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METHOD FOR POLISHING GALLIUM ARSENIDE

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FIG. 1

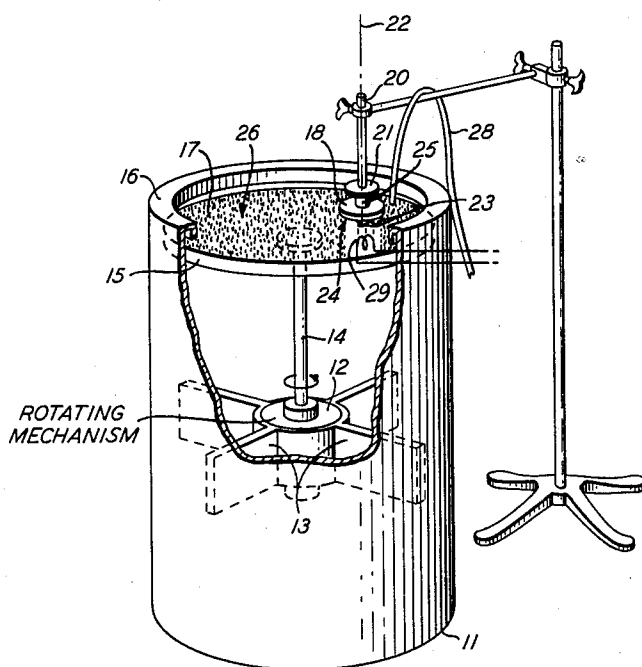
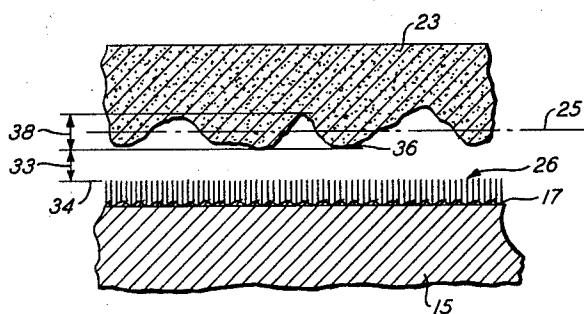


FIG. 2



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This invention relates to a method for polishing gallium arsenide.

More specifically, this invention is directed to a technique for polishing crystals of gallium arsenide with a solution comprising a mixture of bromine and methanol, such solution being particularly well suited as a substitute for or supplement to the usual mechanical polishing procedure for these crystals.

In the fabrication of semiconductor devices it is essential to prepare the (semiconductor) starting material in slices which have flat, smooth, damage-free surfaces. This is particularly critical for diffused devices since imperfect surfaces disturb the even passage of the diffusant into the semiconductor slices. This, in turn, deleteriously affects the electrical characteristics of the device.

Several techniques such as electropolishing, chemical etching and mechanical lapping of semiconductor slices are well known and presently in use in the semiconductor art. By lapping and polishing techniques a surface can be prepared which is about 0.0001 inch per inch flat. The average roughness of this surface is typically 0.3 microinch. The resultant surfaces are smooth and flat enough for satisfactory device fabrication but the mechanical damage which is still present on the surface deleteriously affects the electrical characteristics of devices. Typically, it is necessary to remove such damaged surfaces prior to further processing by chemically etching the surface. Unfortunately, chemical etching with conventional etchants, such as aqua regia or mixtures of nitric and hydrofluoric acids, increases the average roughness of a typical surface to about 3.0 microinches or greater. Thus, the gain in removing mechanical damage by the chemical etching technique is obtained at the expense of increasing the average roughness. In order to obtain a surface which is sufficiently damage-free and still maintain a low average roughness and suitable flatness, these processes, namely, mechanical polishing and chemical etching, may be alternated several times, however, resulting in increased production costs.

In accordance with this invention a technique is described for polishing the surfaces of gallium arsenide crystals with a bromine-containing methanol solution, thereby producing surfaces which are smooth to better than 0.5 microinch, flat to better than 0.0001 inch per inch and free of mechanical damage. As described herein, etching is conducted in conjunction with a mechanical stirring mechanism resulting in agitation proximate the surface to be etched.

In an illustrative embodiment the inventive technique involves mounting the gallium arsenide on a rotatable disk such that the surface of interest is exposed. A second rotatable disk optionally covered by a low-pile cloth is positioned proximate the surface of interest such that the pile of the cloth is almost in contact with such surface. The second disk is rotated about an axis of rotation parallel to but not coincident with that about which the first disk is rotated. The bromine-containing methanol solution is provided to a level above the pile of the cloth for contacting the surface to be polished.

The invention will be more fully understood from the following detailed description taken in conjunction with the following drawing wherein:

FIG. 1 is a perspective view, partially in cross-section,

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of an apparatus suitable for the present inventive purposes; and

FIG. 2 is an enlarged view, partially in cross-section, of a portion of the surface of a gallium arsenide crystal and the stirring mechanism of the apparatus employed.

Referring more particularly to FIG. 1, there is shown a cylindrical container 11 having a centrally located rotating mechanism 12, typically an electric motor, secured to the container by supports 13. A metallic shaft 14 transmits angular motion from the rotating mechanism to a glass stirring disk 15 positioned immediately below the annular lip 16 of the cylindrical container 11. The glass stirring disk is covered by a low-pile cloth 17. The disk-shaped block 18 is secured to a holder 20 by a suitable connection which allows block 18 to rotate about an axis of rotation 22 which is parallel to but eccentrically disposed to shaft 14. A plurality of gallium arsenide slices 23 are affixed to the surface 24 of block 18 such that the surfaces 25 of slices 23 are in contact with the pile 26 of the low-pile cloth 17 which may also be a material such as "Dextilose" paper which is obtained commercially from the Dexter Paper Company. The term "low-pile" refers to any cloth or high wet strength paper having a pile of height of approximately 0.030 inch or less. Tube 28 provides a continuous supply of solution. The level of the solution is kept sufficiently high that the surface of interest is wet by it.

In operation, slices 23 are made to rotate independently of stirring disk 15, or are dragged by the rotation of the disk. In either instance, the result is a continuously changing direction of polishing for slices 23 because of the eccentric arrangement of the axis of rotation 22 and the shaft 14.

The presence of a source of radiation having a wavelength in the visible range, such as a 300–500 watt tungsten filament light bulb has a tendency to reduce preferential etching in heavily damaged regions, thereby resulting in smoother gallium arsenide surfaces. To this end, radiation source 29 is suitably positioned in the apparatus shown in FIG. 1 proximate glass disk 15. It will be appreciated by those skilled in the art that the exact location of such source may be varied as desired.

The solution employed in the present technique comprises methanol and bromine wherein the bromine is present in an amount within the range of 0.001 to 0.05 percent by volume of the total solution. The use of concentrations beyond 0.05 percent adversely affects the polishing in that pitting in the gallium arsenide slice is increased. The lower limit of 0.001 percent of bromine by volume of the total solution is not absolute and is dictated by considerations of etching rate.

The etching solutions herein contain a maximum bromine content of 0.0025 percent and are suitable for polishing all faces of gallium arsenide including the (111) and (111) and such range is preferred for the practice of this invention. However, higher concentrations up to 0.05 percent which are unsuitable on the (111) face are useful and often desirable for polishing the other faces of this crystalline system.

FIG. 2 shows on an expanded scale the spatial relations of the various elements for optimum operation.

In particular, the spatial relations are such that the pile 34 is separated advantageously from the high points 36 of the surface a distance 33 which is of the same order as magnitude, preferably between three times and a third, as the depth 38 of an average depression below the surface. However, it is tolerable if the pile makes grazing contact with the high points of the surface.

Experimentation has shown that by maintaining the stirring means at such a distance, the etch rate at the high points can be increased by at least a factor of ten. This

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results in gallium arsenide surfaces which are smooth to within 0.05 microinch and flat to within 0.0001 inch per inch over a square centimeter of surface area.

Several examples of the present invention are described in detail below. These examples and the illustration described above are included merely to aid in the understanding of the invention, and variations may be made by one skilled in the art without departing from the spirit and scope of the invention.

Example I

Three slices of $(\bar{1}\bar{1}\bar{1})$ gallium arsenide, approximately 0.5 inch by 0.5 inch by 0.02 inch lapped with 1950 mesh alumina were affixed to the surface of block 18 in the apparatus shown in FIG. 1. Disk 15 was an 8 inch glass cylinder having "Dextilose" paper attached to one surface thereof. A bromine-methanol solution containing 0.05 percent bromine by volume of solution was admitted to container 11 in an amount sufficient to wet the surfaces of the gallium arsenide. Disk 15 was rotated at 72 revolutions per minute while illuminated by a 500 watt tungsten filament. After 25 minutes the thickness of the slices was reduced from approximately 0.02 to 0.019 inch, the smoothness of the surfaces changed from 4.0 to 0.1 microinch and the flatness was unchanged from its original 0.0001 inch per inch on all but the outer 10 percent of the surface.

Example II

Three slices of (111) gallium arsenide, approximately 0.5 inch by 0.5 inch by 0.02 inch were lapped with 1950 mesh alumina and then with 0.3 micron alumina and were affixed to the surface of block 18 in the apparatus shown in FIG. 1. The procedure of Example I was next repeated with the exception that a bromine-methanol solution containing 0.0025 percent bromine by volume of total solution was employed. After 40 minutes the thickness of the slices was reduced from approximately 0.02 to 0.0199 inch, the smoothness of the slice changed from 0.5 to 0.1 microinch and the flatness was unchanged from its original 0.0001 inch per inch on all but the outer 10 percent of the surface.

While the invention has been described in detail in the foregoing specification, it will be appreciated by those skilled in the art that various modifications may be made

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without departing from the spirit and scope of the invention, reference being had to the appended claims.

What is claimed is:

1. The method of polishing a crystal of gallium arsenide which comprises the steps of wetting said crystal with a mixture consisting essentially of bromine and methanol, said bromine being present in an amount within the range of 0.001 to 0.05 percent by volume of the total solution and stirring along a plane substantially parallel to and at a distance from the high points of said crystal of the order of the depth of the discontinuities of said crystals.
2. The method of claim 1 wherein said stirring means is a glass disk.
3. The method of claim 2 wherein said crystal is illuminated.
4. The method of claim 1 wherein said stirring means is a low-pile cloth covered glass disk.
5. The method of claim 4 wherein the distance between said crystal and said cloth covered disk is less than 0.030 mil.
6. The method of polishing the (111) face of gallium arsenide which comprises the steps of wetting said (111) face with a mixture consisting essentially of bromine and methanol, said bromine being present in an amount within the range of 0.001 to 0.0025 percent by volume of the total solution and stirring along a plane substantially parallel to and at a distance from the high points of said (111) face of the order of the depth of the discontinuities of said (111) face.
7. The method of claim 6 wherein said stirring means is a glass disk.
8. The method of claim 7 wherein said crystal is illuminated.
9. The method of claim 6 wherein said stirring means is a low-pile cloth covered glass disk.
10. The method of claim 9 wherein the distance between said crystal and said cloth covered disk is less than 0.030 mil.

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