

June 20, 1967

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3,326,176

WORK-REGISTRATION DEVICE INCLUDING IONIC BEAM PROBE

Filed Oct. 27, 1964

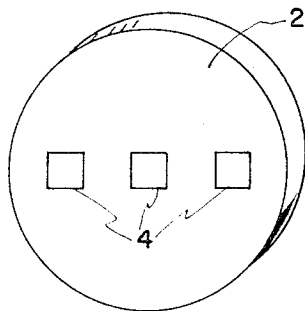


Fig.-1

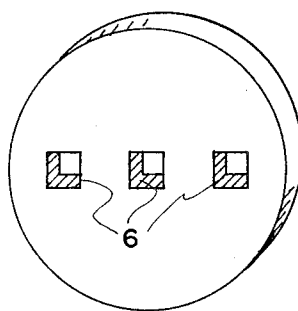


Fig.-2

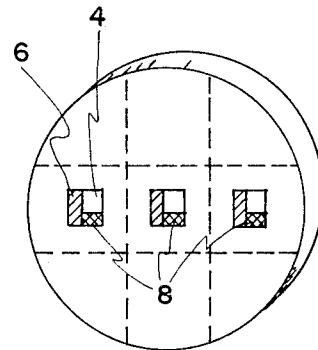


Fig.-3

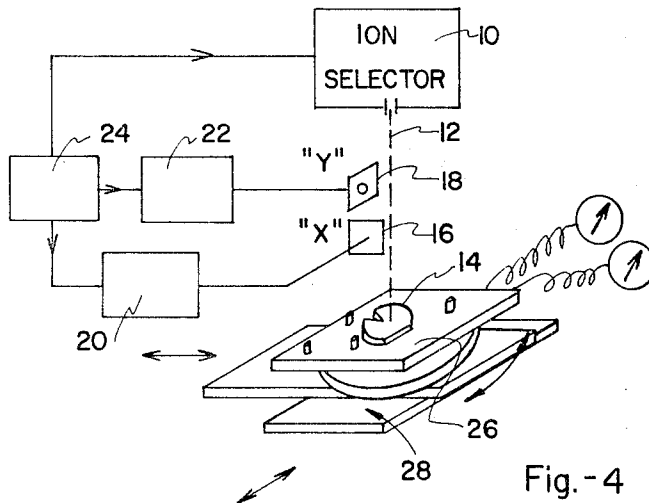


Fig.-4

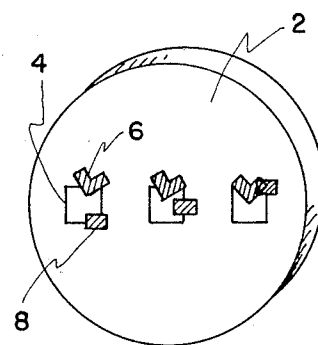


Fig.-3A

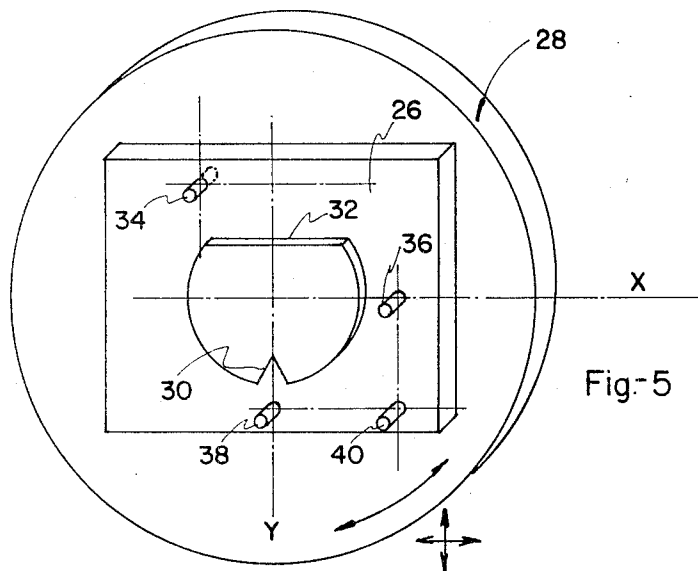


Fig.-5

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WORK-REGISTRATION DEVICE INCLUDING
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Filed Oct. 27, 1964, Ser. No. 406,707

4 Claims. (Cl. 118—6)

The present invention relates to ion beam processing systems and more particularly to ion implantation systems used in the processing and production of microcircuits, integrated circuits and microminiaturized electric circuit components.

Ion implantation is taught in U.S. Patent 2,787,564 to Shockley and U.S. Patent 2,842,466 to Moyer and ion surface deposition is taught in U.S. Patent 3,117,022 to Bronson et al. Patents 2,666,814; 2,691,736 and 2,750,541 are also of interest. It is also known to etch a surface using an ion beam. It is a common problem of all these processes to provide a program for deflection of the ion beam and provide a reliable and repeatable registration of the program with the workpiece to be bombarded with ions.

It is the object of this invention to provide a means for aligning a workpiece in an ion beam processing chamber prior to bombarding it with ions to write a predetermined ion pattern (1) so that the ion pattern will be set in the right location and orientation with respect to the workpiece (2) so that the deflection sensitivity of the program writing deflection amplifiers can be checked out prior to writing the pattern, and (3) so that the registration and check out steps can be automated for mass production usage of the ion beam processing system.

The invention accordingly comprises an improved ion beam processing apparatus, including novel articles in the apparatus and the combination of conventional articles with each other and with the novel articles in the apparatus, the scope of which will be indicated in the claims.

Briefly stated, the invention utilizes the ion beam to seek check points around the workpiece, and utilizes the workpiece and ion beam deflectors to get the predetermined pattern of ion beam impingement in register with the desired location of the workpiece. The deflectors are then checked out for proper operation. Then the system is ready for the feeding of a predetermined program to the ion source and ion deflectors to write the desired ion beam pattern.

A preferred embodiment of the invention is now described with reference to the accompanying drawings, wherein:

FIGS. 1, 2 and 3 are diagrams of wafers at various stages of ion beam processing;

FIG. 3A is a similar diagram of a wafer processed with improper registration;

FIG. 4 is a diagram of an ion beam processing system according to the preferred embodiment of the invention; and

FIG. 5 is an expanded view of the work support means of the FIG. 4 system.

FIGURES 1-3A

FIGURE 1 shows a wafer which is bombarded with ions to form the blocks 4. Only three blocks are shown for purpose of illustration, but those skilled in the art will appreciate that hundreds of blocks can be formed in a one-inch diameter wafer. The wafer is then shifted to a new processing chamber for exposure to ions of another material or exposed to a new ion source in the same chamber for a second ion bombardment step. The second bombardment step produces the blocks 6 in alignment

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with the blocks 4 as shown in FIG. 2. A third ion bombardment step produces the blocks 8.

Typically, the wafer 2 could be made of silicon. The block 4 could comprise donor impurities implanted in the wafer and the block 6 could comprise implanted acceptor impurities, forming a junction diode with block 2, while the block 8 could comprise a deposited contact. The wafer is diced along the dashed lines of FIG. 3 to provide individual circuit blocks.

Each ion bombardment step entails deflection of ions emerging from a source to write a predetermined pattern on the wafer. It is necessary to provide proper registration of the deflection system with the wafer from step to step. The results of improper registration are indicated, in exaggerated form, in FIG. 3A.

FIGURE 4

Referring now to FIGURE 4, a preferred embodiment of apparatus is described. An ion selector 10 is arranged to emit a collimated beam of ions 12 of a selected mass against a workpiece 14. The ion selector comprises a conventional analyzer section (e.g. of the magnetic type or massfilter type) and a source of ions of the desired dopant element, e.g. phosphorus, and a mass selector for separating the ions from ions of other masses which are present in the source and accelerating the desired ions toward the workpiece. A typical ion source is described by Knight in Proceedings of the 1961 Symposium of the American Vacuum Society (Pergamon Press, 1962) pp. 265-270. This source is reported to be capable of focusing a 30,000 electron volt beam of argon ions to a current density of 30 milliamperes per square centimeter at a distance of 15 inches from the source. This is equivalent to 0.15 microampere in a 25 micron spot. Half the area of a one inch diameter wafer having several small areas to be implanted (about 12 square mils of area each) on a workpiece can be implanted to 5×10^{14} ions per square centimeter in about 5 minutes.

The ion beam 12 is deflected along X-axis and a Y-axis by electrostatic deflectors 16 and 18, respectively, which are controlled by deflection amplifiers, 20 and 22, respectively. The deflection amplifiers are controlled by a programmer to deflect the ion beam over a predetermined path to "write" an integrated circuit on the workpiece or to make a plurality of individual circuits or components on the workpiece which can later be separated by known dicing techniques. The programmer can also control the ion selector 10 to stop the beam, if desired, while the deflection amplifier program is changing the voltage at the deflectors. One mechanism of cut-off is by an electrostatic cut-off grid (not shown) located in the ion source structure and responsive to the programmer. Another preferred mechanism of cut-off is by deflection over an aperture. The deflection at the workpiece along the X and Y axes, for purposes of ion implantation, should be on the order of ± 1.25 centimeters.

The programmer 24 comprises a taped program which is fed to a reader to change the signals from digital to analog, for transmission to the deflection amplifiers and the ion selector. Such deflection amplifiers are in commercial use for controlling electromagnetically deflected electron beams.

The workpiece 14 is a silicon wafer which is specially edged as described below. It is mounted by clamping in place on a worktable 26 having electrical contacts, as described below.

The work table is mounted on a conventional work holder 28 movable in the X, Y, and rotary directions. The work holder may be of the type used in milling machines or electron beam welders. The entire path length of the ion beam from source to workpiece is enclosed by vacuum chamber structure (not shown). A vacuum of about

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10⁻⁸ Torr is maintained throughout the working region to avoid contamination.

Unfortunately, the repeatable use of the programmer for controlling the processing of one wafer after another, from run to run, is limited by the difficulty of registration of the workpiece with the program. It is difficult for an operator to control the registration; because, unlike the high energy electron beam machining beams, the ion beam may not produce a visible spot on the surface of the workpiece.

FIGURE 5

According to the invention, this difficulty is overcome by the use of a special technique described below. Preferred apparatus for this technique is described in connection with FIG. 5 of the drawings which is an expanded schematic view of the workpiece 14 and worktable 26 of FIG. 1. The workpiece is provided with specially machined flat and grooved edges, as shown, for aligning it with corresponding clamps (not shown) on the worktable. The worktable is made of an insulator material and is equipped with four conductive probes. A first one of the probes, probe 34, is aligned with the center of rotation of the workholder 28. The other three probes, 36, 38 and 40, form a right triangle, the legs of which correspond to the X and Y axes of ion beam deflection. This relationship can be established by hand using a microscope or with an automatic work feeder.

The probes consist of .001 inch diameter tungsten wires. Banana plug extensions of the probes are used to plug the worktable into the work holder 28 which has corresponding sockets. The programmer includes signals for X and Y adjustments corresponding to the X and Y coordinates of each of the probes and also includes a zero setting for the intersection of lines X and Y indicated in FIG. 2. Sensitive ammeters are connected to each of the probes.

The procedure for checking registration is to set the deflectors' signals at the -X and -Y coordinates corresponding to the expected location of probe 34. In the case where the deflection program and workpiece are properly registered, the ion beam will strike probe 34 and a maximum current will register on the ammeter connected to probe 34. Movement of the workholder in the X and Y directions will decrease the current. Where the program is out of registration with the workpiece, the X and Y positions of the workholder are adjusted until a peak signal is obtained from probe 34. Then the beam is switched to the +X and +Y coordinates corresponding to probe 40. Rotation of the workholder, and possibly X and Y adjustment, may be necessary to get a peak signal from probe 40.

Then the X and Y zero settings are checked by trying to peak on probes 38 and 36, respectively. This provides a measure of deflection sensitivity of the respective deflection amplifiers.

After alignment and sensitivity check out, it is only necessary to switch on the program and implant the desired dosage. This makes it possible to automate the processing of wafers. An analog computer can be used to automatically perform the above-described alignment steps in combination with servomechanisms for controlling the workholder.

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It will be understood that the improved ion beam processing system can be used with various gases, e.g. nitrogen, argon, xenon, boron or vapors of metals such as aluminum, indium, tin. Where electrostatic type deflectors are used, one gas can be used for the registration and another for writing steps since electrostatic deflection is mass insensitive. Another possible variation is to form the probes within the workpiece by prediffusion. It is therefore intended that the above description and the drawings shall be read as illustrative and not as limiting.

What is claimed is:

1. In an ion beam processing system for selectively bombarding surface portions of a workpiece with a focussed beam of ions and comprising a chamber, means for evacuating the chamber, work support means for supporting the workpiece in the chamber on a surface of the work support means, means for forming ions, means for accelerating said ions to the workpiece as a focussed beam, means for deflecting the ion beam, program control means for automatically controlling said deflecting means so that the ion beam produces a predetermined pattern and location of bombardment with respect to predetermined reference coordinates set in said control means, means for adjusting the work support means to change the orientation of the workpiece to bring the reference coordinates of said control means into registry with predetermined reference coordinates on said work support surface, and wherein the work support means comprises first and second conductive probes which are insulated from each other and located on said work support means on the same surface as the workpiece and adjacent to the workpiece but spaced from each other, said probe locations being points on said predetermined coordinates of the work support surface and means for extracting and measuring electrical current through said probes when the said ion beam is deflected to strike said probes to produce a signal indicative of registration or lack of registration of the said control means coordinates with the said work surface coordinates.

2. The ion beam processing system of claim 1 wherein the probes are located on opposite sides of the work and wherein the said means for moving a portion of the work support means rotates said work support means about an axis defined by the first probe.

3. The ion beam processing system of claim 2 further comprising additional conductive probes located on said work support and insulated from each other and from said first and second probes, the additional probes being located so that they form lines with said second probe which correspond to the directions of ion beam deflection provided by said ion beam deflection means.

4. The ion beam processing system of claim 3 wherein the conductive probes are formed by wires.

References Cited

UNITED STATES PATENTS

2,640,948	6/1953	Burrill	219—121
3,112,391	11/1963	Sciaky	219—124

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