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(12) # EUROPEAN PATENT APPLICATION

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(54) **Spherical microgrid.**

(57) Spherically convex microgrids may be prepared from a flat microgrid structure by using a process depending on the differential thermal expansion between the material of the flat structure and a layer of other material applied thereto. A flat process blank 2 is etched with grid apertures in a microgrid area to which a curvature is to be added during fabrication. The blank is then subject to the deposition of a thin layer 4 of aluminium nitride (or other differential thermal expansion material having a positive thermal expansion mismatch with the material of the microgrid substrate) over at least the microgrid area (Step A). The differential thermal expansion layer is coextensively with the grid area, so as to confine the warping substantially to the grid area where curvature is desired. Curvature (Step B) is accomplished by a controlled heat warping step in an inert atmosphere (for a silicon microgrid structure of 250 micrometers thickness, heating at 1200C to soften the silicon). Permanent deformation, occuring as a result of the differential thermal expansion, is controlled by selection of temperature and time of heat treatment to achieve the desired curvature. The aluminium nitride layer (Step C) is removed prior to cooling.

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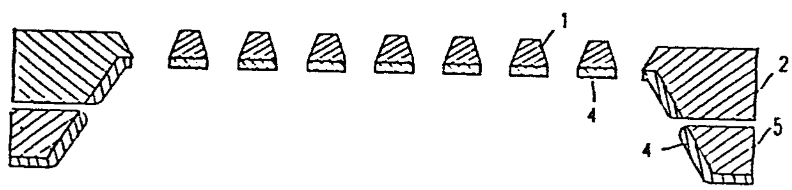
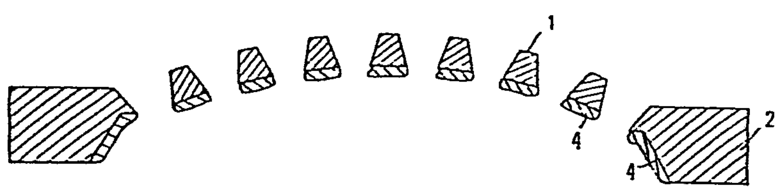
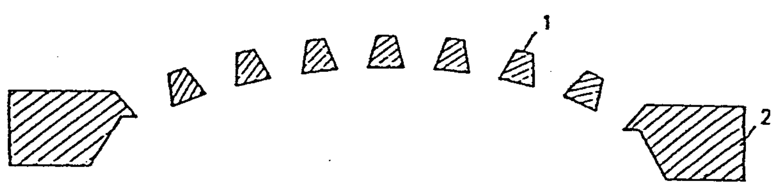


STEP A



STEP B



STEP C

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SPHERICAL MICROGRID

This invention relates to microminature grids, and relates more particularly to a method for making a spherically curved microgrid.

Description of Related Art

Spherically curbed silicon microgrids are required in ion beam devices as ion beam extraction grids, to accelerate and decelerate ionized particles, and in particle energy analyzers for focusing the beam. These applications place microgrids in environments which are very hot and subject to high voltage potentials, but nevertheless demand very high dimensional stability. Existing methods of making curbed microgrid structures involve careful machining to achieve the desired curvature, plus careful handling of the grid after machining, but are currently incapable of achieving the desired tolerances.

Existing coated microgrids are coated for a different reason. They are coated for protection; they are not coated with a differential expansion process layer to achieve curvature by means of differential expansion.

Related Prior Art Patent

United States Patent Number 4,263,528, Miram, GRID COATING FOR THERMIONIC ELECTRON EMISSION SUPPRESSION, April 21, 1981. Miram shows a microgrid with a coating of boron nitride to control thermionic emissions. There is no teaching of any use of multiple layers to achieve curvature.

Related Prior Art Publications

J. L. Speidell, J. M. E. Harper, J.J. Cuomo, A. W. Kleinsasser, H. R. Kaufman, A. H. Tuttle, IBM Research Report 9344,-------.

J. L. Speidell, J. M. E. Harper and A. H. Tuttle, SILICON ION SOURCE GRIDS, IBM TDB Vol. 23, No. 6, November 1980, pp. 2582-2583.

J. L. Speidell, D. S. Yee and H. R. Kaufman, INTEGRAL INSULATED SUPPORT STRUCTURES FOR ION OPTICS, Vol. 25, No. 3B, August 1982, pp. 1673-1676.

J. L. Speidell, SILICON ION-EXTRACTION GRIDS, IBM TDB Vol. 25, No. 10, March 1983, pp. 504-505.

H. R. Kaufman, J. M. E. Harper and J. J. Cuomo, ------ J. Vac. Sci. Technol. Vol. 16, 1979, p. 899.

These publications describe techniques for making similar grids, but do not extend the teaching to the inventive method of providing curvature to the grid.

SUMMARY OF THE INVENTION

An object of the invention is to fabricate a curved microgrid structure of silicon, gallium arsenide or other material, with precision and at low cost, using differential expansion of a layer added temporarily for the purpose of controlling warping of the microgrid as it is heat treated.

A more specific object of the invention is to achieve the desired curvature of a microgrid structure by coating a planar microgrid with a layer of relatively high softening temperature material (such as aluminium nitride) which has a higher coefficient of thermal expansion at the softening temperature of the microgrid substrate material, and then heating the composite to the softening temperature of the microgrid substrate material to cause controlled warping by differential thermal expansion during heat treatment.

A feature of the invention is its use of relatively standard integrated circuit techniques to achieve a curved microgrid configuration normally requiring micromachining techniques.

An advantage of the invention is the absence of contaminants and the absence of curvature-causing forces in flat areas around the microgrid.

Another advantage of the invention is that it lends itself to operations based upon a microgrid process intermediate structure which may be stored and shipped flat and later formed into the desired shape.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of the finished curved microgrid structure.

FIG. 2 is a cross-sectional view, similar to that of FIG. 1, of the microgrid flat blank prior to processing for curvature.

FIG. 3 is a cross-sectional view, similar to that of FIGs. 1 and 2, of the microgrid process intermediate structure, after the substrate has been coated with a differential thermal expansion process layer, but prior to the thermal expansion heat treatment step.

FIG. 4 is a cross-sectional view, similar to that of FIGs. 1, 2 and 3, illustrating the curvature resulting from differential thermal expansion during the controlled warping step.

FIG. 5 is a cross-sectional view, similar to that of FIGs 1, 2, 3 and 4, illustrating the removal of the differential thermal expansion process layer.

DESCRIPTION OF THE PREFERRED EMBODIMENT

CURVED MICROGRID STRUCTURE

FIG. 1 is a cross sectional view of the spherically curved microgrid structure, which structure includes grid 1 in border 2 loosely supported in brackets 3. This spherically curved microgrid may be used for a number of processes including ion beam devices and particle energy analyzers, as a focusing grid or electrostatic lens.

MICROGRID CURVATURE PROCESS

The starting point for the production of a spherically curved microgrid structure is a flat silicon substrate microgrid blank. The flat silicon microgrid blank is fabricated according to known techniques, for example the technique described by Speidell et al in the IBM Technical Disclosure Bulletin article identified above under the caption "Related Prior Art Publications." Other techniques could be used as well--so long as the result is a flat microgrid blank. The blank may be a round wafer; typical is a 57 millimeter diameter wafer of 250 micrometer thickness, with 750 micrometer nominally square apertures on 1000 micrometer centers in the grid area. Typical differential thermal expansion process layer thickness (aluminum nitride) is 0.5-5 micrometers, preferably 2.5-3 micrometers, with a thickness ratio of substrate to differential thermal expansion process layer of 100:1 to 1000:1, preferably about 300:1. Heat treatment to achieve the desired curvature (with wafer loosely supported outside the microgrid area, and convexity in the direction of gravity) is typically at 1200C for 30 minutes (silicon substrate, softening temperature approximately 900-1100C). Typical reagent for removal of the differential thermal expansion process layer (aluminum nitride) is hot phosphoric acid. The dimensions, including microaperture dimensions and thickness dimensions, are not critical to the process of this invention, but are selected as required for the application, the equipment available and time-temperature requirements one of which may be arbitrary.

The thickness and stress of the differential thermal expansion process layer must be sufficient to overcome the resistance to deformation provided by the substrate, which resistance varies with substrate material, thickness and temperature. These can be calculated or can be measured, and are not at all critical because the deformation takes place at the softening temperature of the substrate, which is a lower temperature than the softening temperature of the differential thermal expansion process layer. In the usual case, the differential thermal expansion process layer is temporary and is removed before the spherical microgrid structure is put into use; where its presence is tolerable, it may remain

Aluminum nitride is the preferred differential thermal expansion process layer material. Other materials may be substituted, so long as the substitute material is capable of producing compression stress to the selected substrate at the softening temperature of the substrate, and is removable without damage (or of a material which may be tolerated in the application); examples are silicon dioxide and c axis pyrolitic graphite. Substitute materials may require different reagents for their removal; for example, silicon dioxide may be removed from silicon with hot hydrofluoric acid.

The requirements for the differential thermal expansion process layer are:

1. Its coefficient of expansion must be significantly greater than that of the substrate.
2. It must adhere well to the substrate.
3. It must be a relatively high stress material.
4. It must be tolerable in the application or removable without damage or contamination by the reagents.

FIGs. 2-5 illustrate the process by which this flat blank is made into the curved microgrid structure shown in FIG. 1.

1. Prepare microgrid blank.

2. Mount microgrid blank in processing chamber. (See FIG. 2.)

3. Deposit aluminium nitride differential thermal expansion layer 4 (by reactive RF sputtering) on one surface only of the microgrid. (See FIG.3.) Use shadow mask 5 to limit the differential thermal expansion process layer to the grid to be curved.

(In the case of gallium arsenide grids, the entire grid must first be encapsulated with a protective layer of a material such as silicon dioxide. This protective layer seals the gallium arsenide to prevent the decomposition of the gallium arsenide by the heat applied during the controlled warping step. An alternative is a heat treatment in an arsenic atmosphere which would prevent decomposition.)

4. Heat the composite microgrid--flat grid blank with differential thermal expansion process layer--in a controlled warping step, using heat above the softening point for the microgrid material, in an inert atmosphere. (For silicon, heat to 1200C in helium.) (See FIG. 4.)

5. Remove the differential thermal expansion process layer by chemical etching. (For aluminum nitride on silicon, etch in hot phosphoric acid.) (See FIG. 5.)

DIMENSIONS AND SPECIFICS

The following dimensions and specifics are preferred, although a great range of dimensions and specifics may be used:

Silicon microgrid blank------250 micrometers thickness, 57 millimeter wafer, 750 micrometer square apertures on 1000 micrometer centers

Radius of curvature---------30 centimeters

Grid Materials--Silicon, gallium arsenide, c axis pyrolitic graphite

Differential thermal expansion process layer materials--Aluminum nitride, silicon dioxide

The invention has been described with respect to a limited number of microgrid materials appropriate for the applications listed, and with respect to a simple spherical deformation. Those skilled in the art may be expected to provide other materials appropriate for the applications selected, and may, where convex shapes other than spherical are called for, be expected to vary the geometry of the microgrid process intermediate structure accordingly, without departing from the spirit and scope of the invention as pointed out in the following claims.

CLAIMS

1. A process for fabricating convex microgrid structures of microgrid substrate material from a flat microgrid blank characterised by:

(a) coating a microgrid area of the flat microgrid blank with a differential thermal expansion process layer to form a composite microgrid process intermediate structure, the material of said differential thermal expansion process layer having a coefficient of thermal expansion greater than that of the microgrid material; and

(b) heating treating said composite process intermediate structure to a temperature above the softening temperature of the microgrid substrate material;

whereby differential thermal expansion provides a controlled warp to the microgrid area of the composite structure.

2. A process for fabricating convex microgrid structures according to claim 1, further characterised in that the substrate thickness of the microgrid blank is greater than 100 micrometers and less than 500 micrometers, the thickness of the differential thermal expansion process layer is less than 5 micrometers, and the differential thermal expansion layer is removed subsequent to curvature-inducing heat treatment.

3. A process for fabricating convex microgrid structures according to claim 1 further characterised by an atmosphere of inert gas used during said heat treatment, said heat treatment being at 1200C, the material of the microgrid structure being silicon of thickness approximately 750 micrometers, and the material of said differential thermal expansion layer being aluminium nitride of thickness 2.5-3 micrometers.

4. A process as claimed in claim 1, 2 or 3, in which the intermediate structure comprises a substrate provided by a wafer of silicon, gallium arsendide, or c axis pyrolitic graphite, in which said differential thermal expansion process layer is aluminium nitride or silicon dioxide and in which the thickness ratio of substrate to differential thermal expansion process layer is greater than 100 to 1.

5. A process as claimed in claim 1, modified in that the material of said differential thermal expansion process layer has a coefficient of thermal expansion less than that of the microgrid material.

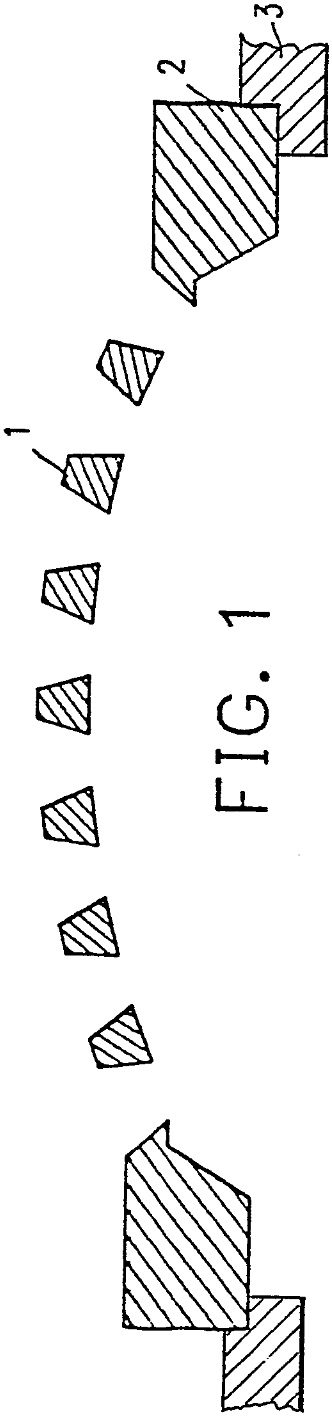

FIG. 1

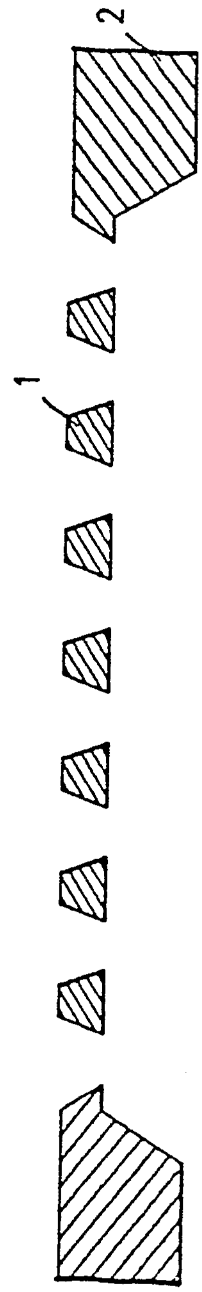

FIG. 2

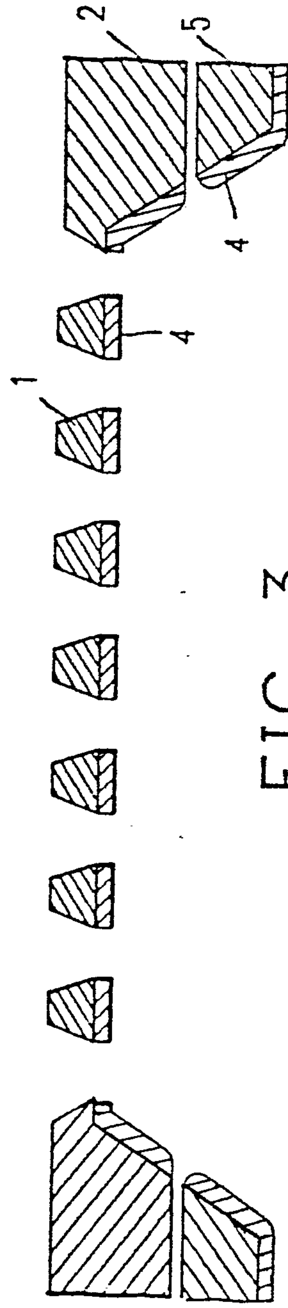

FIG. 3

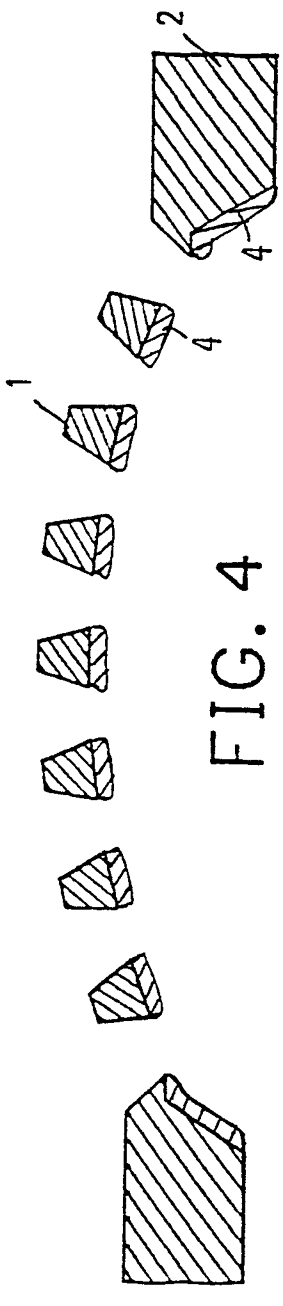

FIG. 4

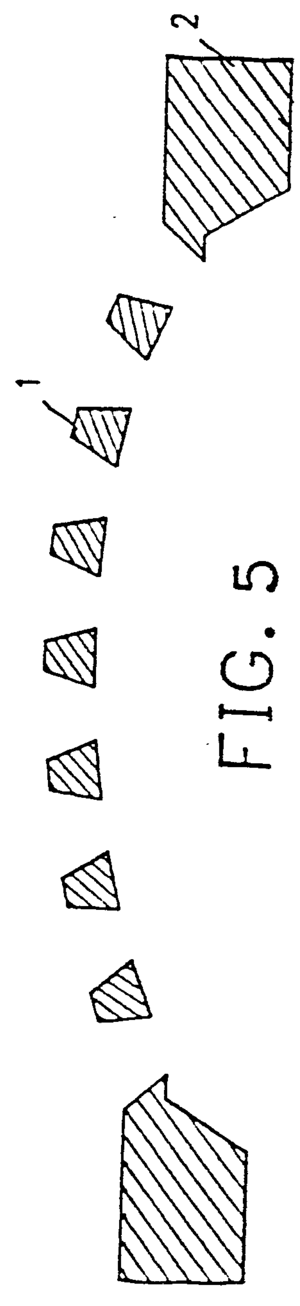

FIG. 5