

May 1, 1962

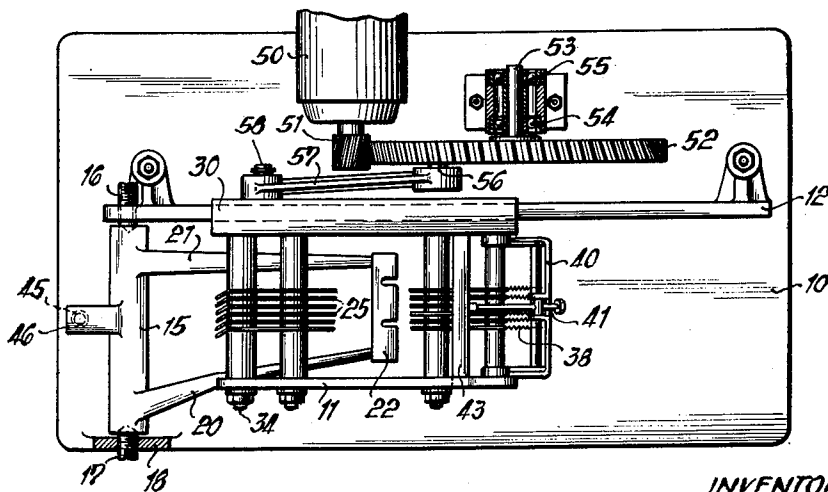
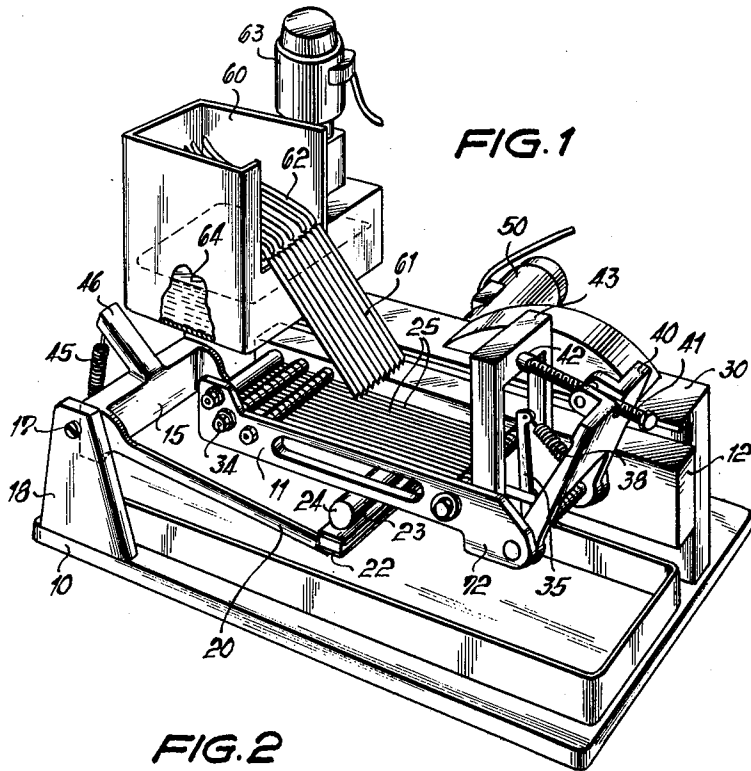
G. RAABE

3,032,026

DEVICE FOR SLICING SEMICONDUCTOR CRYSTALS AND THE LIKE

Filed June 28, 1960

2 Sheets-Sheet 1



INVENTOR

GOTTHOLD RAABE

BY

W. H. Rau

ATTORNEY

May 1, 1962

G. RAABE

3,032,026

DEVICE FOR SLICING SEMICONDUCTOR CRYSTALS AND THE LIKE

Filed June 28, 1960

2 Sheets-Sheet 2

FIG. 3

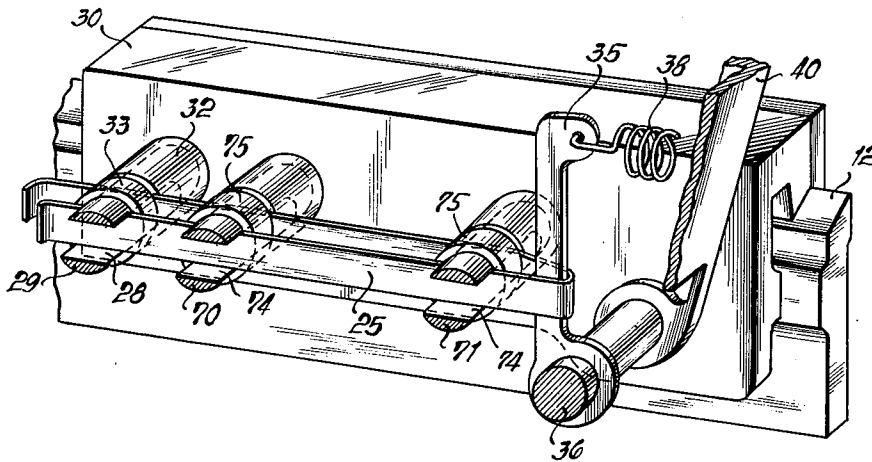


FIG. 4

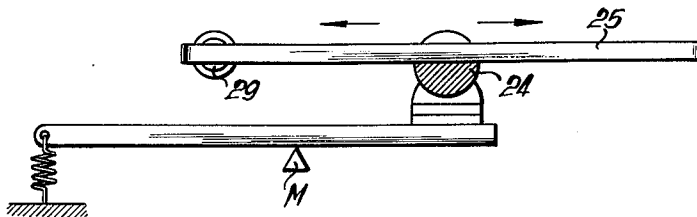
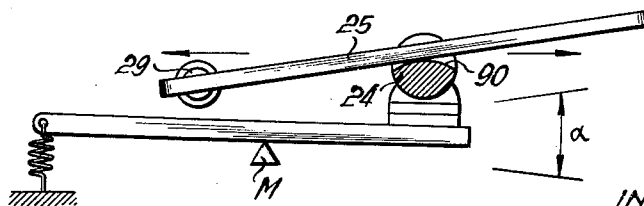


FIG. 5



INVENTOR

GOTTHOLD RAABE

BY

W. H. 7. 1962

ATTORNEY

1

3,032,026

DEVICE FOR SLICING SEMICONDUCTOR CRYSTALS AND THE LIKE

Gotthold Raabe, Stuttgart, Germany, assignor to Robert Bosch G.m.b.H., Stuttgart, Germany
Filed June 28, 1960, Ser. No. 39,325
Claims priority, application Germany July 18, 1959
17 Claims. (Cl. 125-21)

The present invention relates to means for cutting bodies of semiconductor crystal and the like material into thin slices of less than about 0.6 mm. thickness, more particularly to the cutting of single-crystal rods which have been drawn by means of a crystal pulling method from a melt consisting of germanium, silicon or the like single-crystal semiconductor material and suitable for use in the fabrication of diodes, transistors and other solid state semiconductor devices.

It has already become known in semiconductor device fabrication to utilize a plurality of parallel rotating cutting discs each being constructed in a manner of a circular saw and consisting of phosphor bronze or the like material, said discs having their cutting edges coated with a layer of sintered diamond dust. By the use of cutting devices of this type it has been possible to saw or slice semiconductor crystal rods having a diameter of not more than about 10 mm. by reason of the fact that the cutting discs must be fitted with relatively heavy central guide discs or separating plates, to prevent bending or distortion under the effect of the relatively high cutting pressures required. For the same and similar reasons, cutting discs of this type require a certain minimum thickness, whereby to result in a substantial wastage of precious semiconductor material due to the fact that the cutting width is at least equal to or in general greater by about 0.05 mm. than the thickness of the discs.

An important object of the present invention is, therefore, the provision of an improved apparatus or device for cutting semiconductor and the like bodies into thin slices, practically having a thickness of less than 0.6 mm., by which the above-mentioned and related drawbacks and defects inherent in the prior art cutting methods are substantially avoided.

Another object of the invention is the provision of a single-crystal cutting or slicing device by which loss or wastage of costly semiconductor material is reduced to a minimum.

Another object of the invention is the provision of a crystal cutting device enabling the cutting of a single-crystal rod into a large number of thin and uniform slices of constant thickness in a single cutting operation.

Yet another object of the invention is the provision of a single-crystal cutting or slicing device of the type mentioned, which is both simple in construction, efficient and easy to operate, as well as reliable in the results obtained.

Another object of the invention is the provision of a crystal cutting device of the type mentioned which will ensure the production of relatively thin semiconductor discs or slices having a constant thickness and improved uniformity compared with conventional crystal cutting devices and methods known in the art.

The invention, both as to the above and ancillary objects, as well as novel aspects thereof, will be better understood from the following detailed description of a preferred practical embodiment, taken in conjunction with the accompanying drawings forming part of this specification and wherein:

FIG. 1 is a perspective view of a crystal cutting device for producing multiple slices from a single crystal rod, and constructed in accordance with the principles of the invention;

2

FIG. 2 is a plan view of FIG. 1, being shown with certain parts removed for better illustration;

FIG. 3 is an enlarged perspective partial view of FIG. 1, more clearly showing the construction and mounting of the cutting bands forming a basic element of the invention;

FIG. 4 is a further partial and schematic view more clearly illustrating the cutting or slicing action in accordance with the invention; and

FIG. 5 is a schematic view similar to and illustrating a modification of FIG. 4.

Like reference characters denote like parts in the different views of the drawings.

With the foregoing objects in view, the invention, according to a preferred embodiment for carrying the same into effect, involves generally the provision of a plurality of thin metal cutting bands or straps of steel or the like material and having a thickness of less than about 0.3 mm., said bands being arranged parallel to each other in stretched condition and separated by spacing distances equal to the thickness of the slabs or slices into which is to be cut a semiconductor crystal, such as a rod or single-crystal germanium or an equivalent material. The bands being mounted upon a suitable sliding carriage engage the crystal rod in edgewise fashion and with a relatively slight resilient pressure, such as by supporting the crystal upon a spring-loaded carrier, said carriage and carrier being mounted upon a common base or support. As a consequence, upon reciprocation of the carriage by a suitable drive or operating means, the crystal body will be cut into a multiplicity of thin wafers or slices by said bands maintained under adequate longitudinal operating tension.

There is further provided a suitable abrasive feed or supply means, such as in the form of a bucket elevator and drip feed device, to continuously apply liquid abrasive solution to said bands during the cutting operation. The cutting bands may be maintained at a desired constant distance from each other by the provision of suitable guide or aligning means or devices, to ensure the attainment of perfectly parallel and uniform slices or wafers of semiconductor material of a desired thickness and suitable for further cutting into small units or chips required in the fabrication of semiconductor devices, such as diodes, transistors and the like.

Referring more particularly to FIGS. 1 to 4 of the drawings, the crystal cutting device shown comprises a base or support 10, a frame-like sliding carriage 11 supporting a number of cutting bands and being mounted upon said support for reciprocation in a horizontal direction, a guide plate 12 for said carriage normal and secured to said base, and a spring-loaded rocker having a pivoted cross arm 15 and serving to support the crystal rod or body 24 to be cut. The rocker arm 15 is pivotally supported at one end of the guide plate 12 by means of a first centering screw 16, FIG. 2, on the one hand, and upon the base 10 by means of a further centering screw 17 mounted in the top of a supporting bracket 18 upon said base, on the other hand. Extending from both ends of the rocker arm 15 are a pair of side arms or links 20 and 21 which have their free ends opposite to the arm 15 joined by a supporting plate 22. The latter serves to support or hold the crystal rod 24 being securely affixed thereto through the aid of a further removable plate or holder 23 in any suitable manner, such as by means of a putty or the like substance firmly securing the crystal to the plate or holder 23. The latter may be removably mounted upon the support plate 22 in any suitable manner, such as by a slip-fit, bayonet or the like joint or connection.

The crystal rod 24 which may have a diameter of from 20 to 30 mm. may consist, for instance, of highly puri-

fied germanium to which has been added a slight amount of an impurity material, such as antimony, to result in a single-crystal body of desired conductivity type suitable for use in connection with semiconductor device fabrication.

In an arrangement afore-described, the cutting band or bands may have a reduced thickness, that is, practically less than about 3 mm. and preferably about 1 mm., whereby to enable the cutting of relatively thin slices with a minimum loss of or wastage of semiconductor material.

Let it be assumed, for the sake of this description, that the crystal rod 24 is to be cut into one hundred uniform slices or wafers of about 0.4 mm. thickness in a single cutting operation. For this purpose, there are provided fifty cutting bands consisting of steel or the like material, one of which is shown more clearly at 25 in FIG. 3. Said bands are mounted upon the sliding carriage 11 in parallel relation to each other with each band being reversely bent upon itself to form a loop, to provide a total of one hundred parallel cutting sections, in the example mentioned. The ends of each of said bands 25 are passed through a longitudinal slot 28 of a bolt 29 arranged with one end being secured to the rear support or side plate 30 of the carrier slidably mounted upon the guide plate 12. The rearmost cutting band 25 adjoining the supporting plate 30 has one of its end portions arranged to engage the front face of a separating sleeve or washer 32 mounted upon the bolt 29, while the other end portion of the band 25 is maintained at a fixed distance from said first end portion by means of an accurately cut separating disc or washer 33 also mounted upon the bolt 29. The next following band or band sections (not shown in FIG. 3) may be maintained at the desired distance from the last-mentioned end portion of the band 25 and from each other, respectively, and so on for the remaining bands, by the provision of additional separating or spacing washers interposed between the adjacent bands or sections and mounted upon the bolt 29, in a manner readily understood and shown in FIG. 2.

All the ends of the cutting bands are firmly locked to or secured against slippage relative to the carriage 11 by means of a securing nut 34 engaging the threaded end of the bolt 29 being passed through and projecting from the front side plate 72 of the carriage 11. As a consequence, all the cutting band sections may be firmly secured in stretched condition or subjected to a considerable longitudinal tension, in accordance with the underlying concept of the invention, substantially without involving the danger of slippage of the bands during the crystal cutting or slicing operation.

The tensioning force necessary for the efficient cutting of the crystal material is produced, according to the example shown, by the aid of a stretching lever 35 being pivotally mounted upon the carriage 11, one such lever being provided for each cutting band 25. Each of the levers has a portion being engaged by the bent portions of the respective cutting bands and all the levers are advantageously mounted upon a common pivot shaft 36. Further connected between each of the free ends of said levers, on the one hand, and a common stretching plate or tensioning member 40 are a plurality of tension springs 38, member 40 being, in turn, secured to the shaft 36. Stretching of the bands 25 may be effected by means of a tensioning screw 41 supported in the member 40 by an articulate joint and arranged with its end engaging a cup 42 upon a frame or bracket 43 which is connected to the side plate 72 of the carriage 11. As a consequence, all the cutting bands may be subjected to the required longitudinal tension for effectively cutting the crystal 24 by a proper adjustment or setting of the screw 41.

In order to maintain the required resilient cutting pressure between the edges of the bands 25 and the crystal 24, there is provided, according to the example shown,

a further tension spring 45 having one end connected to an extension 46 of the rocker cross arm 15 and having its opposite end connected to a further adjusting screw (not shown) mounted in the base plate 19.

The reciprocating carriage 11 supporting the cutting bands 25 may be driven by an electric motor 50 mounted upon the base 10 through a driving pinion 51 being in meshing engagement with a toothed wheel or gear 52. The latter has a shaft 53 supported by a pair of ball bearings 54 and 55 mounted upon the base 10. Gear 52 has an eccentric pin 56 engaging one end of a connecting rod 57 which has its opposite end pivoted upon a further pin 58 projecting from the rear or sliding plate 30 of the carriage 11. As a consequence, operation of motor 50 causes the carriage to move to and fro in opposite directions and through a predetermined operating stroke or path, whereby to cut or slice the crystal rod 24 by the bands 25, in a manner readily understood.

The supply of the abrasive material to the cutting bands or sections, such as for instance in the form of a solution of boron carbide in petroleum, may be effected in any suitable manner as will suggest itself to those skilled in the art. In the embodiment shown, there is provided for this purpose a bucket elevator 60 comprising a reservoir containing the abrasive solution, indicated at 64, and a plurality of juxtaposed bucket troughs 62 each terminating at one of the ends of a corresponding number of drip or feeding troughs 61 which serve to apply abrasive material to the upper or free edges of the bands or cutting sections 25. The bucket troughs may be mounted upon a common swivelling axis (not shown) and operated by a further electric motor 63, in such a manner as to periodically dip into the solution 63 and to intermittently feed abrasive material to the bands, in the manner readily understood from the drawing.

In the cutting of the crystal rod 24 into thin slices or wafers suitable for use in semiconductor device fabrication, an important requirement consists therein that the wafers or slices are of a highly uniform thickness, both as regards any single slice produced, as well as for all the slices obtained by a single multiple cutting operation. In order to achieve this object by a proper alignment of the bands 25, there are further provided, according to the invention, suitable aligning means, consisting, in the example shown, of a pair of further guide bolts 70 and 71 mounted upon the support or guide plate 30 in a manner similar to the securing or mounting bolt 29, said guide bolts being located between the mounting bolt 29 and the tensioning levers 35. The bolts 70 and 71 project with their threaded front ends through bores in the front side plate 72 and are secured to the latter by means of locking nuts, in the manner shown and similar to the mounting of the securing bolt 29. Each of the guide bolts 70 and 71 is furthermore provided with a longitudinal slot 74 through which are passed the bands 25, the latter being maintained at their proper spacing distance by the provision of a plurality of further spacing or guiding washers 75 mounted upon the bolts 70 and 71, to ensure the maintenance of an exact parallelism of the bands during the crystal cutting operation. In other words, while the securing nut 34 is sufficiently tightened to firmly lock the bands 25 together and to the carriage 11, the nuts engaging the ends of the bolts 70 and 71 are adjusted to leave an adequate clearance for the bands passing between adjacent spacing washers 75 during the to and fro movement of the carriage 11.

The distance between the bolts 70 and 71 is advantageously so chosen in relation to the operating stroke of the carriage 11, depending upon the radial distance of the eccentric pin 56 from the shaft 53, that the bolt 70 closely approaches the crystal rod 24 near the end of movement of the carriage in one direction and that the bolt 71 closely approaches the crystal near the end of movement of said carriage in the opposite direction. This

results in a self-aligning of the bands 25 by the grooves cut in the crystal during the operation of the device.

In the embodiment of the invention afore-described, the carriage 11 supporting the cutting bands 25 may be guided, as shown more clearly by the schematic diagram of FIG. 4, in such a manner that the direction of movement of the carriage, as indicated by the arrows, coincides with the cutting edges of the bands 25 engaging the crystal rod 24. It has been found, however, that the cutting efficiency may be increased and other improved results obtained by an arrangement wherein the cutting edges of the bands include a slight angle, say about 5° to 10°, with the direction of movement of the carriage. In this case, the movement of the bands 25 being mounted in an inclined position relative to the carriage displacement results in an oscillation of the crystal rod 24 about a pivot M and within an angular range α , as shown in FIG. 5. This, in turn, produces an arc-shaped cutting surface of the crystal as shown at 90, that is, the bands engage only a fraction of said surface at a given instant. As a result of the oscillating movement of the crystal rod relative to the cutting bands, the cutting grooves are freed during brief intervals during an oscillating cycle, in such a manner as to enable the abrasive liquid to penetrate into the spaces between the cutting surfaces and the edges of the bands.

Since, furthermore, the lateral faces of the bands produce a polishing action upon the surfaces of the discs or slices being cut by the action of the abrasive material adhering thereto, the oscillating movement of the crystal rod has the further effect of preventing the formation of groovings or scorings upon the surface of the wafers or slices being cut, due to the fact that the crystal performs an oscillation in a direction transverse to the bands during a full operating cycle of the device.

In the foregoing, the invention has been described with reference to a specific operative device. It will be evident, however, that variations and modifications, as well as the substitution of equivalent elements for those shown and described herein for illustration, may be made without departing from the broader scope and spirit of the invention as set forth in the appended claims. The specification and drawings are accordingly to be regarded in an illustrative rather than a restrictive sense.

I claim:

1. A device for cutting a semiconductor crystal body comprising at least one relatively thin metal cutting band being reversely bent upon itself, to provide a pair of parallel cutting sections spaced by a distance equal to the thickness of a slice to be cut from said body, a carrier with means to secure thereto the open ends of said sections, a spring-loaded stretching lever pivoted upon said carrier and having a portion engaged by the bent portion of said band, to maintain said sections under longitudinal tension, spring-loaded supporting means for said body, said carrier and supporting means being arranged relative to one another such as to cause said band to engage said body in edgewise fashion and under slight resilient pressure, drive means to reciprocate said carrier while maintaining said band in cutting engagement with said body, and drip feed means to continuously apply a liquid abrasive to said band.

2. In a crystal cutting device as claimed in claim 1, the direction of reciprocation of said carrier coinciding with the cutting edge of said band.

3. In a crystal cutting device as claimed in claim 1, the direction of reciprocation of said carrier including a slight angle with the cutting edge of said band.

4. In a crystal cutting device as claimed in claim 1, guide means to maintain said cutting sections at a constant distance during the operation of said carrier.

5. In a crystal cutting device as claimed in claim 1, a reservoir containing an abrasive solution, and bucket elevator means and a pair of drip troughs cooperating therewith, said troughs terminating at points adjacent to

the free edges of said sections, and operating means for said elevator means to continuously feed abrasive solution to said sections during the operating of said device.

6. A device for cutting a semiconductor crystal body into relatively thin slices comprising a carrier, a plurality of relatively thin metal cutting bands mounted upon said carrier in parallel relation to and spaced from each other by distances equal to the thickness of the slices into which said body is to be cut, stretching means mounted upon said carrier to maintain said bands under longitudinal tension, spring-loaded supporting means for said body mounted upon said carrier, to cause said bands to engage said body edgewise with slight resilient pressure, drive means to reciprocate said carrier while maintaining said bands in cutting engagement with said body, a reservoir containing an abrasive solution, and bucket elevator and drip feed means to continuously apply abrasive material from said reservoir to said bands.

7. A device for cutting a semiconductor crystal body into relatively thin slices comprising a support, a carriage mounted upon said support for reciprocation in a predetermined direction, a plurality of relatively thin metal cutting bands mounted upon said carrier in parallel and spaced relation from each other by distances equal to the thickness of the slices into which said body is to be cut, stretching means mounted upon said carriage to maintain said bands under longitudinal tension, a spring-loaded carrier supporting said body and pivotally mounted upon said support, to cause said bands to engage said body edgewise with slight resilient pressure, drive means to operate said carriage while maintaining said bands in cutting engagement with said body, a reservoir containing an abrasive solution, and drip feed means to continuously supply abrasive material from said reservoir to said bands.

8. In a crystal cutting device as claimed in claim 7, the direction of reciprocation of said first carriage coinciding with the cutting edges of said bands.

9. In a crystal cutting device as claimed in claim 7, the direction of reciprocation of said first carriage including a slight angle with the cutting edges of said bands.

10. A device for cutting a semiconductor crystal body into relatively thin slices comprising a support, a carriage mounted upon said support for reciprocation in a predetermined direction, a plurality of relatively thin metal cutting bands each being reversely bent upon itself, to provide a plurality of parallel cutting sections with the sections of all said bands being spaced from each other by distances equal to the thickness of the slices into which said body is to be cut, means securely connecting the free ends of said bands to said carriage, a plurality of levers having a common pivot upon said carriage and each comprising a portion engaged by one of the bent portions of said bands, common spring loaded stretching means connected to all said levers, to maintain said cutting sections under longitudinal tension, a spring-loaded carrier supporting said body and pivotally mounted upon said support, to cause said cutting sections to engage said body edgewise and with slight resilient pressure, drive means to operate said carriage while maintaining said sections in cutting engagement with said body, a reservoir containing an abrasive solution, and drip feed means to continuously supply abrasive solution from said reservoir to said cutting sections.

11. In a crystal cutting device as claimed in claim 10, the direction of reciprocation of said carriage including a slight angle with the cutting edges of said bands.

12. In a crystal cutting device as claimed in claim 10, guide means to maintain said cutting sections at a constant distance during the operation of said carriage.

13. In a crystal cutting device as claimed in claim 10, said drip feed means comprising a bucket elevator having a plurality of bucket troughs, a plurality of drip troughs each having one end terminating at one of said cutting sections and having its opposite end arranged for

7

cooperation with one of said bucket troughs, and operating means to periodically immerse said bucket troughs in said reservoir, to feed abrasive solution to said cutting sections simultaneously with the operation of said first carriers.

14. A device for cutting a relatively thin slice from a semiconductor crystal or the like comprising a support having affixed thereto said crystal, a relatively thin metal cutting band being reversely bent upon itself, to provide a pair of parallel cutting sections spaced by a distance equal to the thickness of the slice to be cut, a carrier including means to support the ends of said band, stretching means upon said carrier engaging the bent portion of said band, to impart a longitudinal stress to said sections, said support and said carrier being arranged relatively to one another to cause one of the edges of said band to be in edgewise cutting engagement with said crystal, and means including resilient means to effect a relative reciprocating movement between said support and said carrier while maintaining said crystal in resilient cutting engagement with said sections by said resilient means.

15. A cutting device as claimed in claim 14, said cut-

8

ting band being arranged vertically with the cutting edges being constituted by the lower edges of said sections, and means to feed liquid abrasive to the upper edges of said sections.

16. A cutting device as claimed in claim 14, including spacing means to maintain accurate parallelism between said cutting sections.

17. A cutting device as claimed in claim 14, including additional identical reversely bent and stretched cutting bands mounted upon said carrier in a manner similar and parallel to each other and to said first band, to simultaneously cut a plurality of slices from said crystal.

References Cited in the file of this patent

UNITED STATES PATENTS

2,774,194	Thatcher	Dec. 18, 1956
2,939,777	Gregor	June 7, 1960
2,967,381	Brown	Jan. 10, 1961

OTHER REFERENCES

"Crystal Cutting" from Machinery, December 9, 1955, volume 87, 99, 1351-53. (Copy in Scientific Library.)