. of distilled water) will yield, when bonded, results very similar to 1% antimony doped gold wire. The reproducibility of uniform results in this operation may be improved by adding to the above solution about 0.1 gram of wetting agent which apparently has the effect of cutting through residual die-lubricants and other impurities on the surface of the wire. The only apparent criticality of impurity content seems to be that the antimony content should certainly not exceed 1%. In studies carried out on face-to-face gold bonded transistors using .003" gold wire with first, no emitter or collector doping; second, 1% gallium emitter doping and 1% gallium collector doping; third, 5% indium emitter doping, 1% antimony collector doping; fourth, 1% indium emitter doping and 1% antimony collector doping; and finally, fifth, 1% gallium emitter doping and 1% antimony collector doping. Carrying out these experiments on units with common .002" point spacing, utilizing germanium ranging in sensitivity from 3 to 30 ohm cm., measurements of the small signal parameters of the resulting transistors establish the following:

(1) Units with 1% gallium doped emitters and collectors, exhibit junction-like properties with the α always less than 1. Values of .5 to .7 are typical. Collector impedances of 10 to 20 thousand ohms are readily obtainable with α cut-off frequencies as high as 7 megacycles and power gains of 15 db or more.

(2) No difference in emitter characteristics can be discerned between the 1% gallium and 1% indium doping. While the 5% indium doping also affords satisfactory emitter characteristics, some difficulty is experienced in bonding successfully when using this wire.

(3) Antimony doping (presumably, arsenic will do as well) of the collector is essential if current gains greater than 1 are to be obtained. While 1% antimony doping makes it possible to obtain current gains as high as 5 to 6, these high current gains are always accompanied by collector impedances of the order of a few hundred ohms. This is interpreted as indicating that the antimony doping level is much too high.

Although specific embodiments of this invention have been described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention.

I claim:

A method of antimony doping 99.99% gold wire for use as emitter and collector elements in signal translating devices comprising the steps of preparing an aqueous solution containing 10 mg. antimony-potassium tartrate and 0.1 g. wetting agent per 3 cc. distilled water and dipping said gold wire into said solution until the antimony content of said wire approaches 1%.

References Cited in the file of this patent

UNITED STATES PATENTS

2,658,839	Talmey et al.	Nov. 10, 1953
2,683,672	Chester	July 13, 1954