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METHOD FOR PROVIDING ELECTRICAL CONTACTS TO A WAFER OF GaAs

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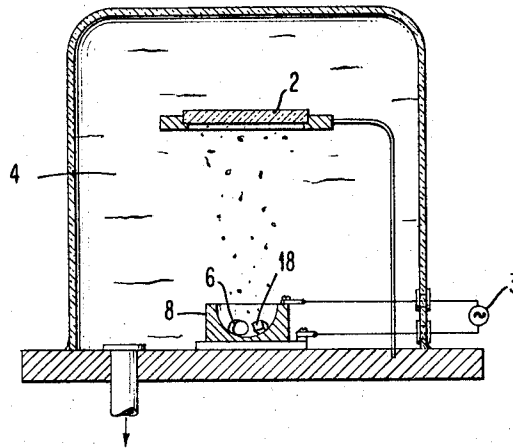


FIG. 1

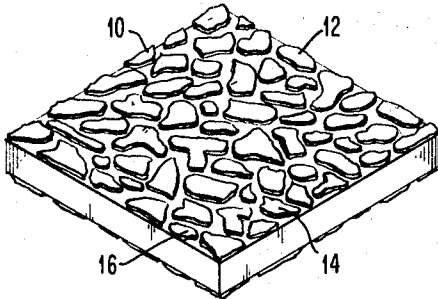


FIG. 2

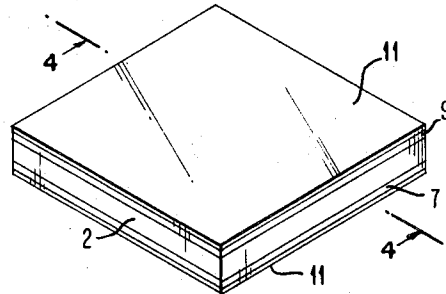


FIG. 3

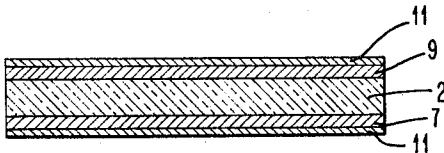


FIG. 4

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METHOD FOR PROVIDING ELECTRICAL CONTACTS TO A WAFER OF GaAs

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This invention relates to the manufacture of electrical contacts, and more particularly to the manufacture of electrical contacts for N-type GaAs.

A new phenomenon, called the "Gunn Effect," is described in the April 1964 issue of the IBM Journal of Research and Development, vol. 8, No. 2. On pages 141-159 of said Journal, the new phenomenon is described by the discoverer, J. B. Gunn, in an article entitled, "Instabilities of Current in III-V Semiconductors." Gunn discovered that the application of an electric field, i.e., a few thousand volts per centimeter, to a homogeneous sample of N-type GaAs produces, once a well-defined threshold field is reached, a time dependent decrease in current, the latter being substantially independent of external circuit conditions. For short specimens of GaAs, coherent oscillations are observed whose period is equal to the transit time of electrons between ohmic electrodes connected on either side of the GaAs wafer.

As is set forth in certain sections of the above-noted paper by J. B. Gunn, the electrical contacts for the wafer of GaAs had to have very low resistance, less than 0.1Ω. Moreover, such contacts, in the presence of a strong electric field, had to exhibit linear conductivity, be non-injecting and geometrically regular.

A successful electrical contact comprises the use of a eutectic composition of gold and germanium. The deposition of such eutectic composition on N-type gallium arsenide has resulted in low resistance-type contacts mentioned in the article by J. B. Gunn.

After evaporation of the eutectic mixture on the GaAs substrate at room temperature, alloying must be accomplished by raising the substrate temperature to over 450° C. until the reaction between the gold-germanium eutectic and the substrate surface is complete (30 sec.—1 min.). Since the gold-germanium eutectic temperature is approximately 325° C., the eutectic mixture becomes fluid and begins to globulate prior to reaching the alloy reaction temperature. The result upon attaining alloy reaction temperature is an array of electrically discontinuous puddles or globules alloyed to the substrate surface in a random manner.

Since it is desired to batch fabricate electrical contacts to gallium arsenide, such erratic distribution of the electrical contacts on the surface of the gallium arsenide make it difficult to obtain uniform units comprising a substrate of gallium arsenide and an alloyed electrode.

What is desired in the batch fabrication of units of gallium arsenide with suitable electrical contacts attached thereto is the ability to uniformly distribute the gold-germanium composition over the entire surface of a relatively large wafer of gallium arsenide. Moreover, such distribution should be free of erratic globules of gold-germanium so that when the wafer is sliced, after the deposition of gold-germanium, such slices will result in uniform ohmic contacts on each slice cut from the wafer.

Applicant has discovered that the addition of nickel to the eutectic mixture of gold and germanium acts as a film that discourages the globulation or "puddling" of the gold-germanium mixture and thus permits such eutectic mixture to remain in intimate contact with the gallium arsenide substrate. The order of deposition of the contact constituents during vapor deposition is in direct proportion to the temperature required to attain a specified vapor

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pressure. Therefore germanium (1251° C. @ 10 microns Hg vapor pressure) evaporates first and coats the substrate followed by gold (1465° C. @ 10 microns Hg) and nickel (1510° C. @ 10 microns Hg). During the alloying cycle the Au and Ge depositions recombine to form the eutectic compositions at approximately 325° C. and, owing to the low solubility of Ni in AuGe at the alloying temperature, the Ni layer remains intact and retains the liquid AuGe in uniform intimate contact with the substrate surface until the alloy reaction temperature (450°-480° C.) is reached and the reaction is completed.

It is an object of this invention to provide improved electrical contacts for gallium arsenide wafers.

It is yet another object to provide a method for making electrical contacts for N-type gallium arsenide substrates that is particularly suitable for batch fabrication techniques.

Another object is to employ a metal having a much higher melting point than the eutectic gold-germanium during the deposition of gold-germanium onto N-type gallium arsenide but low solubility in said eutectic composition.

Still another object is to employ nickel as the high melting point metal when evaporating a eutectic mixture of gold-germanium onto an N-type gallium arsenide substrate.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention, as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a schematic showing of a suitable vacuum chamber for vapor depositing nickel and a eutectic mixture of gold-germanium.

FIG. 2 shows an erratic deposition of the electrodes onto a gallium arsenide wafer when the invention is not practiced.

FIG. 3 shows the manner in which uniformity of electrode deposition is obtained when nickel is employed during the vapor deposition process.

FIG. 4 is a cross-section taken along line 4—4 of FIG. 3.

In the normal process of making ohmic contacts to gallium arsenide, the gallium arsenide wafer 2 is supported in a suitable vacuum chamber 4. The eutectic mixture of gold-germanium is placed as a pellet 6 within crucible 8. Such eutectic mixture is 88% gold and 12% germanium by weight. Such pellets are heated by conventional means, such as a source of electrical energy 3 supplying current to contacts 5 and 7 so as to raise the temperature of crucible 8, in the evaporation chamber to completion, leaving a thin film of the eutectic mixture on one surface of the wafer 2. The rate of heating is controlled by well known means and such means are not shown in that they do not contribute toward a better understanding of the invention. When one side of the wafer has been treated in this manner, the wafer is inverted in the vacuum chamber so that a similar film of gold-germanium can be deposited on the opposite side of the wafer.

After such two depositions have been completed, the wafer is transferred to an oven, the latter also being in a vacuum. The gallium arsenide and its deposited layers of gold-germanium are heated to about 480° C. However, an alloying reaction takes place between the film of gold-germanium and the substrate material gallium arsenide. Before the alloying temperature of 450° C. is reached, the gold-germanium tends to globulate at a temperature range between 325° C. and 450° C. When such occurs, the end product is shown in FIG. 2. Representative globules 10; 12; 14; 16; etc., indicate how erratic the alloyed

electrodes are distributed over the gallium arsenide substrate 2. Consequently, it is impossible to slice the finished product in a uniform manner to obtain an end product that would comprise a sandwich consisting of a central portion of gallium arsenide and two outer portions of alloyed electrodes comprising the eutectic composition of gold-germanium.

If during the deposition process shown in FIG. 1, a strip of nickel 18 is inserted in the crucible 8 with the pellet 6, the following takes place: the pellet 6 evaporates first and, at somewhat higher temperatures, the nickel evaporates as a layer above the eutectic deposition of gold-germanium. Both sides of the wafer 2 are deposited with the eutectic composition and the flash of nickel over such eutectic composition. Now, when the wafer 2 is placed in an oven located in a vacuum chamber, the gold-germanium attempts to globulate at the temperature range of 325° C. to 450° C., but the film of nickel acts as a barrier preventing such "puddling" when the alloying temperature of 450° C. is reached. Such alloying, which consists of heating the wafer and its deposited layers for approximately a minute, causes a uniform distribution of electrode material over the entire surface (top and bottom) of the wafer 2. The wafer is allowed to gradually cool to room temperature, at which time it is ready to be sliced into uniform chips. As can be seen in FIG. 3, the distribution of the eutectic compositions 7 and 9 is uniform and kept so by the nickel coatings 11 and 13 so that the wafer 2 can now be sliced to produce many small units of a gallium arsenide material having two alloyed contacts on both sides of such gallium arsenide chip.

The amount of nickel 18 that is placed in the crucible 8 with the pellet 6 is 2 to 11% by weight of the eutectic mixture of gold and germanium and 5% approximates the optimum percentage of nickel to be employed. It is not certain why the presence of nickel produces the inhibition of globulation of the gold-germanium mixture. It is believed that the nickel has very low solubility in gold or germanium. The nickel, by not being dissolved substantially in the gold-germanium mixture, stiffens the eutectic layer and helps to maintain such eutectic layer in intimate contact with the substrate 2. As seen in FIG. 4, the end product would comprise the middle layer 2 of gallium arsenide and on either side of such layer would be the eutectic layers 7 and 9 and above each of such layers is the nickel layer 11.

Although germanium-gold eutectic is desirable as an electrode material for gallium arsenide, such electrode materials could not be employed in the process of batch fabricating chips of gallium arsenide and electrical contacts alloyed thereto. The present invention results in mechanically and electrically uniform contacts over a large area of substrates and is particularly suitable for batch fabrication techniques where uniformity of contacts is essential.

While the invention has been particularly shown and described with reference to a preferred embodiment thereof, it will be understood by those skilled in the art

that various changes in form and details may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. A method for providing electrical contacts to a wafer of GaAs comprising the steps of maintaining said wafer in an evacuated chamber, vapor depositing a eutectic mixture of gold-germanium onto said wafer,
- 10 vapor depositing a metal onto said eutectic mixture, said metal having a higher melting point than said eutectic mixture and a low solubility therein, and alloying said gold-germanium to said wafer.
2. A method for providing electrical contacts to a wafer of GaAs comprising the steps of maintaining said wafer in an evacuated chamber,
- 15 vapor depositing a eutectic mixture of gold-germanium onto said wafer,
- 20 vapor depositing nickel over said eutectic mixture, and then alloying said gold-germanium to said wafer.
3. A method for providing electrical contacts to a wafer of N-type GaAs comprising the steps of maintaining said wafer in an evacuated chamber,
- 25 vapor depositing a eutectic mixture of gold-germanium onto said wafer,
- 30 vapor depositing nickel over said eutectic mixture, and then alloying said gold-germanium to said wafer.
4. A method for providing electrical contacts to a wafer of N-type GaAs comprising the steps of maintaining said wafer in an evacuated chamber,
- 35 vapor depositing a eutectic mixture of gold-germanium onto said wafer,
- 40 vapor depositing nickel over said eutectic mixture, and then heating said wafer to a temperature of 450° C. and maintaining said temperature for a period of about 30 seconds to a minute so as to alloy said gold-germanium to said wafer.
5. The method of claim 3 wherein said nickel is between 2-11% by weight of the eutectic mixture of gold-germanium.
- 45 6. An electrical unit comprising a GaAs wafer having at least two opposing faces, a eutectic mixture of gold-germanium intimately affixed to said faces, and a coating of nickel on said eutectic mixture.
- 50 7. An electrical unit comprising an N-type GaAs wafer having at least two opposing faces, a eutectic mixture of gold-germanium intimately affixed to said faces, and a coating of nickel on said eutectic mixture.

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