

Jan. 18, 1966

J. V. DOMALESKI

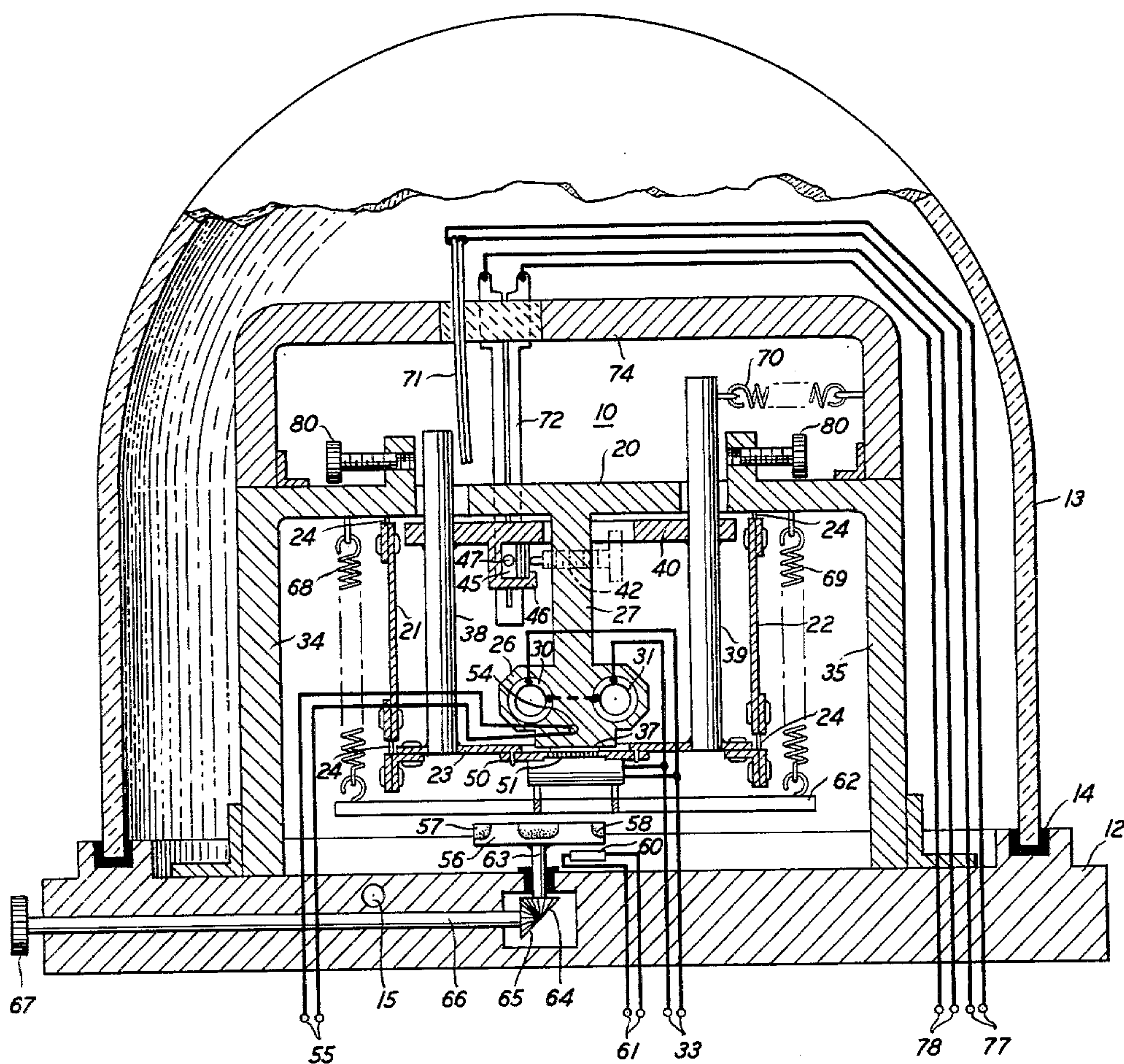
3,230,109

VAPOR DEPOSITION METHOD AND APPARATUS

Filed Dec. 18, 1961

4 Sheets-Sheet 1

FIG. 1



INVENTOR
J. V. DOMALESKI
BY *Q. E. Hirsch Jr.*
ATTORNEY

Jan. 18, 1966

J. V. DOMALESKI

3,230,109

VAPOR DEPOSITION METHOD AND APPARATUS

Filed Dec. 18, 1961

4 Sheets-Sheet 2

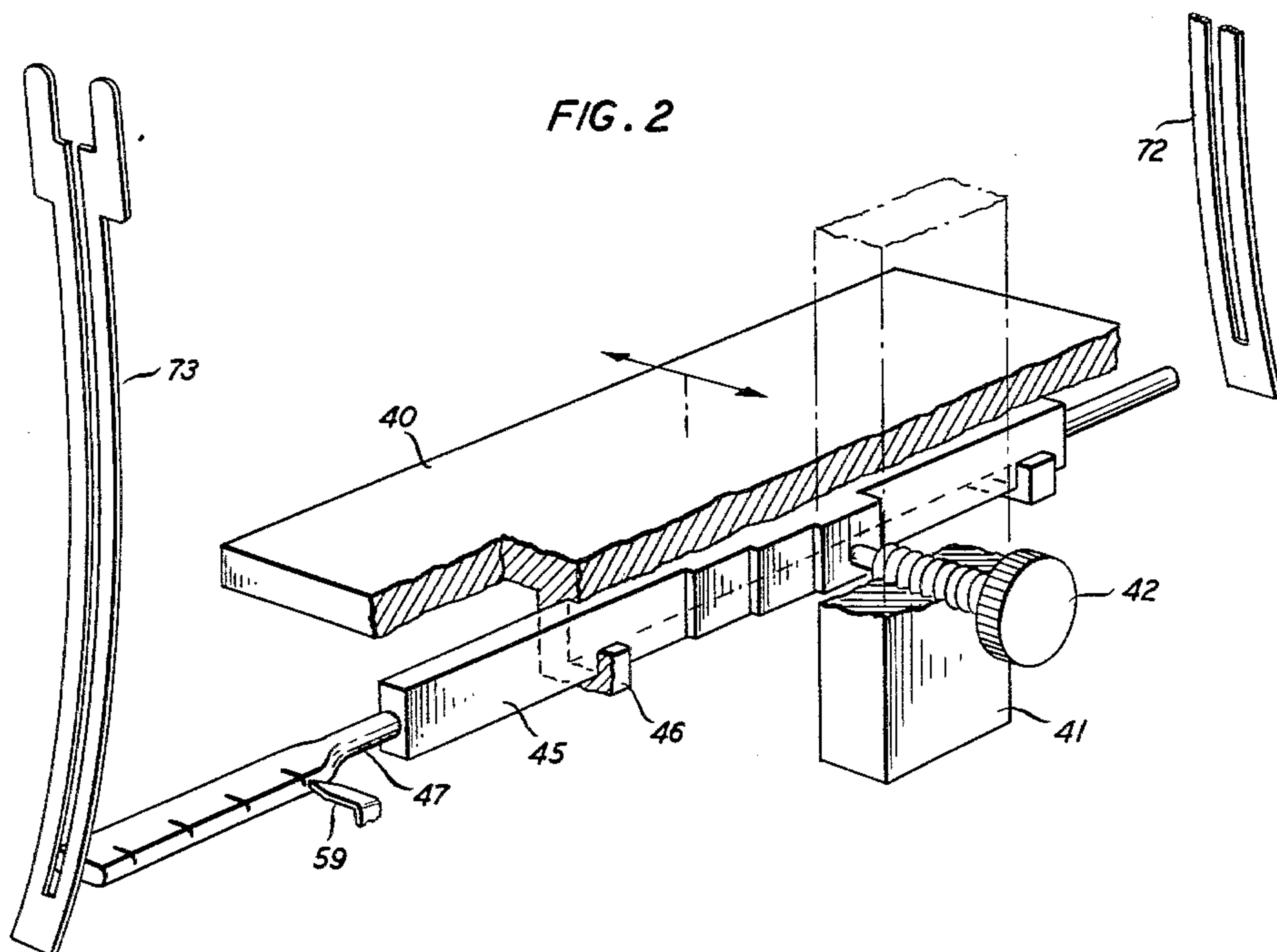
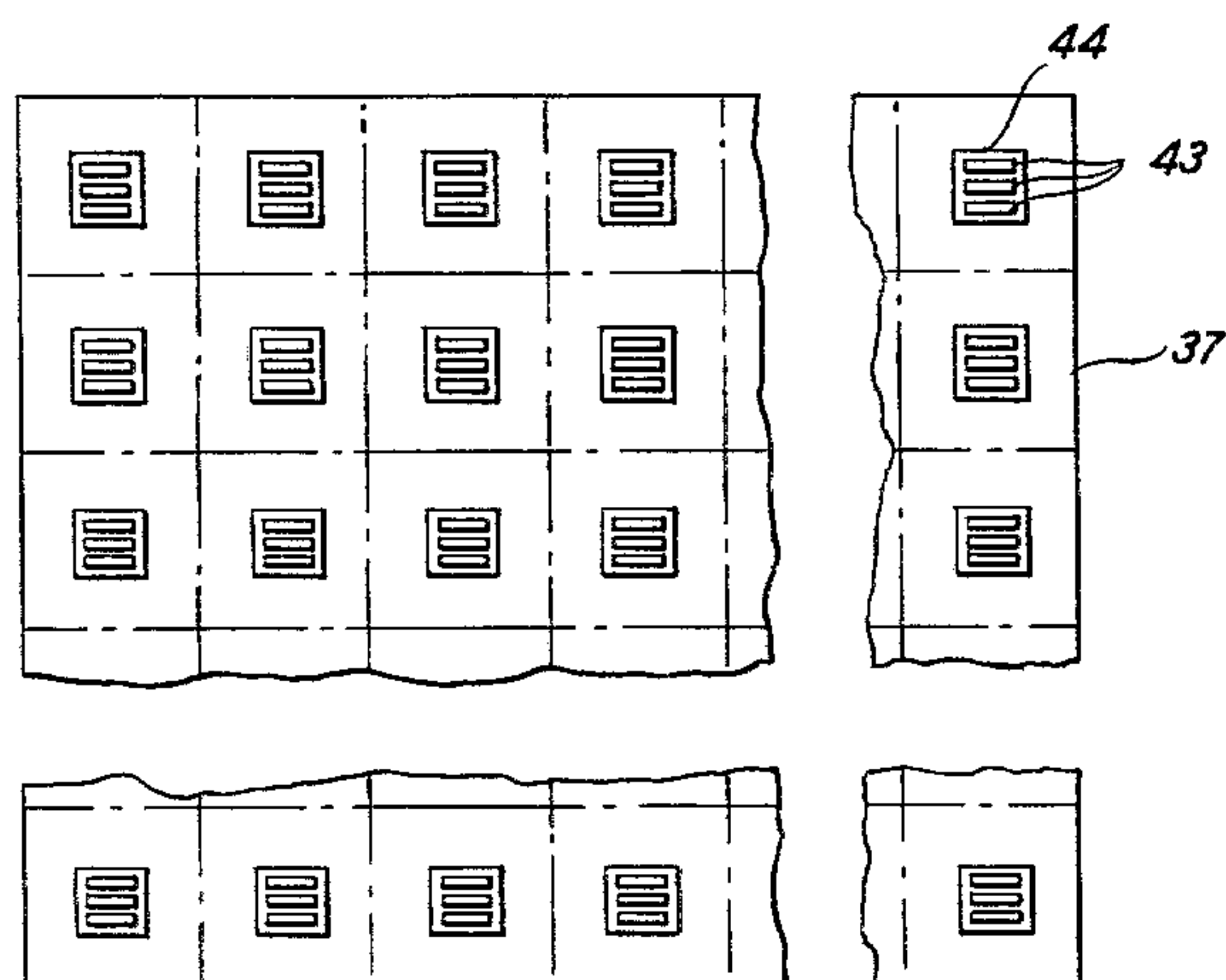


FIG. 5



INVENTOR
J. V. DOMALESKI
BY *C. E. Hirsch Jr.*
ATTORNEY

Jan. 18, 1966

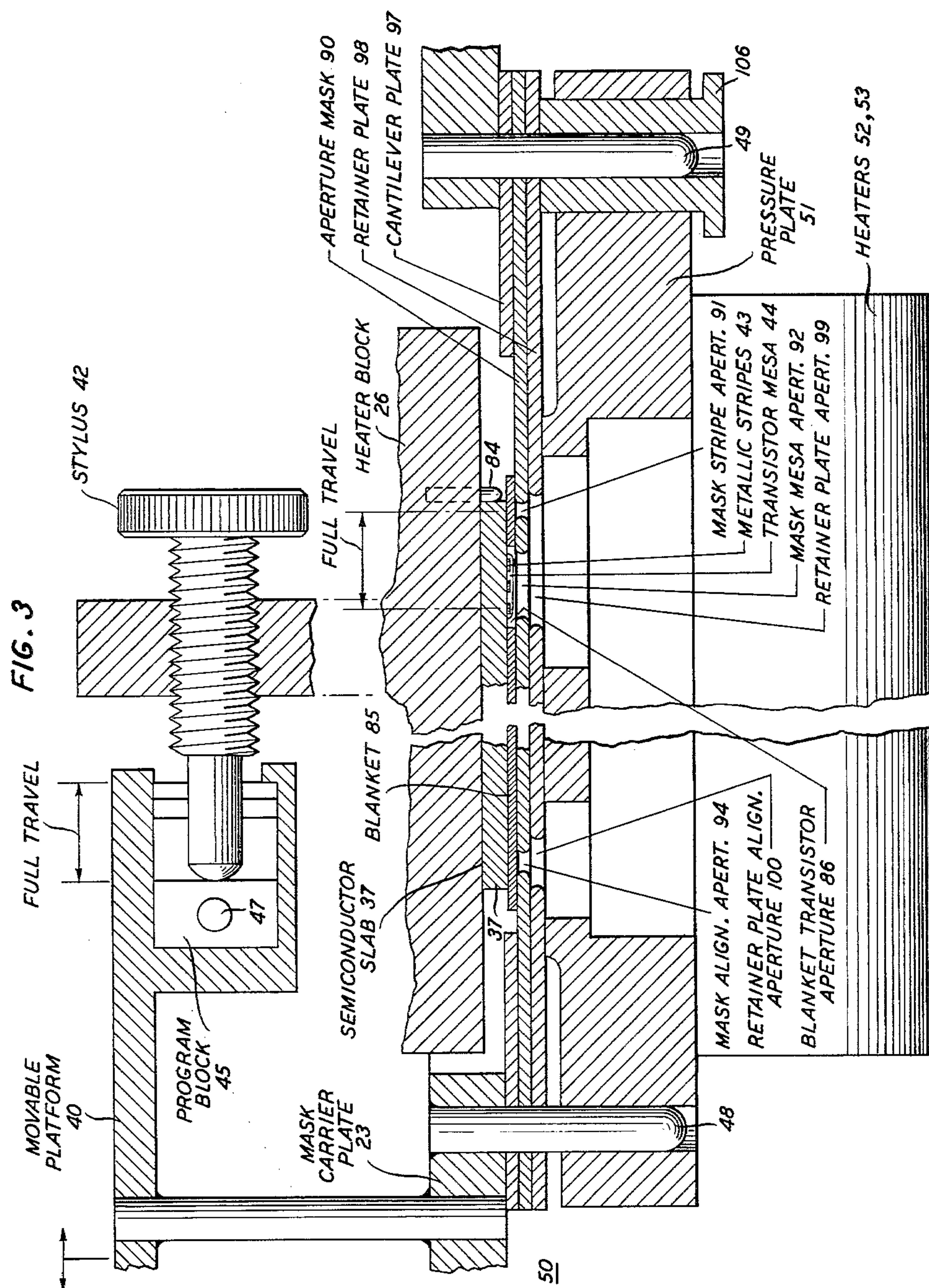
J. V. DOMALESKI

3,230,109

VAPOR DEPOSITION METHOD AND APPARATUS

Filed Dec. 18, 1961

4 Sheets-Sheet 3



INVENTOR

J. V. DOMALESKI

BY C. E. Hirsch Jr.
ATTORNEY

ATTORNEY

Jan. 18, 1966

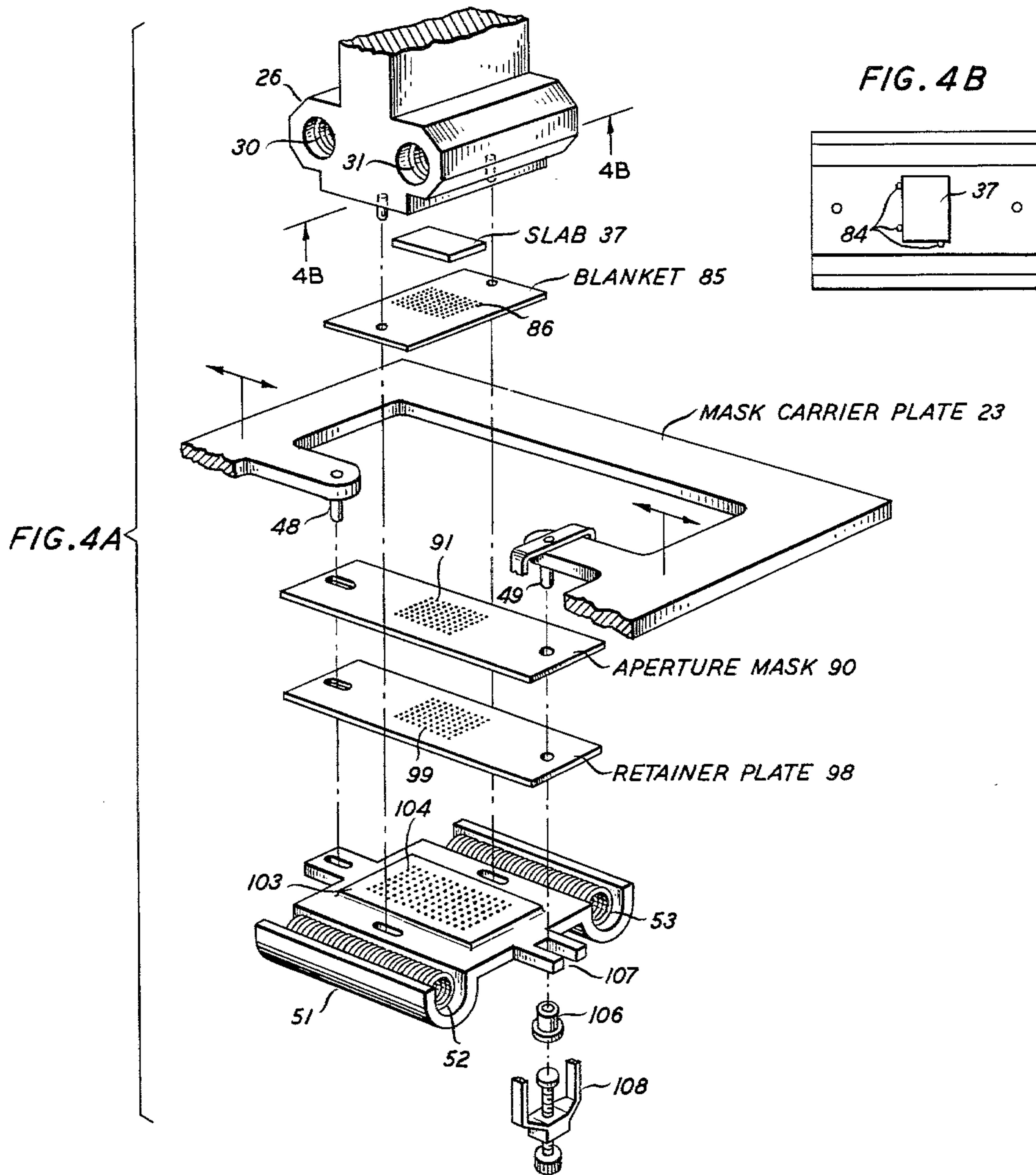
J. V. DOMALESKI

3,230,109

VAPOR DEPOSITION METHOD AND APPARATUS

Filed Dec. 18, 1961

4 Sheets-Sheet 4



INVENTOR
J. V. DOMALESKI
BY *A. E. Hirsch Jr.*
ATTORNEY

1

3,230,109

VAPOR DEPOSITION METHOD AND APPARATUS

Joseph V. Domaleski, Berkeley Heights, N.J., assignor to Bell Telephone Laboratories, Incorporated, New York, N.Y., a corporation of New York

Filed Dec. 18, 1961, Ser. No. 159,886

12 Claims. (Cl. 117—212)

This invention relates to a method and apparatus for the vapor deposition of metal coatings on a suitable supporting specimen and, more particularly, to a method and apparatus for making microscopically small electrode stripes accurately spaced in juxtaposed relation on a semiconductor slab.

Techniques for the evaporation of metals on a supporting specimen in a partial vacuum have been known and utilized for many years. Only recently, however, due especially to improved vacuum techniques, has the vacuum-metalization process grown to huge proportions in industry. This has become particularly true in the manufacture of semiconductor devices, particularly, multielectrode transistors.

As is well known in the art, the frequency response of diffused-base transistors is highly dependent on the electrode mesa geometry. Specifically, it has been found that the width of the emitter electrode together with the space separating it from the juxtaposed base electrode (or electrodes) is a key high frequency parameter.

To obtain an appreciation of the sizes of the electrodes involved and the difficulties obviously encountered in their manufacture, a typical diffused-base germanium transistor designed to operate in the 500 megacycle range requires emitter and base electrodes measuring approximately 0.001 by 0.002 inch and spaced less than 0.001 inch apart in juxtaposed relation. As the collector electrode need not be of comparable size, it is often made a part of the encapsulating housing. It of course may be made by the same vapor deposition process utilized for the base and emitter electrodes.

One of the virtues of the metal vaporization process is that the thickness of a uniform metallic coating may be accurately controlled. Considerable difficulty has been priorly encountered, however, in precisely spacing two or more metallic stripes in juxtaposed relation on a supporting specimen by this process. When the spacing between stripes must be of the order of one mil or less, it is obvious that the use of externally controlled mechanical linkages is ruled out.

A much more refined technique for effecting the necessary spacing between stripes has involved the use of a vapor deposition fixture comprised of members of different thermal expansion coefficients. With the specimen supported on one of these members, vapor deposition of two spaced stripes of the same or different contact metals at different temperatures is accomplished by the resulting lateral movement of one member relative to the other as a function of temperature. Disadvantageously, it has been found very difficult to utilize one or more thermally expandable elements to translate directly motion accurately in a straight line and in a single plane, even over distances of only a few mils. In addition, it is exceedingly difficult at elevated temperatures to hold the movable elements unwaveringly in fixed relation at a plurality of discrete lateral stops. Temperature fluctuations normally experienced in such expansion elements have been found to make stripe spacing variations less than ± 0.01 mil unfeasible.

Another technique referred to as cross-evaporation has made possible two vapor depositions of either the same or different contact metals without requiring any relative movement between members of the apparatus. With this

2

technique, the electrode spacing is determined by initially establishing the proper distance from the mask to the specimen and then controlling the lateral displacement of two oppositely inclined evaporation sources. Unfortunately, a number of secondary factors are encountered with this technique which have been found to impose minimum tolerances of approximately ± 0.16 mil on strip spacing variations, even under carefully controlled conditions. In addition, cross-evaporation does not allow for the vapor deposition of more than two metallic stripes per set on a specimen. In the transistor art, certain types of these devices often are characterized by as many as five minute stripes in juxtaposed relation on a single transistor mesa.

The inadequacies of the aforementioned techniques become more acutely and readily apparent when the dimensions of transistors contemplated for use in the gigacycle frequency range are examined. More specifically, it has been shown recently that a junction triode transistor with three parallel, rectangular electrodes, for example, could oscillate at 40 gigacycles if the engineering difficulties of producing emitter and base electrodes 2.5 microns (0.0001 inch) wide with spacings half this wide could be resolved. Prior art vapor deposition techniques for making transistor electrodes are wholly inadequate to cope with such microscopic dimensions and spacings, not to mention the critical tolerances that must also be maintained.

In addition, prior art vapor deposition techniques do not readily permit a protective oxide or wax coating to be deposited on a transistor mesa immediately after the metallic electrode stripes have been formed thereon. Such a coating greatly facilitates a subsequent etching operation utilized to separate the transistors on the slab. As the electrodes and the mesa coating may be effected in the same vacuum cycle, the time required to fabricate a complete transistor (or a plurality of them) is thus considerably reduced in accordance with the invention.

Accordingly, it is an object of this invention to provide an improved method and apparatus for making a plurality of metal coatings, each of microscopic dimensions, on a supporting specimen.

It is a more specific object of this invention to provide an improved method and apparatus for making and spacing a plurality of sets of metallic electrodes in juxtaposed relation on slabs of semiconductor materials, being processed on an assembly line basis, to form a plurality of semiconductor devices.

It is an additional object of this invention to make a plurality of sets of extremely thin, precisely dimensioned and critically spaced metallic stripes on a supporting body, by a process in which adjacent stripes in each set are formed without the necessity of cross-vaporization paths, fixtures comprised of elements exhibiting different coefficients of thermal expansion, or continuous, externally controlled movement of mechanical elements within a controlled atmosphere.

It is still an additional object to form an oxide coating on each of a plurality of transistor mesas during the same vacuum cycle that one or more microscopically small electrodes are formed on each of the mesas.

In accordance with one illustrative embodiment of the invention, vapor deposition apparatus comprises, within an evacuated enclosure, a stationary base forming a part of a hinged parallelogram framework. The base is adapted to support a slab, for example, a semiconductor slab and, in part at least, to heat the slab to a predetermined temperature in preparation for the vapor deposition of metallic electrodes or stripes thereon. The framework supports a mask containing appropriate evaporation apertures between the slab and a vaporization source.

In accordance with an aspect of the invention, a stepped gauging block is utilized to program the lateral

movement of the apertured mask relative to the semiconductor slab. The program block is associated with the framework and abuts against a spring biased stylus rigidly affixed to the base. The number of discrete steps and the lateral displacement of the apertured mask relative to the slab between steps is thus made dependent on the step increments in the program block. Advantageously, the necessary degree of accuracy in the step increments may be readily obtained with conventionally machined blocks. Three bimetal drives, selectively actuated external to the vacuum enclosure, move the program block relative to the stylus whereby the latter successively abuts against different steps of the program block in any preselected sequence. With this arrangement, a plurality of microscopically small electrodes advantageously may be made with equal or different spacings, the number of spacing intervals and their widths being dependent solely on the number of steps and their increments in the program block.

Inasmuch as lateral movement of the framework (supporting the apertured mask) relative to the semiconductor slab is effected exclusively by the bimetal drives, the various parts of the vapor deposition apparatus are made of materials exhibiting very low coefficients of thermal expansion. Accordingly, in applications where vapor deposition of two different metals in one vacuum cycle dictates two different operating temperatures, such temperature variations significantly effect practically no lateral movement or displacement of the critical parts. Further, as the electrode spacings are determined solely by successive, accurately machined step increments in the program block, the spacings may be easily altered by simply interchanging program blocks constructed for different predetermined applications.

Finally, as the stylus is rigidly affixed against a particular step of the program block during each period of vapor deposition, the degree of lateral movement between the apertured mask and semiconductor slab during the spacing intervals has no adverse effect on the spacing accuracy obtainable. As a result, the steps in the program block advantageously may be dimensioned to provide the degree of lateral movement necessary to form not only a plurality of spaced juxtaposed transistor electrodes, but also, for example, to form a protective oxide or wax mask over the mesa in one operating vacuum cycle. The described apparatus thus facilitates greatly the mass production of ultra-high frequency transistor devices and with a degree of precision control in manufacture not found possible heretofore with prior art techniques and apparatus.

The method and apparatus for its practice is disclosed herein as related to one preferred application, i.e., the manufacture of transistors. It is to be understood, however, that the invention has particular utility in any application where the accurate placement of metal (or other material) coatings of minute size in juxtaposed relation on a supporting specimen is desired.

The invention will be more fully apprehended from the following detailed description of the preferred illustrative embodiments thereof, considered in conjunction with the appended drawing, in which:

FIG. 1 is an elevational view, primarily in section, of apparatus embodying the principles of the invention;

FIG. 2 is a partial, detail view in perspective of fixtures of the apparatus depicted in FIG. 1;

FIG. 3 is a partial, detail view in section of fixtures included in the apparatus of FIG. 1;

FIG. 4A is an exploded view of certain fixtures of the apparatus of FIG. 1;

FIG. 4B is a cross-sectional view of FIG. 4A along the line 4B—4B;

FIG. 5 is a plan view of a semiconductor specimen after the vaporization of a plurality of sets of electrodes and a protective mesa coating thereon with the apparatus of FIG. 1.

Considering the drawing more particularly, FIG. 1 depicts, mainly in cross section, a thermal vapor deposition apparatus 10 supported within a vacuum chamber comprising, for example, a base 12 and a bell jar 13 as shown. The interior of the jar is sealed from the outside atmosphere by a gasket 14 which may be of any suitable material, such as rubber, positioned in a peripheral groove in the base 12. The interior of the jar is placed under a partial vacuum through a vacuum connection 15 to any conventional vacuum system or station, not shown.

The evaporation apparatus within the jar comprises a parallelogram framework including a stationary base 20, two side plates 21, 22, and a bottom plate 23, often referred to hereinafter as the mask carrier. Adjacent edges of these members are joined by single pieces of flexible lamination 24 which form hinges. These hinges permit the side plates and bottom plate to move laterally (sidewise as depicted in FIG. 1) relative to the base plate 20. The parallelogram framework is supported above the base 12 of the vacuum enclosure by two side members 34, 35, which may either be attached to the stationary plate 20 or may comprise an integral part thereof. An upper heater block 26 is supported below the base 20 by two posts 27, 28, which, in the drawing, are superimposed and therefore appear as one. Two filaments 30, 31 extend into holes in the heater block 26 and are energized, in series relation, through leads 33, normally connected to a suitable current source, not shown. Mounted on the bottom side of the heater block 26 is a specimen 37, best seen in FIGS. 3 and 4A, to be vapor deposited with metal.

Attached to the movable bottom plate 23 and extending upwardly therefrom are two posts 38, 39 which protrude through oversized holes in the base plate 20. Below the base plate 20 and parallel thereto is a movable platform 40, which is affixed to posts 38, 39 passing there-through.

A center post 41, seen only in FIG. 2, is interposed between the two heater posts 27, 28 and is affixed to the base plate 20. Post 41 passes through an oversized aperture in the platform 40 and carries a threaded stylus 42.

Extending downwardly from the bottom plate 23 of the parallelogram framework are two pins 48, 49, best seen in FIGS. 3 and 4A, which maintain an apertured mask assembly 50 and a pressure plate 51 in proper alignment. The mask assembly is shown and will be considered in greater detail in regard to the description of FIGS. 3 and 4 hereinbelow. The pressure plate 51 includes two semi-circular wall portions, best seen in FIG. 4A, in which are positioned two filaments 52, 53. These filaments are shown connected in parallel relation with the filaments in the lower heater block 26; however, the two pairs of filaments may also be connected in series relation or separately energized. A clamping member 62 and two springs 68, 69, provide the desired pressure to be exerted by the pressure plate 51 on the mask assembly 50. A thermocouple circuit 54 mounted in the heater block 26, including leads 55, is utilized to convey information to the outside relative to the temperature in the region of the specimen.

Mounted directly below the mask assembly 50 and pressure plate 51 is a rotatable platform 56 of any suitable material having a plurality of cup-shaped cavities 57 therein, preferably arranged in a circular array. Cavities 57 may selectively contain different charges of metal 58, for example, aluminum and gold-antimony which are normally utilized as the emitter and base electrodes, respectively, of a transistor. Another cavity may advantageously contain an oxide powder or wax for producing, for example, a protective mask coating impervious to etching chemicals over the mesa of each transistor. The various metals and protective coatings to be vapor deposited on the bottom surface of the specimen 37 are heated to the necessary temperature by a heater element 60 con-

connected to a suitable electrical source, not shown, through leads 61. The heater element 60 may be of the conventional filament type or comprise a suitable high-frequency coil to provide electromagnetic induction heating when suitably energized. It is to be understood, however, that separate, movable vaporization sources, such as in the form of tungsten filaments with the different metal vaporant charges selectively placed therein may also be utilized. The platform 56 is affixed to one end of a rotatable support shaft 63. The other end of shaft 63 has attached thereto a bevel gear 64 which is driven by a mutually engaged bevel gear 65 affixed to one end of a rotatable shaft 66. The other end of shaft 66 extends beyond the base of the bell jar 13 and has a knurled knob 67 attached thereto for facilitating rotational movement of the platform 56 relative to the heater element 60.

In accordance with a feature of the invention, a stepped program block 45 abuts against the stylus 42 on its stepped side and against an L-shaped extension 46 affixed to the platform 40 on its opposite planar side. A more detailed view of the program block 45, stylus 42 and the associated supporting structure is illustrated in FIG. 2. As clearly seen in FIG. 2, the program block 45 has a number of steps of varying thickness cut therein. The thickness of the particular step against which the stylus bears determines the relative position between the mask assembly 50 and the specimen 37.

A small rod 47, best seen in FIG. 2, is normally inserted in the program block 45, both to provide a simple extension of the program block beyond the sides of the apparatus 10 so as to facilitate movement of the block, and to provide an end section which has suitable graduated markings visible to an operator looking through the wall of the bell jar. A pointer 59, supported by the stationary base 20 of the apparatus, provides a visual indication of the relative lateral movement between the rod and pointer. By correlating the markings on the rod with the steps of the program block, the pointer may be utilized to indicate the particular step of the block against which bears the stylus 42.

Movement of the stepped program block 45 relative to the stylus 42 is effected by a combination of a spring 70, which normally biases the block against the stylus, and three bimetal drives, drive 71, shown in FIG. 1, and drives 72, 73, shown in FIG. 2. The spring 70 and bimetal drives are all supported on a frame member 74 which is parallel with and attached to the stationary base plate 20 as shown. Leads 77, 78 and 79 (only the first two are shown in FIG. 1) direct current from suitable sources (not shown) to drives 71, 72 and 73, respectively, for selective actuation thereof. The manner in which the relative position between the block and stylus is changed by selectively energizing the bimetal devices will be considered in greater detail in the description of the operation of the apparatus given hereinbelow.

FIG. 3 depicts, in cross section, a detailed arrangement of the mask assembly 50. This figure includes elements having secondary roles which were not shown in FIG. 1 for reasons of simplicity and clarity. In order to facilitate a better understanding of the movable relationship between the various mask elements, FIG. 4A depicts most of the mask elements seen in FIG. 3 in an exploded view. Positioned on the bottom surface of the heater block 26, only partially shown in FIG. 3, is the specimen 37. The specimen will hereinafter be considered as comprising a slab of diffused-base semiconductor material having a plurality of transistor mesas 44 on each of which are to be vapor deposited sets of metallic stripes or electrodes 43. The slab is positioned with one side edge and one end edge aligned against three pins 84 in the heater block 26, best seen in FIG. 4B. The specimen is prevented from shifting away from the pins by a "blanket" 85 positioned thereagainst. The blanket is preferably made of a sheet of molybdenum approximately one half mil thick and containing an array of apertures 86, shown in FIG. 4A,

each of which corresponds to the location and cross-sectional area of a different set of stripes or electrodes to be made on the slab 37. Accordingly, in the manufacture of transistors, for example, apertures 86 are slightly larger than the transistor mesas. In addition to immobilizing the specimen 37 on the heater block, the blanket 85 advantageously functions as a friction buffer between the slab and the mask assembly 50 which moves laterally directly below it. The blanket also prevents alloying of the slab with nickel elements of the mask assembly at elevated temperatures during the periods of vapor deposition. Without taking such precautions, alloying may take place between a semiconductor slab of germanium and nickel.

An apertured mask 90, positioned directly below the blanket 85, is carried with the laterally movable bottom plate 23 of the parallelogram framework by pins 48, 49, best seen in FIGS. 3 and 4A. Because of its function, plate 23 will hereinafter be referred to as the mask carrier and is so labeled in FIGS. 3 and 4A. The mask 90 is preferably made of nickel, as this is one of the few materials adaptable to the electroforming process and also suitable for use in vapor deposition systems. The mask fits snugly on pin 49 but is slotted at pin 48 to allow for any differential thermal expansion at elevated temperatures.

As utilized for the manufacture of transistors, the mask 90 normally contains an array of pairs of apertures, a stripe aperture 91 and a mesa aperture 92, best seen in FIG. 3. Each of these pairs is in alignment with a larger corresponding aperture 93 in the blanket 85. For obtaining initial alignment with the parallelogram framework, apertured mask 90 also has a single alignment aperture 94 used for sighting on the edge of the blanket 85.

As seen in FIG. 3, a cantilever plate 97, preferably made of molybdenum, supports the mask 90 at both ends, from above, in the free span between the edges of the blanket 85 and the edges of the mask carrier 23 of the parallelogram framework. In this position, the cantilever plate serves to prevent the rather fragile mask 90 from buckling when pressure is applied to its underside by the pressure plate 51.

A retainer plate 98 lies directly beneath the mask 90. It has end holes similar to those in the mask through which pins 48, 49 extend. As seen in the exploded view of FIG. 4A, the mask 90 and retainer plate 98 thus move together with the mask carrier 23 of the parallelogram framework. The retainer plate has an array of apertures 99, each of which is superimposed, for example, on an electrode and mesa pair of apertures 91, 92 in the mask 90. Each aperture 99 in the retainer plate surrounds each pair or set of apertures in the mask with very little overlap in order that the pressure received from below is applied as close to the mask apertures as possible to prevent the edges thereof from deforming. The retainer plate 98 also has a sighting aperture 100 coinciding with the similar aperture 94 in the mask, through which the edge of the blanket 90 is sighted in the initial alignment procedure.

As also seen in FIGS. 3 and 4A, the pressure plate 51 is positioned directly beneath the retainer plate and similarly engages pins 48, 49. The outer area on the bottom surface of the pressure plate 51 is partially machined away to provide a raised ridge or pad 103 in which a plurality of apertures 104 are located. Apertures 104 coincide with and are slightly larger than apertures 99 in the retainer plate 98. The outer periphery of pad 103 is just slightly larger than the surface area of the slab 37. The pad thus serves to concentrate the pressure received from the spring biased clamping member 62 positioned against the bottom side of the pressure plate 51. The resulting transmitted pressure compacts the mask 90 against the blanket 85 and presses the slab 37 into close, uniform contact with the heater block 26.

Completing the mask assembly is a bushing 106, seen in FIGS. 3 and 4A, which fits coaxially about pin 49 and extends through an oversized slot 107 in the pressure plate 51. Independent upward pressure is exerted on the bushing 106 by a suitable clamp 108, shown in FIG. 4A, which is attached to the mask carrier plate 23. The clamp 108 thus applies local pressure to the retainer plate 98, mask 90 and cantilever plate 97 between the bushing 106 and the mask carrier 23 of the parallelogram framework.

In accordance with the invention, motion of the program block 45, relative to the slab 37, is accomplished as follows: Bimetal drive 71, seen in FIG. 1, is energized first to overcome the force of the spring 70, and then to move the platform 40 supporting the program block away from the stylus 42. Either bimetal drive 72 or 73, best seen in FIG. 2, is then energized to move the program block appropriately to the left or to the right until the stylus is opposite the desired step in the block. Bimetal drive 71 is then made inoperative, whereby the spring 70 again rigidly biases the stylus against the chosen step of the program block for the duration of a vapor deposition period. Two screws 80, threaded into the base plate 20 and protruding respectively into the oversized apertures through which posts 38, 39 pass, limit the degree of lateral movement effected by bimetal drive 71.

In the manufacture of diffused base transistors, the emitter electrode is usually of aluminum, whereas the base and collector electrodes are usually of gold or gold antimony. In accordance with the present invention, a plurality of such electrodes having planar surface dimensions ranging from one or more mils to tenths of a mil and with spacings of the order of half those dimensions may be readily deposited on a semiconductor slab. Moreover, the coating thickness, which generally is of the order of 500 atom layers thick, may be accurately controlled.

Considering the fabrication process more specifically, the semiconductor slab is initially cleaned to remove any foreign material on the surface thereof. Thereafter, the slab, for example, of germanium, is placed between the apertured mask assembly 50 and the upper stationary heater block 26. The bell jar 13 is then evacuated to a pressure of approximately 5×10^{-6} mm. Hg by a vacuum system (not shown). The upper heater filaments 30, 31 and the lower heater filaments 52, 53 are then energized and the resulting temperature in the region of the slab is measured through thermocouple 54. For the emitter electrodes, which usually are of aluminum, a preselected temperature of approximately 500 degree centigrade is generally employed to improve the sticking or wetting of the contact metal on the slab.

After the wetting temperature for aluminum is reached, the correspondingly aligned apertures in the mask assembly 50 are shifted laterally, if not previously done, to coincide with a first set of predetermined emitter electrode areas on the slab to be vapor deposited. This is accomplished by the selective actuation of the bimetal drives which position the stylus 42 against the appropriate step of the program block 45. The platform 56 is then rotated until a cavity 57 with a charge of aluminum therein is positioned directly over the heating element 60. Upon energizing heating element 60 and raising the charge of aluminum to the proper temperature, the resulting charge vapors successively pass through the correspondingly aligned apertures of the pressure plate 51, retainer plate 98, apertured mask 90 and blanket 85 before being deposited on the specimen. The thickness of the electrodes deposited is readily determined by the time interval that the heating element is energized and/or by the amount of charge material vaporized. This information is specifically correlated in any well known handbook as, for example, "Vacuum Deposition of Thin Films," by L. Holland, John Wiley, 1956. The temperature may then be increased to alloy the aluminum into the slab so as to

form the emitter junction or this step may follow the vapor deposition of the base electrodes.

To place a plurality of base electrodes on the slab in juxtaposed relation with the emitter electrodes, respectively, the temperature in the region of the slab is lowered to its wetting temperature for gold or gold-antimony, which is approximately 300 degrees centigrade. Thereafter, the correspondingly aligned apertures in the mask assembly are again shifted laterally to provide the requisite spacing between electrodes through the selective actuation of the bimetal drives. The platform 56 is then rotated until a cavity 57 with a charge of gold therein is positioned directly over the heating element 60. Heating element 60 is then energized and the charge of gold vaporized on the appropriate base electrode areas of the specimen to the desired thickness. The temperature within the enclosure is then increased to alloy the gold into the slab to form the base junction.

In accordance with the invention, as many spaced electrodes per set may be vapor deposited on the slab in this manner as there are steps in the program block to effect the successive, requisite lateral displacements of the mask assembly apertures relative to the slab.

After the electrodes have all been formed and alloyed into the slab, the platform 56 may be rotated so that a cavity 57 containing, for example, an appropriate oxide powder or wax is located directly above the heating element 60. The bimetal drives may then be selectively actuated so that the stylus 42 bears against a particular step of the program block that aligns the mesa apertures 91 of the apertured mask 90 directly over the transistor mesas 44 of the semi-conductor slab. The heating element 60 may then be energized to a suitable temperature for vaporizing, for example, a wax coating on each of the transistor mesas 44 in the same vacuum cycle utilized for vaporizing the metallic electrodes 43.

The appearance of a typical semiconductor slab fabricated in accordance with the invention with a plurality of vapor deposited sets of base and emitter electrodes 43 and associated wax coated mesas 44 is shown in FIG. 5.

After the vapor deposition process, the portions of the semiconductor slab that have not been wax coated are normally etched away by a chemical process to a thickness which is below the diffused base junction. This facilitates the subsequent breaking of the slab into minute pieces defining the individual transistor, e.g., by "scribing" the slab with a diamond point into the appropriate sections and then breaking it along the scribe marks. A plurality of transistors, which may number as many as 900, depending on their size, are readily fabricated in this manner.

It is to be understood that the specific embodiment described herein is merely illustrative of the general principles of the instant invention. Appropriate apertures may, for example, be provided in the mask assembly to diffuse into the surface of the slab the appropriate materials which form the base and emitter layers prior to the step of vapor depositing the electrodes on the slab. In other words, a transistor mesa may be formed as well as oxide or wax coated with apparatus embodying the features of the instant invention. Numerous other structural arrangements and modifications as well as applications therefor may be devised in the light of this disclosure by those skilled in the art without departing from the spirit and scope of this invention.

What is claimed is:

1. The method of vapor depositing in one vacuum cycle, both a plurality of sets of juxtaposed metallic electrodes on a semiconductor specimen and a nonmetallic coating over said sets of electrodes, the electrodes in each set being of at least two different metals, respectively, comprising the steps of masking all areas on one surface of said specimen other than a first electrode area in each set to be vapor-deposited with a first contact metal, evaporating said first contact metal on said first electrode areas,

masking all areas on said one surface of said specimen other than a second electrode area in each set to be vapor-deposited with a second contact metal, evaporating said second contact metal on said unmasked second electrode areas, masking all areas on said one surface of said specimen other than said first and second electrode areas and the space therebetween in each set, and the vapor-depositing a nonmetallic coating on said last mentioned unmasked areas encompassing each set of areas.

2. Apparatus for the vapor deposition of materials onto juxtaposed surface areas of a work-piece, comprising a chamber capable of being evacuated and including therein a base for supporting a work-piece, a hinged framework movably mounted on said base, masking means with predetermined apertures supported by the framework and superpositioned with said work-piece, means for moving the framework and thereby said masking means relative to said work-piece, means on the side of said masking means opposite said work-piece for evaporating at least one evaporant material through said apertures onto the surface of said work-piece, and means for programming the lateral movement of said framework relative to said work-piece independently of temperature over a distance subdivided into a plurality of distinct, preselected stops.

3. Apparatus in accordance with claim 2 wherein said means for programming the movement of said framework comprises a stepped program block supported thereon and further including a stylus rigidly affixed to said base, and means for normally biasing one end of said stylus against a preselected step of said program block.

4. Apparatus in accordance with claim 3 further including first means for moving said program block in a first predetermined direction away from said stylus and second and third means for selectively moving said program block laterally in mutually opposite second and third directions perpendicular to said first predetermined direction.

5. Apparatus in accordance with claim 4 wherein said first, second and third means each comprises a bimetal drive mounted on said stationary base and are selectively actuated by means remote to said apparatus.

6. Apparatus for making microscopically small coatings in juxtaposed relation on a surface of a work-piece, said apparatus comprising an enclosure capable of being evacuated, a hinged parallelogram framework including a stationary base, two movable side walls and a movable bottom plate, vaporization means for evaporating at least one vaporant material on predetermined surface areas of said work-piece, masking means interposed between said work-piece and said vaporization means and supported on said bottom plate, said masking means having a plurality of apertures comprising at least one set in register with predetermined areas of said work-piece, means for precisely moving said masking means laterally relative to said work-piece over a distance subdivided

into a plurality of preselected subdistances, said means including a stepped program block supported by said framework and movable with said bottom plate, the height of successive steps in said program block being determinative of the lateral displacement of the masking means relative to said work-piece.

7. Apparatus in accordance with claim 6 further including a stylus affixed to said stationary base and having one end normally spring-biased against the stepped surface side of said program block.

8. Apparatus in accordance with claim 7 further comprising first heater means mounted on said stationary base for heating said work-piece to a preselected temperature prior to the vapor deposition of material on the surface thereof.

9. Apparatus in accordance with claim 8 further comprising means mounted on said bottom plate for heating said work-piece in cooperation with said first heater means.

10. Apparatus in accordance with claim 7 wherein said means for moving said masking means laterally further includes means for abutting said stylus selectively against different steps on said program block, said means comprising at least three bimetal drives actuated externally of said enclosure, said bimetal drives selectively moving said program block laterally from said stylus in mutually perpendicular directions.

11. Apparatus in accordance with claim 10 wherein a succession of small step increments in said program block register a plurality of small apertures in said masking means with a plurality of juxtaposed sets of areas on the surface of said work-piece and wherein at least one large step increment in said program block registers a plurality of large apertures in said masking means with the surface area encompassing each of said sets of areas on the surface of said work-piece.

12. Apparatus in accordance with claim 11 wherein said vaporization means includes at least two different metallic evaporant charge materials movable with respect to said masking means and further includes nonmetallic evaporant charge means movable with respect to said masking means for evaporating a nonmetallic protective coating through said large apertures in said masking means on the surface areas encompassing each set of juxtaposed areas on said work-piece.

References Cited by the Examiner

UNITED STATES PATENTS

2,614,524	10/1952	Haynes	118—49
2,745,773	5/1956	Weimer	117—45 X
2,969,296	1/1961	Walsh	117—106 X
3,066,053	11/1962	Hunt et al.	117—200 X
3,117,025	1/1964	Learn	118—504 X

RICHARD D. NEVIUS, *Primary Examiner*.