United States Patent

[11] 3,607,382

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[31] **S 112516**

[54] **METHOD OF PRODUCING PHOTOVARNISH MASKS FOR SEMICONDUCTORS**
14 Claims, 3 Drawing Figs.

[52] **U.S. Cl.** .... **117/212,** 117/5.5, 117/8.0, 117/8.5, 117/93.3, 250/49.5 T
[51] **Int. Cl.** **B44d 1/02,** B44d 1/18, B44d 1/50
[50] **Field of Search** .... 117/5.5, 8.5, 8.0, 93.3, 93.31, 212; 96/35.1, 36, 36.2; 156/8; 250/49.5 T

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ABSTRACT: Described is a method of producing photovarnish masks for semiconductors. A photovarnish layer, positioned on a workpiece, is selectively illuminated, whereupon portions of the photovarnish layer are removed through developing. The illumination is effected by means of a thin electron beam, moved essentially along a single coordinate direction. The photovarnish layer to be illuminated is moved perpendicularly to the movement direction of the electron beam. The respective movement length of the electron beam is limited according to the pattern of the photovarnish mask to be produced.

Fig.1

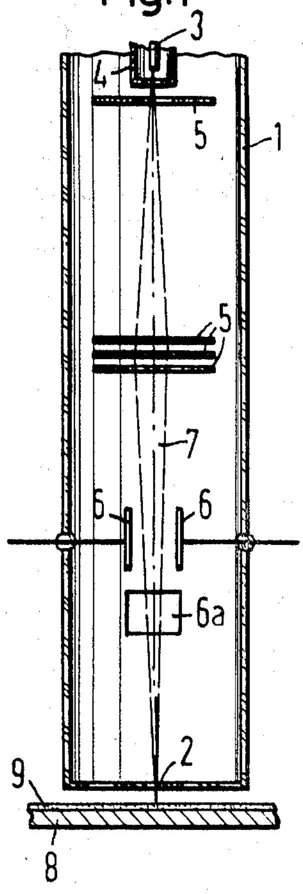


Fig.2

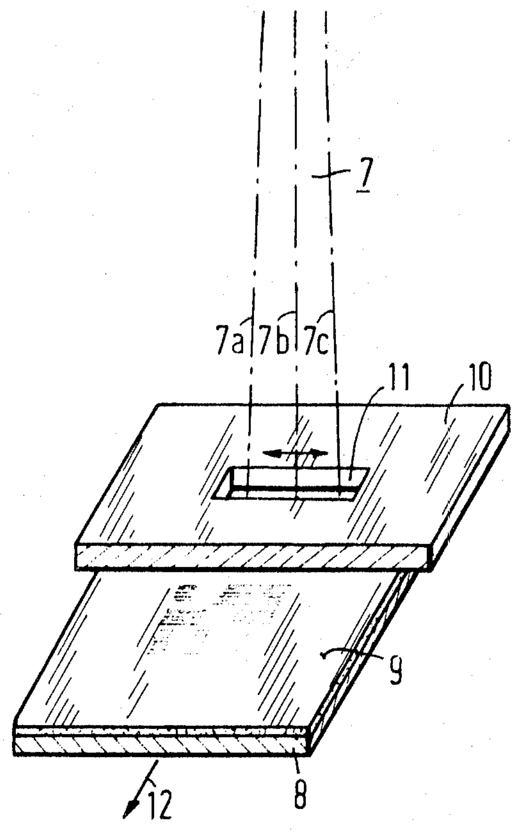
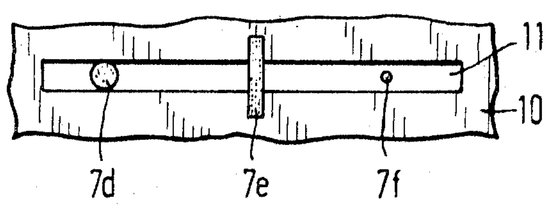


Fig.3



METHOD OF PRODUCING PHOTOVARNISH MASKS FOR SEMICONDUCTORS

The production of photovarnish masks for semiconductors entails the placing of thin layers of photovarnish upon the surface of a carrier body, more particularly a semiconductor wafer. The photovarnish layer is then locally illuminated and developed in a desired manner. Developing of the photovarnish layer results in windings therein which extend locally to the semiconductor surface. The remaining portions of the photovarnish layer continue to cover the semiconductor surface and offer protection for the subsequent treatment, especially against etching or vaporization processes. Usually, following the treatment process, the photovarnish layer is loosened or dissolved off, for example by means of acetone.

The defining or limited illumination of the photovarnish mask poses an optical problem because of the small size of the structure to be produced. The solution of this problem entails considerable technical expenditures, particularly since the minute size of the structures being produced often fall within the range wherein bending problems and similar optical manifestations are of great consequence. Thus, in the production of photovarnish masks for semiconductor components the boundary of optical dissolution is almost reached because structures must be reproduced which are in the order of magnitude of the light sources being used. One could consider shorter wave lengths but the optical instruments needed for this purpose require expensive special developments. Moreover, one is also bound to the sensitivity range of the photosensitive photovarnish layers. When the apparatus for the illuminating optics is enlarged, the depth sharpness is reduced so that the requirement of fine adjustment and the planeness of the carrier body would have to be increased almost to intolerable limits.

Electron beams whose wavelength, e.g. at 100 kv. accelerating voltage is approximately smaller by the factor 10^1 than visible light, are known to lend themselves to very fine bunching. This affords the opportunity to work with an aperture of about 10^1'so that a depth of field is obtained, which is greater by some orders of magnitude than that of a reproduction with light, despite the fact that the image spots are smaller by the factor 10 to 100. One could also consider to draw the mask images in an analogous manner, as a television image. However, this also entails great technical demands since the precision of the deflecting fields must be considerably higher than the one which is needed for television receivers, for example.

The present invention aims to circumvent all these difficulties and to obtain the required accuracy during the production of photovarnish masks in a relatively simple manner.

The present invention relates to a method of of producing photovarnish masks for semiconductors whereby a photovarnish layer which is placed upon a workpiece, for example a semiconductor is selectively irradiated and subsequently portions of the photovarnish layer are removed by means of developing. The method is characterized by the fact that irradiation is effected by means of a thin electron beam which is moved essentially along a single coordinate direction, whereby the photovarnish layer which is to be irradiated is moved perpendicular to the movement direction of the electron beam and the respective length of motion of the electron beam is limited in accordance with the pattern of the photovarnish layer which must be produced.

To perform the method in accordance with the present invention, an electron beam may be used, e.g. focused to a diameter of less than 0.2 μ., and moved only in one coordinate direction, e.g. a stretch of 1 to 2 mm. An electron beam which is moved only in one coordinate direction can be controlled much simpler and more accurately than if the control is required along two coordinate directions. There are various possibilities.

The invention will be further described with respect to the drawing in which:

FIG. 1 shows apparatus for carrying out the invention

FIG. 2 shows an auxiliary device; and

FIG. 3 is a enlarged detail of FIG. 2.

In FIG. 1, an evacuated cylinder **1** is provided with an outlet **2** for the electrons (if necessary sealed by a Lenard window), a known source for electron beams **3**, e.g. a glowing cathode, a Wehnelt cylinder **4**, various diaphragms **5**, a deflection device **6**, e.g. an electrostatic deflector, and various bunching devices. An electron beam **7** is moved back and forth in one coordinate direction when an alternating voltage is applied to said deflection device. The beam **7** impinges upon a photovarnish layer **9**, which is placed, for example, upon a semiconductor disc

To limit the travel length of the electron beam **7**, I may use a slot **11** which is produced in a thin sheet **10**, comprised of resistant metal such as tungsten or tantalum. In the example shown in FIG. **2**, this slot is arranged directly ahead of the photovarnish layer **9** as seen from the source of the electron beam **3**. Furthermore, in the example, the photovarnish layer **9** with its carrier **8** is located outside the device which produces the electron beam **7**. The slot **11** may also be coated at the issue point **2** of the electron beam or be identical therewith. As a last possibility, the photovarnish layer **9** and the slot **11** may also be placed within the device which generates the electron beam **7**. The "writing" length of the electron beam **7**, determined by slot **11**, is indicated as **7*a*** and **7*c*** with the middle position **7*b***. Compared with the corresponding dimension of the geometry to be illuminated, the width of slot **11** is very slight. The slot **11** (see FIG. **3**) may either be traversed in its entire width by the approximately circular cross section **7*d*** of the electron beam **7**, or it may be covered by an electron beam cross section which is a line-focused perpendicular to the length of the slot (**7*e*** in FIG. **3**). In all such cases, the "writing" width of the electron beam **7** on the photovarnish layer **9** is determined and limited by the width of the slot **11**. It is therefore frequently preferred to operate with extremely narrow slots with exactly parallel boundaries.

On the other hand, there is a possibility for a very fine focusing of the electron beams. In this case, as seen at **7*f*** in FIG. **3**, the writing width becomes slighter than the width of the slot **11**, but even in these cases a wider writing track may be desired. In such an event, a weak, additional motion will be given to the beam, by means of a second pair of deflection plates **6*a***. This additional motion runs perpendicular to the length of the slot **11** or generally to the "writing direction." Frequently, a circular fluctuation of movement by $\pm 0.5\mu$ is sufficient, whereby said circular fluctuation of movement is rapid compared to the main writing motion.

In all movements of the electron beam, which can be controlled by electrical as well as by magnetic fields, care must be taken that the area of the photovarnish layer **9**, to be illuminated or irradiated by the writing electron beam, is so densely filled with writing, so that during the subsequent development of the photovarnish layer, the area will behave uniformly, i.e., depending on the type of photovarnish, either be loosened uniformly from the carrier **8** or be maintained uniformly.

It should also be mentioned that the carrier **8** with the photovarnish layer **9** may be arranged in the same vacuum (high vacuum) as the electron beam device, as well as in a poorer vacuum (fine vacuum) and even outside the vacuum chamber. One must make sure, however, that in each case enough electrons impinge with adequate bunching upon the photovarnish layer.

The shifting of the photovarnish layer **9** is preferably controlled by laser beam interferences. This affords an adjustment accuracy of two adjacent writing positions, corresponding to the periodicity of the interference stages of less than one-quarter of the employed wavelength. When a helium/neon laser is used, this amounts to less than 0.16 μ. The writing motion of the electron beam may be released through each interference passage. Even though it is possible to let the electron beam run back and forth during the wiring process, in the main wiring direction, very often only one writing direction is preferred, for example from left to right. This also applies particularly when the control is effected through interference passages. During the return run, which should be very rapid, the electron beam becomes dim. For interference control during writing, the varnish layer should remain stationary. The next writing position of the photovarnish layer should be adjusted only during the return run, for example at a distance of $\lambda/4$.

Since in this case an "one"-"off" control is enough for the electron beam intensity, the electrical stimulations may be stored in a digital data memory. If the deflection in writing direction and the motion of the photovarnish layer are also effected digitally, i.e., in many defined steps, the entire program for writing a mask image can be consolidated in a small data memory. This eliminates the necessity for providing an original image of the mask since only the data memory with the respective coordinator magnitudes needs to be programmed. The feeding is possible, e.g. with perforated tapes, magnetic bands, etc.

Due to the high writing speeds obtainable with electron beams, displacement speeds of the workpieces, which carry the photovarnish layer, of up to an order of magnitude of 50 cm./sec. are feasible. If the sensitivity of the photovarnish is insufficient with respect to energy rich electron beams, then the photovarnish may be made sensitive specifically for energy-rich electrons. To this end, I use heavy atoms, respectively such atoms which easily emit secondary electrons. This affords the possibility to "draw" a mask image retained by a data memory, many thousands of times, in a raster, upon a semiconductor wafer coated with photovarnish. This eliminates the use of contact copies, projections and auxiliary masks. The problem of adjusting various structures, stacked upon each other, may be solved as follows: At specific places of the semiconductor wafer, nondisturbing, small defined spots of material are vapor deposited or indiffused into specific places of the semiconductor wafer at which X-ray fluorescence occurs, due to the effect of the electron beams (such as spots of tungsten, molybdenum, osmium, platinum/iridium, titanium/barium or spots of doping material). When the electron beam impinges upon such spots, X-ray beams of a specific wavelength occur. With the aid of an X-ray receiver, adjusted to this wavelength, one can determine when such an indicator spot enters the range of the writing electron beam or when it leaves the same and, thereby, one can establish also the position of the disc or another workpiece having a photovarnish layer, with respect to the "wiring" electron beam **7**. To indicate the positions, secondary electrons or reflecting electrons may be used in place of the X-ray beams.

The movement of the photovarnish layer may be effected continually, but may also be switched on in stages, in such a way, for instance, that following each to and for passage of the electron beam between the extreme positions *7a* and*7c*, the photovarnish layer advances, perpendicular to the connecting direction between positions *7a* and *7c*, by a distance which approximately corresponds to the width of the electron beam.

Frequently, complicated illuminating structures or a plurality of equal illuminating structures, e.g. rows of mask images, must be produced upon the photovarnish layer, It must, then, be ensured that said rows of mask images lie in sequence behind one another in the direction of the motion of carrier **8**. When one arrives at the end of the carrier, e.g. at the edge of the silicon disc, the carrier is returned, then pushed forward by one strip width and, in exact parallel to the preceding width, writing of the next row of mast, images is resumed. Thus, one row is written next to the other until the carrier is covered with mask images. In this regard see FIG. 2

The rows are determined with respect to one or several marks or fixings (buffers, jigs, dogs, etc. and then mutually displaced by a specific number of interferences. The covering uniformity of the various mask images in one row can also be easily achieved, since relating to one or several marks or fixings secured on the carrier itself one always starts at the appropriate number of interference passages, in the displacement direction of each mask image. Precision is required only during the deflection of the electron beam across the region of a mask image, in a coordinate. Especially suitable for this purpose are not so much the conventional round semiconductor discs, used as substrates, but rather, drawn out, long, narrow tapes of silicon or germanium. In the case of narrow tapes, it is possible to operate fully continuously and, if necessary, to write parallel rows of mask images, with several electron beams which may be synchronously controlled. When using wider, short tapes, the return and the displacement of the strips can be repeated less frequently than in round discs.

In some instances it may be necessary or preferable to omit certain mask images in order to draw in other figures in their place, e.g., for the purpose of controlling the process. The method also makes it very easy to install at specific places, other circuits in order to carry out large-scale integration. To this end, the recording image must only be recalled for the specific places, from another memory.

Even without the use of a slot **11**, mask images can be produced in accordance with the present method. For example, an alternating voltage will then be used, simultaneously, with the displacement of the photovarnish layer **9**, between the plates of the deflection device **6**. This produces, synchronous to the motion of the photovarnish layer **9**, the desired illuminating geometry on the photovarnish layer, e.g. by using controlled and, if necessary, variable writing lengths.

The limitation of the movement of the electron beam is determined in the just described embodiment by the respective magnitude of the deflecting voltage at the deflection plates, A possibility exists, also, to maintain the deflection voltage constant between the plates **6** and to scan the intensity of the electron beam **7**, e.g., in a known manner, via the Wehnelt cylinder **4**. The electron beam may be completely blocked, e.g., at the boundary positions *7a* or *7c* by appropriately high biasing potentials, applied at the Wehnelt cylinder. Another possibility is the blocking of the intensity, for example around the middle position of the electron beam *7b*, while the electron beam is not blocked in the extreme deflections *7a* and *7c*. This affords the writing of ring structures without the use of any masks. The displacement of the electron beam or the control of its intensity and the motion of the photovarnish layer are synchronously controlled by known measures. These are not described in greater detail since they are known. The desired surface of the photovarnish layer is illuminated and the desired mask geometry appears after the photovarnish layer **9** has been developed. If the aforementioned superimposition of the electron beam is used with a small movement amplitude, directed perpendicular thereto, then, in accordance with the present invention, control of said movement will be relinquished and said lateral deflection, wobbling, will be effected by means of a small auxiliary voltage applied between two auxiliary plates or through a magnet coil (not shown in the drawing).

I claim:

1. Method of producing photovarnish masks for semiconductors, whereby a photovarnish layer positioned on a workpiece is selectively irradiated, whereupon portions of the photovarnish layer are removed through developing, said irradiation is effected by means of a thin electron beam, movable essentially along a single coordinate direction, moving the photovarnish layer to be irradiated perpendicularly to the movement direction of the electron beam with the respective movement length of the electron beam limited according to the pattern of the photovarnish mask to be produced, the electron beam being guided closely over the photovarnish layer which is to be exposed, so that the irradiated area will be uniform during the following development of the photovarnish layer.

2. The method of claim **1**, wherein the movement length of the electron beam is limited by the edge of a slot shaped pattern.

3. The method of claim **2**, wherein the electron beam is moved along a slot and the photovarnish layer to be illuminated is guided perpendicularly to the longitudinal direction of the slot.

4. The method of claim 1, wherein the electron beam being used is focused upon a maximum diameter of 0.2 μ., and is essentially moved to and fro by about ±1 to 1 mm., in one coordinate direction.

5. The method of claim 1, wherein the irradiation of the photovarnish layer is effected in the same vessel as the production of the electron beam.

6. The method of claim 1, wherein the gas pressure in the vicinity of the photovarnish layer to be irradiated is adjusted higher than in the generating device of the electron beam, whereby the electron beams are guided from a high evacuation vessel via a Lenard window into an area of higher pressure which contains the photovarnish layer.

7. The method of claim 6, wherein the electron beam is given, in addition to its main movement direction, a small movement component, travelling back and forth perpendicularly to the main movement direction.

8. The method of claim 1, wherein the displacement of the photovarnish layer below the electron beam is controlled by laser interferences.

9. The method of claim 8, wherein the movement of the photovarnish layer, perpendicular to the deflection device of the writing electron beam, is measured by laser interferences and the writing movement of the electron beam is repeated according to a given number of interference passages.

10. The method of claim 1, wherein the electron beam is guided in only one direction across the photovarnish layer to be irradiated, while a movement in the opposite direction is effected in a "darkened state" of the electron beam.

11. The method of claim 10, wherein irradiating traces of the writing electron beam, which runs parallel to each other, are arranged so densely with respect to each other that the area filled with writing by the electron beam behaves uniformly during subsequent developing processes whereby the writing traces overlap one another.

12. The method of claim 11, wherein the electron beam is scanned along its writing path, so that the simultaneous writing upon the carrier produces the mask image perpendicularly to the writing direction of the electron beam.

13. The method of claim 12, wherein following the creation of a row of discreet illuminating places, arranged in displacement direction of the photovarnish layer, the carrier is returned to its original position so that, in parallel to said row, a second row may be filled with writing.

14. The method of claim 1, wherein the photovarnish layer to be illuminated is made more sensitive to electron beam illumination.

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,607,382 Dated September 21, 1971

Inventor(s) Heinz Henker

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the cover sheet insert -- [73] Assignee Simens Aktiengesellschaft, Berlin, Germany --.

Signed and sealed this 18th day of July 1972.

(SEAL)
Attest:

EDWARD M.FLETCHER,JR.
Attesting Officer

ROBERT GOTTSCHALK
Commissioner of Patents

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