

March 19, 1963

W. GERSBACH

3,081,586

DICING SEMICONDUCTOR CRYSTALS

Filed March 29, 1960

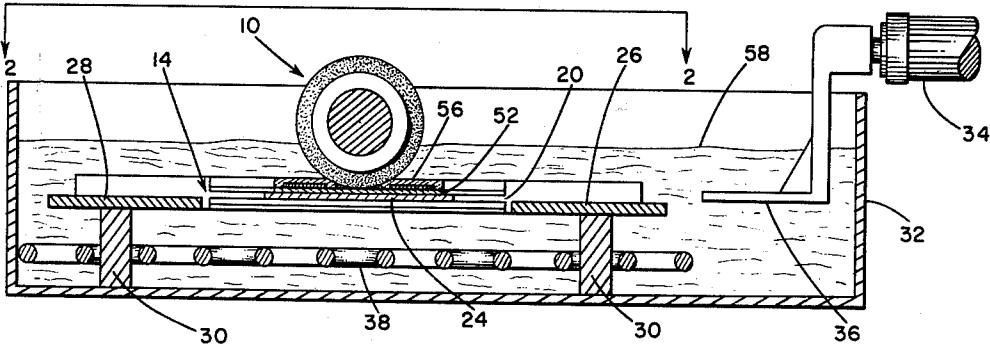


FIG. 1

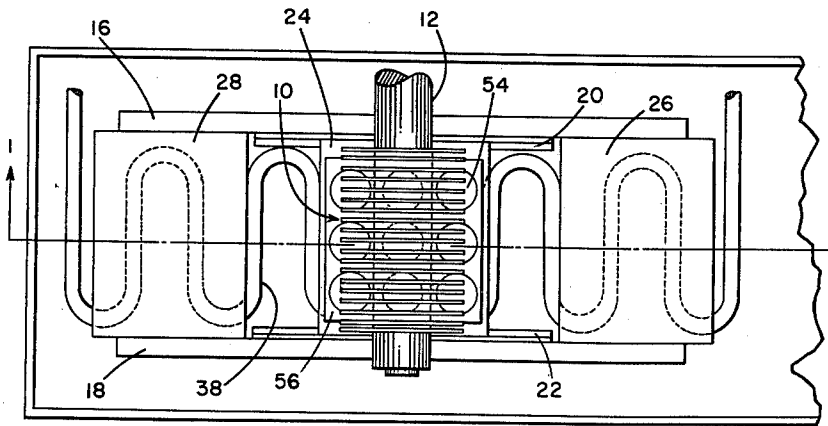


FIG. 2

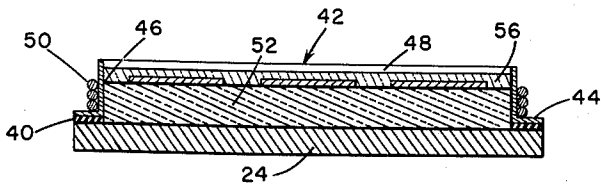


FIG. 3

INVENTOR.
WILHELM GERSBACH

BY

Francis H. Marsella
ATTORNEY

1

3,081,586

DICING SEMICONDUCTOR CRYSTALS

Wilhelm Gersbach, Freiburg, Breisgau, Germany, assignor to Clevite Corporation, Cleveland, Ohio, a corporation of Ohio

Filed Mar. 29, 1960, Ser. No. 18,328

Claims priority, application Germany Apr. 10, 1959

2 Claims. (Cl. 51—283)

This invention relates to methods for processing semiconductor materials.

In the commercial production of semiconductor devices, the semiconductor material, such as germanium or silicon, from which the wafers are formed is initially prepared in relatively large monocrystalline ingots by the Czochralski process, zone levelling, or similar techniques. The ingot usually is of bar-like configuration and the first step toward its subdivision ultimately to form the tiny dice or wafers is to cut the ingot transversely into plates which are then lapped to provide plane parallel faces. The plates are then diced into wafers which is customarily accomplished by passing the crystal plate through a gang saw to make series of parallel cuts across the plate and then rotating the plate 90° and repeating the process to make another series of cuts at right angles to the first.

While various specific types of crystal cutting saws may be employed, it will be assumed for facility in describing the invention, that it is to be applied to a particular type, namely, one in which the gang of cutting wheels are mounted for rotation at a fixed location and the crystal plates are mounted on a work holder which is movable with respect to and carries the work under the cutting blades.

Whatever the type of apparatus employed it is necessary that the crystal plates be immovably mounted on and fixed to a work holder in such a manner that they are not subjected to any substantial stress during the cutting process. The customary practice is to mount a plurality of crystal plates with sealing wax or other suitable wax or resin to a heated plate of glass which in turn is mounted on a steel plate which constitutes the work holder and, in the assumed example, is moved under the cutting wheels.

Inasmuch as it is necessary to cut through the embedding material as well as the crystal a relatively long cutting period is required; furthermore the embedding material fills the cutting wheels decreasing their efficiency. In addition to these disadvantages there are the problems of removing the wafers from the embedding material; cleaning the latter from the wafers; and reclaiming the costly semiconductor material from the cutting waste. The reclamation of semiconductor material from cutting waste contaminated with the embedding material usually requires the application of a tedious and expensive purification process. In some cases the cost of reclamation may be so high in relation to the cost of the material that reclamation is not even economically feasible.

The general object of the present invention is to provide novel methods for dicing semiconductive material into wafers which substantially avoids or at least mitigates one or more of the problems of the prior art as outlined above.

A more specific object of the invention is the provision of improved methods for cutting slices of semiconductor material into wafers at a considerably higher cutting speed than heretofore possible.

Another object is to provide methods for cutting plates of semiconductive material into wafers which facilitate reclamation of semiconductor material from the cutting waste and simplifies further processing of the semiconductor wafers in the fabrication of completed devices.

These and other objects are fulfilled by a method of

2

cutting plates of semiconductor material into wafers which, in accordance with the present invention, includes mounting the plates for cutting by freezing them to a work holder.

In accordance with another feature of the invention apparatus for cutting plates of semiconductor material into wafers includes cutting means; a work holder movable relative to said cutting means; and means for maintaining said work holder and work pieces mounted thereon under refrigeration while in operation.

In accordance with still another feature of the invention, a work holder for mounting semiconductor crystal plates for cutting operations comprises a flat, quadrangular metal plate opposite edges of which are adapted to be slidably received in parallel, opposed guide channels. A quadrangular sealing gasket member is provided which is applicable to a relatively narrow marginal area on one major surface of the plate extending around the entire perimeter thereof. A rim member is applicable to the same plate surface, and has a quadrangular flange portion substantially conforming in configuration to and adapted to be superimposed in surface contact with the sealing gasket member. The rim member also has a quadrangular wall portion extending substantially perpendicularly from the inner edge of its flange portion. When applied to the metal plate, the rim member forms with the plate surface, a shallow liquid-tight receptacle for containment of a quantity of water to be frozen onto the plate surface. A heating element circumscribing the wall portion of the rim member is selectively operable to facilitate removal of the rim member from the plate after the water is frozen.

Additional objects of the invention, its advantages, scope and the manner in which it may be practiced will be more readily apparent to persons conversant with the art from the following description and subjoined claims taken in conjunction with the annexed drawing in which like reference numerals designate like parts throughout the several views and,

FIGURE 1 is a side view of an exemplary form of apparatus as contemplated by the present invention, shown in section along line 1—1, FIGURE 2;

FIGURE 2 is a top plan view as indicated by and looking in the direction of arrows 2—2, FIGURE 1; and

FIGURE 3 is a sectional view through a work holder in accordance with the present invention adapted for use in the apparatus shown in FIGURES 1 and 2.

The basic concept which underlies all other and more specific aspects and details of the invention is the use of ice as the embedding medium by which plates of semiconductive material are mounted on the work holder for the performance of the cutting operation for subdividing the plate into individual wafers. While this concept will be described in greater detail as applied to and used with specific exemplary cutting apparatus, the basic steps of the method consist of coating the work holder on which the crystal plates are to be mounted with a layer of ice; freezing the plates to the layer of ice on the work holder and then performing the cutting operation.

Referring now to the drawing which illustrates one particular example of cutting apparatus embodying the present invention, and first particularly to FIGURES 1 and 2, reference numeral 10 designates collectively a gang of diamond cutting wheels mounted on a horizontally-disposed, rotatable arbor 12 driven from a suitable source of power (not shown). The individual cutting wheels of gang 10 are parallel and axially spaced along arbor 12 at intervals corresponding to the lateral dimension of the wafers to be cut from the crystal plates.

Fixedly mounted beneath the cutting wheels 10 is a bed or frame 14 which includes a pair of spaced parallel

side rails 16, 18, individually extending at right angles to, and collectively lying in a plane parallel to, the axis of rotation of arbor 12. Side rails 16, 18 are provided with means defining respective parallel opposed channels 20, 22 for slidably receiving and guiding a work holder 24 under cutting wheels 10. Work holder 24 consists of a flat plate of steel or other suitable material having opposite edges adapted to engage in the guide channels of the side rails so that the plate slides under the cutting wheels without any substantial clearance space or looseness such as would permit rocking or canting of the plate in any manner or direction. Preferably work holder plate 24 is of square configuration so that it will fit into guide channels 20, 22 without any particular orientation and so that, after the first pass through cutters 10, the work holder plate can be rotated 90° about an axis perpendicular to its major faces and passed through the cutters again to complete the dicing of the crystal slices.

Bed 14 of the cutting apparatus includes also respective flat table surfaces 26 and 28 at each end of the guide channels 20, 22 to facilitate entry and removal of work holder plate 24 into and from the guide channels. Bed 14 is suitably supported, as by means of a number of vertical pillars 30, a distance above the bottom of a relatively shallow tank 32, which is nevertheless of sufficient depth and lateral dimensions to contain the entire bed and at least a substantial lower portion of cutting wheels 10. At one end of bed 14 is provided a pneumatic or hydraulic actuator 34 for advancing and retracting a ram member 36 which feeds work holder plate 24 through its guide channels 20, 22 and under the cutting wheels 10. Aside from the safety factor involved, the power driven ram enables the use of a very tight fit between work holder 24 and its guide channels thus avoiding any possibility of unwanted movement or displacement of the work holder from its rectilinear path beneath the cutting wheels.

Beneath bed 14 of the cutting apparatus is a cooling coil 38 consisting of a tubular conduit of the usual serpentine configuration. The ends of cooling coil 38 are connected to a source, not shown, for supplying and circulating therethrough a suitable refrigerant.

When in service tank 32 may be filled to a depth at least sufficient to submerge work holder guide channels 20, 22 with a suitable cooling medium such as a water and salt solution as hereinafter described in additional detail.

The manner in which work holder plate 24 is prepared and the crystal slices mounted thereon will now be described with reference to FIGURE 3. Plate 24 is provided with a sealing gasket member 40 of rubber or similar material. Gasket member 40 conforms in shape and outer dimensions to plate 24 and extends around its entire perimeter covering a narrow marginal area of the upper surface along all edges of the plate. The width of this marginal area is at least slightly greater than the depth of the guide channels 20, 22 in which edges of plate 24 are to be received. Removably superimposed on seal member 40 is a rim member 42 of copper, aluminum or other suitable metal. Rim 42 has an L-shaped cross-section, the horizontal leg of the L having a length equivalent to the width of sealing member 40 and forming an outwardly extending flange portion 44 which overlies the sealing member. The vertical leg of the L forms a retaining wall 46 extending substantially perpendicular to flange 44. When installed on plate 24 as shown in FIGURE 3, rim member 42 forms with the upper face of the plate, a shallow liquid-tight tank 44. Circumscribing wall portion 46 of rim member 42 are coils 50 of a selectively energizable heat element.

In preparing work holder 24, the recess 48 defined within rim member 42 is filled to the desired depth with water which is then frozen in any suitable manner. In order to forestall melting of the ice the entire assembly may be subjected to temperatures well below the freezing

point of the water so that the ice is super cooled and the assembly brought to thermal equilibrium. After freezing, heating coils 50 are energized causing heating of rim member 42 and localized melting of the contiguous ice. This facilitates prompt and easy removal of the rim and seal member 40 without causing any general melting or elevating of the temperature of the unit as a whole. In this manner work holder plate 24 is provided with a uniform layer 52 of ice, which in practice may be in the order of two or three millimeters thick, while the edges of the plate are maintained ice-free for engagement in guide channels 20, 22.

A plurality of crystal plates 54 are mounted on the work holder in one of two ways. They may be brushed, sprayed, immersed or otherwise coated with water and simply placed on the surface of the ice layer; even without further refrigeration the water coating of the crystal slices freezes almost immediately so that the slices are effectively frozen to the ice layer. Alternatively, or additionally, a second layer of ice as shown at 56, FIGURE 1, may be formed on top of the initial layer (52) after crystal slices 54 are in position. If desired the second layer of ice can be of sufficient thickness as to completely cover the slices to a substantial depth as shown in FIGURE 1.

It will be appreciated that several factors will affect the selection of the precise manner in which the crystal plates are frozen to the work holder plate. Thus, for example, if the required cutting time is to be relatively long and melting of the ice layer is a problem it may be preferred to provide two relatively thick layers of ice completely embedding the crystal slices to a substantial depth. On the other hand if the cutting time is to be relatively brief it may be desirable to mount the elements by simply freezing them to the surface of the initial layer of ice in accordance with the first-described method.

With work holder plate 24 so prepared and crystal slices 54 so mounted, the work holder is inserted into the guide channels 20, 22 and ram 36 actuated to feed the work holder under the cutting wheels (from right to left as viewed in FIGURES 1 and 2) at a predetermined rate. On completion of the first pass under the cutters the work holder is rotated 90°, reinserted into the guide channels and once again fed under the cutting wheels to complete the dicing of the crystal plates.

If, due to the location of the apparatus in a high temperature environment, near a source of strong radiant heat, or for any other reason, there is a problem of the ice melting, the cutting procedure can be carried on under refrigeration. This is accomplished by filling tank 32 with a suitable cooling medium 56 such as water to which salt has been added to reduce the freezing point, to a depth that at least guide channels 20, 22 are submerged.

By use of suitable cooling coils 38 the temperature of cooling medium 58, where a salt and water solution is used, may be reduced to -15° C., with the result that cutting may be prolonged for many hours without danger of melting the ice constituting the embedding medium for crystal slices 54.

Particularly where no cooling medium 58 is employed during the cutting process, melting of the embedding ice may be forestalled by interposing thermal insulation between work holder plate 24 guide channels 20, 22 and the remainder of the saw table and frame.

Inasmuch as the cutting effort expended on the embedding ice layers is negligible and the ice does not foul the cutting wheels but acts as a coolant, a much higher cutting speed is possible shortening cutting time by as much as 90 percent. The work in some cases may be advanced at the rate of approximately 2 mm. per second.

It will be appreciated therefore that melting of the embedding ice usually would not be a problem.

After completion of the cutting process the individual dice are removed from the work holder by simply allowing the embedding ice to melt. There is no special treat-

5

ment necessary for removal of the embedding means and the dice are immediately ready for the next manufacturing operation. Moreover the semiconductor dust produced in the cutting is contaminated only by the presence of water, possibly salt (where cooling is provided during cutting) and particles worn from the cutting wheel with the result that the recovery problem is greatly simplified. The water and dissolved salt of course may be eliminated by simple filtration. It will be appreciated therefore that the stated objects of the invention are fulfilled by the method and apparatus hereinabove described.

What is claimed and desired to be secured by United States Letters Patent is:

1. A method of cutting a plate of semiconductor material into wafers comprising: freezing a layer of ice onto a work holder; disposing at least one plate of a semiconductor material on said layer of ice; forming an additional layer of ice, superimposed on said first mentioned layer and at least partially embedding the plate disposed thereon; and cutting through said plate and additional layer of ice into said first-mentioned ice layer.

2. A method of cutting a plate of semiconductor ma-

6

terial into wafers comprising: freezing a layer of ice onto a work holder; applying water to at least one major face of the plate to be cut; placing said surface of the plate in surface contact with said layer of ice so that the plate freezes to said layer of ice; thereafter freezing an additional layer of ice superimposed on said first mentioned layer and at least partially embedding the plate disposed thereon; and cutting through said plate and additional layer of ice into said first-mentioned ice layer.

References Cited in the file of this patent

UNITED STATES PATENTS

995,537	Hertner et al. -----	June 20, 1911
1,969,238	Robinson -----	Aug. 7, 1934
2,167,215	Leary -----	July 25, 1939
2,511,962	Barnes -----	June 20, 1950
2,586,532	Granfield -----	Feb. 19, 1952
2,641,879	Dalrymple -----	June 16, 1953
2,905,064	Nielsen -----	Sept. 22, 1959
2,937,437	Cole et al. -----	May 24, 1960