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METHOD FOR ELECTROLYTIC ETCHING

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FIG. 1.

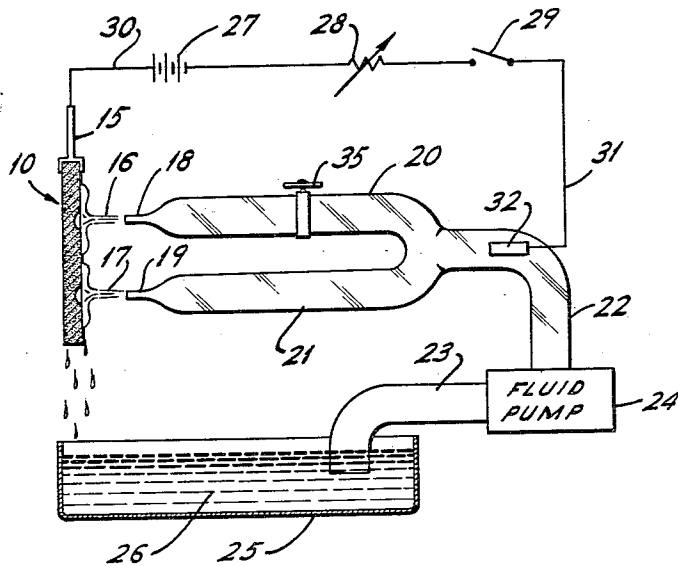


FIG. 2.

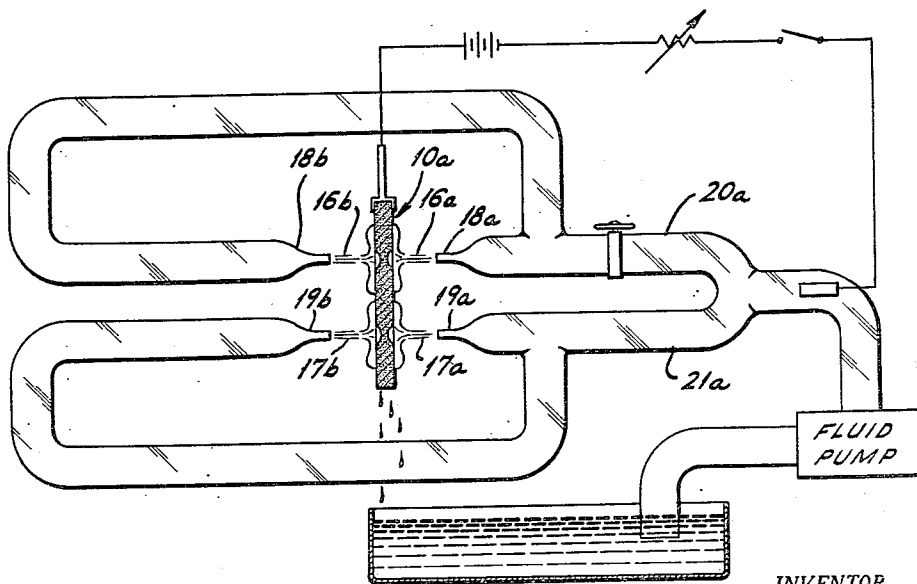
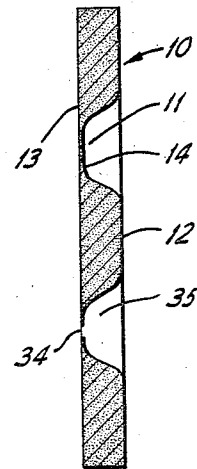


FIG. 3.

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METHOD FOR ELECTROLYTIC ETCHING

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6 Claims. (Cl. 204—143)

The present invention relates to etching and is especially concerned with methods of producing regions of predetermined thickness in blocks or sheets of etchable material. While of broader applicability, the present invention relates to improved methods for utilizing jet etching to shape semiconductive bodies or structures suitable for use in electrical circuit devices, the methods being particularly characterized in that the configurations of said structures may be controlled readily and with great accuracy.

In the manufacture of certain devices, and particularly in the fabrication of semiconductive devices for example of the kind known as transistors, it has become important to provide, readily, consistently and on a mass production basis, bodies of predetermined critical configurations. Especially it has become important to provide regions of very minute and accurately controlled thickness in small wafers of semiconductive material.

Important advances have recently been made in this art and, specifically, in the use of electrolytic jet etching to provide the aforesaid regions, or laminae, of very minute and accurately controlled thickness. For example, in the co-pending application of Tiley and Williams, entitled "Semiconductive Devices and Methods for the Fabrication Thereof," bearing Serial No. 472,824, filed December 3, 1954, and assigned to the assignee of the present invention, there are described and claimed processes for shaping semiconductive bodies by electrolytic jet-etching. Contemplated by the teaching of the said co-pending application is a method which includes the steps of utilizing one jet in the etching of a semiconductive structure until perforation of the structure by said jet occurs, and producing the desired lamina by thereafter utilizing a second jet, directed at another portion of said structure, for a predetermined period of time slightly less than that required to produce perforation at said one jet. While this technique represents a significant advance in the art, it has proven, in practice, to be subject to disadvantages in that the process is unduly time consuming and because it is necessary to time, in each instance, the period of operation of the first jet in order to determine the lesser period of time during which the second jet must be operated. In brief, to fabricate, reproducibly, laminae of the requisite thinness in semiconductive bodies of parallel surface configuration, and in the simplest and most rapid manner, has remained as a problem.

With the foregoing in mind it is, broadly, the objective of my invention to provide improved jet-etching methods for producing restricted regions of extreme thinness, in bodies of etchable material.

More specifically, my invention has as an object the provision of improved methods for producing cavities of accurately controlled depth in semiconductive bodies having parallel surfaces.

A highly important feature characteristic of the invention, is that production of such accurately controlled

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pits or cavities, that is, achievement of a residual lamina of known and precisely controlled thickness, is substantially independent of the thickness of the block or body under treatment, and the process may be applied repetitively in mass production without the necessity of determining the length of time required to produce perforation of the body.

To the foregoing general ends, my invention contemplates simultaneous utilization of a pair of jets of suitable etchant, particularly electrolytic etchant, to etch spaced regions of a block of material having parallel sides, it being particularly characteristic of the invention that the jets are controlled in such manner that, during the time required for one of said jets substantially to perforate the body under treatment, the other jet has been effective to etch for a period of time which is less, by a predetermined interval, than the time required by the first jet to complete its penetration, after which the process is terminated. Conveniently, although not necessarily, such control is effected by initiating operation of the second jet at a predetermined time interval after the initiation of etching at the first jet. By this technique, and substantially independently of the thickness of the body, there is produced in the surface region etched by the second jet a cavity of predetermined depth, that is, the process results in the production of a residual lamina of known and precisely controlled thickness.

It is to be borne in mind, however, that the etching rates at the two jets should be equal, to insure that the resultant lamina is of known and precisely controlled thickness. In this regard the significant relationship between the two jets is that the curve of cavity depth versus time should be substantially identical for both jets.

The manner in which the foregoing and other objects of my invention may best be achieved, will be fully understood from a consideration of the following detailed description taken together with the accompanying drawing, in which:

Figure 1 is a schematic representation of apparatus suitable for practicing a method in accordance with the invention;

Figure 2 is a cross-sectional illustration, on an enlarged scale, of a semiconductive body or structure resulting from the practice of this invention; and

Figure 3 is a schematic representation of apparatus adapted for use in the practice of a modified method contemplated by this invention.

As indicated hereinabove the techniques of this invention may be utilized in the production of a variety of articles or devices, but since the principles of the invention are of particular applicability in the field of semiconductors, the following detailed description, and the accompanying drawing, are illustrative of the use of the invention in the shaping of semiconductive bodies.

Now making more detailed reference to the drawing, and initially to Figure 2 thereof, it will be seen that the practice of my invention results in production of a body or wafer 10 of semiconductive material having therein a depression or cavity 11 which is formed in one surface 12 of said body and extends nearly to the other surface 13 thereof, it being understood that the surfaces 12 and 13 are substantially parallel. The very thin web or lamina 14 which remains is the desired end product of the practice of my invention as described hereinafter.

To produce such a structure the apparatus of Figure 1 may conveniently be used. It will be understood that this figure is presented for the purpose of explanation and that the various components thereof are not necessarily to the same scale; in particular the semiconductive body or wafer 10 is, in the interest of clarity, greatly magnified as compared with the other elements appear-

ing in the figure. The wafer 10 is shown as having soldered, or otherwise connected thereto, an electrode 15 which serves also as means for supporting the wafer 10 in a position to permit impingement of said wafer by the jets 16 and 17 formed, respectively, by the pair of identical nozzles 18 and 19.

The wafer 10 may be composed of any suitable semiconductive material as for example N-type germanium, it being understood that other materials such as silicon may also be used. Such materials are now well known in the art and, since the invention is not concerned with such materials except insofar as they are modified by the operation of the methods of my invention, description of said materials per se is not required herein.

To form the jets 16 and 17, there is illustrated for exemplary purposes a pumping circuit preferably formed of an appropriate transparent material, for example glass, and which circuit includes the identical nozzles 18 and 19 referred to above, each of said nozzles having a substantially circular aperture of small diameter, for example of the order of a few mils. The nozzles 18 and 19 are, respectively, fed by conduits 20 and 21 which comprise branched extensions of conduit portions 22 and 23 between which is disposed a fluid pump 24, of any suitable type. As shown, the apparatus includes a reservoir 25 arranged to catch and permit recirculation of the electrolyte impinging upon the wafer 10. Preferably all portions of the apparatus which come in contact with the electrolyte are substantially non-reactive therewith, in order to avoid contamination of the solution.

Where it is desired to provide electrolytic etching of germanium, for example, the electrolyte 26 may comprise any of a large variety of readily ionizable alkali salts or acids. Although either aqueous or non-aqueous electrolytes may be used, it is preferred to employ an aqueous solution such as sodium nitrite, sodium chloride, potassium nitrate, sodium potassium sulphate, nitric acid or any one of many others.

Electric current is supplied between the jets 16 and 17 and the wafer 10 by means of potential source 27, a current-regulating resistor 28, switch 29, and leads 30 and 31. The electrical circuit is completed by attachment of lead 31 to an electrode 32 which is disposed within conduit 22, said electrode being non-reactive with the electrolyte and, suitably, comprising by way of example a stainless steel sheet.

While the present invention is concerned with the etching of body or wafer 10, it will be understood that in the preferred practice of a complete method for fabricating semiconductive circuit devices it may be desired to utilize the same electrolyte which is used for etching in the electroplating of metal upon the wafer 10, in which case the electrolyte will ordinarily be a salt of the metal deposited. This plating process, of course, necessitates reversal of the current flowing in the above described circuit and, if such plating is to be resorted to, switch means suitable for reversing the flow of current may be provided. For the purposes of this invention it is not necessary to illustrate such switch means in the accompanying drawing.

It will further be understood that the conductivity of the solution should be sufficiently high to provide for relatively rapid etching and, to utilize the apparatus of Figure 1 to produce a semiconductive device having a residual lamina 14 of any desired thickness, for example, 0.2 mil, the jets 16 and 17 are employed simultaneously to etch spaced regions of said block, the jet 16 etching the above described cavity 11 and, the jet 17 etching a second cavity 33, which is spaced from the cavity 11. As will now be clear, etching of the second cavity is carried to, or substantially to, the point of perforation, in which connection the aperture 34 will be noted.

As hereinbefore indicated the opposed major surfaces of the wafer 10 are parallel and, in essence, my invention involves recognition of the fact that if the two jets

have equal etching rates and are controlled in such manner that one thereof is effective to etch for a period of time which is less, by a predetermined interval, than the time required by the other jet to produce perforation of the wafer, then the residual lamina 14 will be of known and precisely controlled thickness, and this result will be repetitively achieved regardless of possible variations in thickness of the wafers being operated upon. Furthermore it is significant that the time required for the complete etching operation is equal to about one-half the time required by prior practice, this being the case since both jets are in operation simultaneously.

Considering this method in greater detail, it is to be understood that the jet 17 of electrolytic etchant 26 circulated by pump 24 is formed and directed against the wafer while passing an electric current between said wafer and said jet in a direction to produce etching, and that the other jet 16 is formed and directed against said wafer, while passing an electric current between said wafer and said second jet, the etching time of said second jet being less, by a known time increment, determined by the desired thickness of lamina, than the etching time of jet 17.

It will be understood by those familiar with the art to which the present invention pertains, that the rate of etching is to some extent a function of the illumination of the point of impingement of the jet upon the wafer. It has been found, for example, that without illumination the etching process is substantially slower. Desirably, equal illumination should be provided at the two jets, equivalent etching rates facilitating practice of the invention.

As stated above the etching rates of the two jets should be equal, although this should not be understood as implying that the rate of etching necessarily remains constant throughout each etching cycle. However regardless of whether or not the etching rate remains constant, at any particular jet, identity of the two etching nozzles and related equipment will insure that the average etching rates are equivalent.

Preferably, although not necessarily, the difference in effective etching time, as between the two jets, is achieved by delaying direction of the jet 16 against the wafer for a short period of time (for example for an interval of the order of a few seconds) following initiation of operation of jet 17. It will be appreciated, however, that the period of time during which the jet 16 is inactive to produce etching may occur at any time during the operating period of said jet 16.

To produce the desired delay of initiation of operation of the jet 16, and for exemplary purposes only, the apparatus is provided with a valve device shown schematically at 35 and, as illustrated, being of manually operable type. It will be recognized that it may be desirable to control this valve automatically, for example, by the use of a solenoid, but a manually operable valve is sufficient for the purposes of this description.

The electrolytic current during etching may be controlled by adjustment of the value of resistor 28, a typical current range being from 1 to 3 milliamperes, for wafers having resistivities of from 1 to 7 ohm-centimeters.

Having determined the difference in total etching time which is required to achieve the thickness of lamina desired, there are a variety of methods by which an operator may determine the appropriate time to discontinue the etching operation. One method is to observe the semiconductor from the side opposite jet 17, with the assistance of a suitable magnifying glass if desired, terminating the etching at the jet 16, as by means of valve 35, when perforation is visible. It will be understood that illumination may be provided in the vicinity of jet 17 to assist in recognizing the time at which perforation occurs.

It is also possible, on the other hand, to use valve-actuating mechanism (not shown) automatically operable in response to emergence of a portion of the jet

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stream 17 through the wafer material. Further it will be recognized that actual perforation, as well as penetration just short of complete perforation, is contemplated by the term "substantially perforated," and similar definitions used in the appended claims.

As respects termination of the etching process, it is to be borne in mind that, if desired, this result may be accomplished by opening the circuit at switch 29, although it is preferred to close the valve 35.

Referring now to Figure 3, there is shown apparatus adapted for use in practice of a modified method contemplated by the present invention. In accordance with this modification two pairs of opposed jets of electrolyte are utilized, the nozzles 18a and 18b serving to direct opposed jets 16a and 16b against opposite sides of the wafer 10a, whereas a similar pair of opposed jets 17a and 17b are formed and directed by the pair of nozzles 19a and 19b. Said pair of jets 17a and 17b correspond to the jet 17 of the apparatus shown in Figure 1, and serve, as will be understood, to produce or approach perforation of the wafer 10a by etching said wafer simultaneously from both sides thereof. This method is of course more rapid than the method practiced with the form of apparatus shown in Figure 1, and results in disposition of the residual lamina in the vicinity of the mid-plane of the wafer. The nozzles 18a, 18b, and 19a, 19b, all of which are identical, are fed by branched conduits 20a and 21a, the valve, pumping and electric circuits being the same as the corresponding components illustrated in the form of Figure 1. Methods for determining the proper time for cessation of etching at the jets 16a, 16b may be similar to those described previously herein.

From the foregoing description it will be understood that by the present invention methods are provided for forming regions of predetermined thickness in bodies or wafers of electrolytically etchable material, for example in semiconductive material, and that the methods of the invention result in production of a lamina of known and precisely controlled thickness. This advantageous result is entirely independent of the thickness of the original piece or wafer, and is rapidly and conveniently obtained.

Although it has been convenient to describe the invention with particular reference to two specific embodiments thereof, it will be understood that variations may be made in the apparatus and in the technique of the method without departing from the essential spirit of the invention. For example it will be apparent that the electrolytic jets may have any of various cross-sectional shapes, and that the various parameters such as electrical current, jet pressure, and electrolyte constitution may each or all be varied between or during the processing steps. However, it will be understood that the invention contemplates any changes and modifications which may come within the scope of the appended claims.

I claim:

1. A method for providing a region of accurately controlled thickness in a flat wafer of semiconductive material, which method comprises: forming a pair of jet etching means; applying one of said jet etching means to one side of said wafer to reduce the thickness of one portion of said wafer; simultaneously applying the other of said jet etching means to said one side of said wafer to reduce the thickness of another portion spaced from said first portion, the etching rates at both said jet etching means being substantially equal; and controlling both said jet etching means in such manner that said first-mentioned jet etching means is effective to etch said wafer only for a period of time which is less, by a predetermined interval, than the time required for said other jet etching means substantially to perforate said wafer.

2. A method for producing a region of predetermined thickness in a block of etchable material, which method comprises: forming a pair of jet etching means; simultaneously applying said pair of jet etching means to one side of said block to etch spaced regions of said block, the etching rates at said pair of jet etching means being

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substantially equal; and controlling said jet etching means in such manner that, during the time required for one of said jet etching means substantially to perforate said block, said other jet etching means has been effective to etch for a period of time which is less, by a predetermined interval, than the time required by said first jet etching means to produce substantial perforation of said block, whereby, independent of the thickness of said block, there is produced in the region etched by said second jet etching means a residual lamina of known and precisely controlled thickness.

3. A method for producing a region of predetermined thickness in a body of semiconductive material having parallel opposed surfaces, which method comprises: forming a plurality of pairs of jet means of electrolytic etchant; simultaneously applying said pairs of jet means of electrolytic etchant to said parallel opposed surfaces to etch spaced regions of said body, the etching rates at said pairs of jet means being substantially equal; and controlling said jet means in such manner that, during the time required for one of said jet means to reduce the thickness of said body to a predetermined extent, another of said jet means has been effective to etch for a period of time which is less, by a predetermined interval, than the time required by said first jet means to produce the afore-said reduction in thickness, whereby, independent of the thickness of said body, there is produced in the region etched by said other jet means a residual lamina of known and precisely controlled thickness.

4. In the method of forming structures of semiconductive material which structures are suitable for use in electrical circuit devices, the steps which comprise: forming first jet etching means and applying said jet means to effect etching of said material; forming second jet etching means parallel to said first jet etching means and, beginning at a predetermined time interval after the initiation of etching at said first jet means and during the etching process at said first jet means, applying said second jet means to effect etching of said material at a region spaced from the region of impingement of said first jet means upon said material, the etching rates at said first and second jet means being substantially equal; continuing the etching process at each jet means until said first jet means has reduced the thickness of said material to a predetermined extent; and then terminating the etching process at least at said second jet means.

5. A method for producing a region of predetermined thickness in a block of electrolytically etchable material, which method comprises: forming a first jet of electrolytic etchant and directing said jet to effect etching of a depression in said block; forming a second jet of electrolytic etchant parallel to said first jet and, for a predetermined time interval shorter than the total etching time at said first jet and during the etching process at said first jet, directing said second jet to effect etching of a depression in said block at a point spaced from the depression first-mentioned, the etching rates at said first and second jet means being substantially equal; continuing the etching process at each jet until said first jet has substantially perforated said block; and then terminating the etching process at least at said second jet.

6. In the method of forming structures of semiconductive material, which structures are suitable for use in electrical circuit devices, the steps which comprise: forming two pairs of jets of electrolytic etchant; directing the jets of one pair against opposite sides of said material while passing an electric current between said material and said jets in a direction to produce etching; and directing the jets of the other pair against opposite sides of said material at locations spaced from the points of impingement of the jets of said one pair, beginning at a predetermined time interval after initiating the directing of the jets of said one pair and while passing an electric current between said material and said other pair of jets in a direction to produce etching; continuing the etching process simultaneously at each pair until the jets of said one pair have reduced the thickness of said body to a prede-

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terminated extent; and then terminating the etching process at least at said other pair of jets.

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