United States Patent

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[72] Inventor **Bryan H. Hill**
Dayton, Ohio

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[54] **ION IMPLANTATION MEANS INCLUDING A VARIABLE RATIO ION SOURCE**
1 Claim, 1 Drawing Fig.

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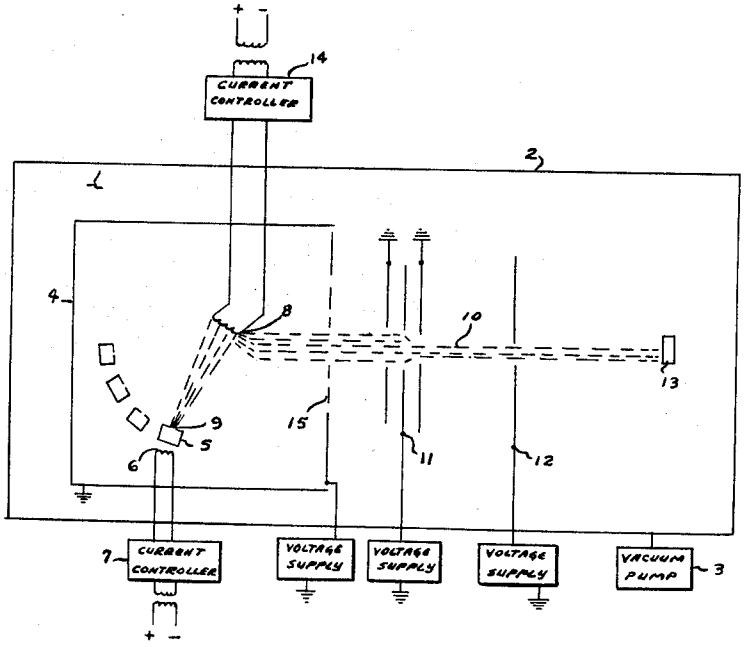
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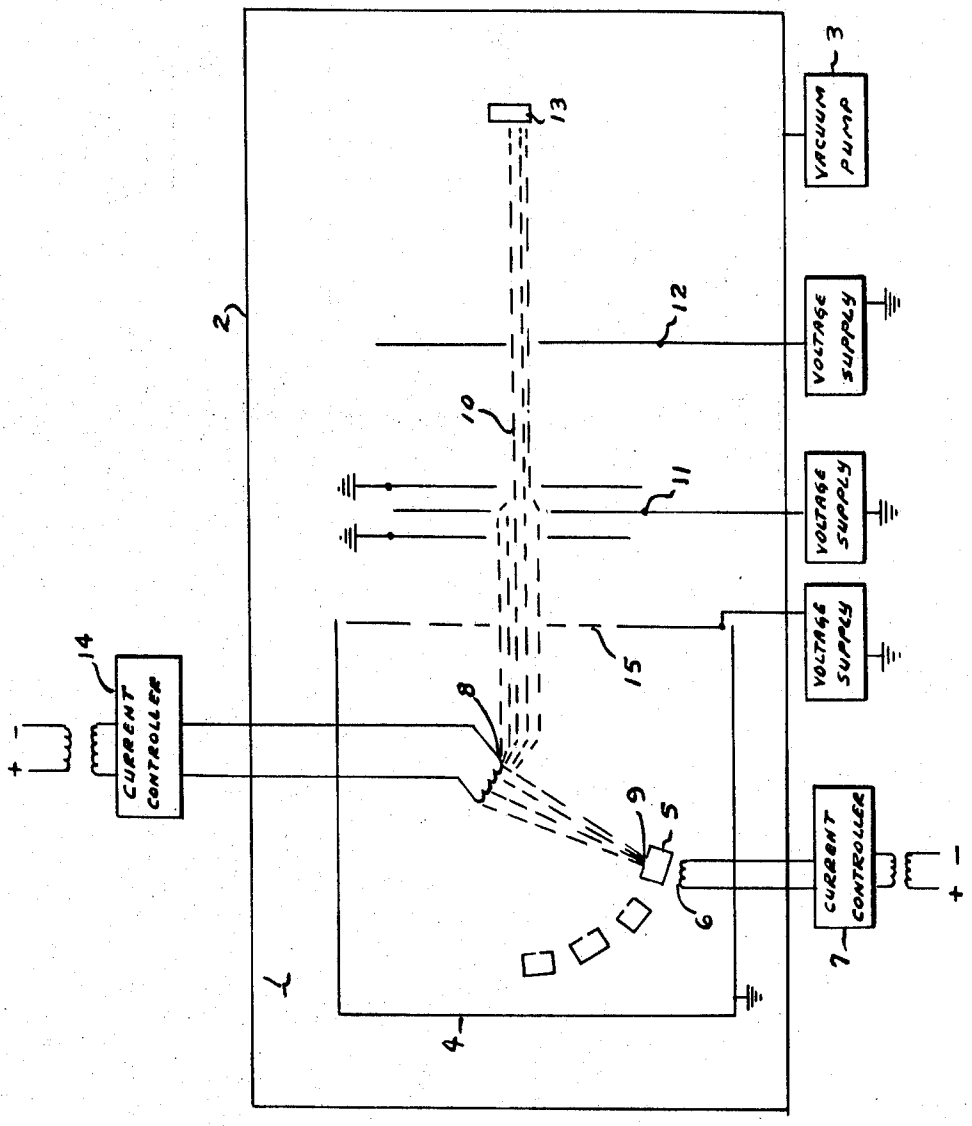
Primary Examiner—Morrid Kaplan
Attorneys—Harry A. Herbert, Jr. and Robert Kern Duncan

ABSTRACT: An ion source capable of producing an ion beam comprised of a plurality of controlled ion species. A plurality of effusion cells, each containing a particular evaporant, are positioned at equal distances from a hot ionizing surface. The number of molecules effusing from the respective effusion cells are controlled, thereby controlling the ratio of the molecules effusing from a particular cell with respect to the sum total of the molecules effusing from all the cells. The molecules, as they exit from each effusion cell, are directed to strike a hot ionizing surface where the neutral atoms are ionized. The ions are then extracted from the ion chamber to be deposited on some substrate.



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3,566,829



INVENTOR.
BRYAN H. HILL

BY Harry A. Herbert Jr.

ATTORNEY

ION IMPLANTATION MEANS INCLUDING A VARIABLE RATIO ION SOURCE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an ion source capable of producing an ion current composed of a plurality of controlled ion species.

2. Description of the Prior Art

In the manufacture of some types of semiconductor devices, the normal practice is to start out with a crystal and diffuse a desired impurity content into it in order to convey some desired electrical characteristic to the crystal. In general, this has been accomplished by placing a substrate in a hot furnace and passing a specific vapor over the substrate. This vapor diffuses into the substrate thus resulting in a semiconductor having the desired characteristics. The above method requires great amounts of heat which may cause some damage to the substrate and also requires prolonged periods of time if the semiconductor is to be doped to a high impurity content, i.e., degenerate material. Doping by diffusion is not the best method to use in the formation of PN junctions in a compound such as CdS, GaAs, SiC or in the formation of unique impurity profiles.

The instant invention permits the formation of semiconductor devices at relatively lower temperature and could be applied in the manufacture of interconnects, contacts, resistors, microcircuitry, etc. The invention further provides a method by which rather highly insoluble materials can be implanted onto a substrate. It also permits the simultaneous implantation or deposition of more than one element into a substrate in carefully controlled amounts. Thus, the instant invention, because of its simplicity, gives better control over the desired impurity profile and better control of the desired physical configuration of the implanted impurity.

SUMMARY OF THE INVENTION

The present invention relates to an ion source capable of creating multiple specie ions. The ion source consists of up to four effusion cells arranged equidistant from a hot ionization surface. Thus, the ion source is of the surface contact type whereby materials with ionization potentials below 6.3 ev. are placed in the respective effusion cells to be converted into a molecular beam. This molecular beam is directed into contact with a hot surface having a high work function which causes the atoms to become ionized. The individual ion species in the ion beam are controlled by controlling the number of molecules effusing from each individual cell. The ion beam is then focused and accelerated out of the ion source to a substrate which is to be bombarded or implanted. The velocity of the ion determines whether ion bombardment or ion implantation occurs.

BRIEF DESCRIPTION OF THE DRAWING

In the drawing the sole figure is a schematic of a multiple species ion source comprising the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the sole FIGURE which depicts a multiple species ion source assembly **1** positioned within the confines of a gastight tank shown generally at **2**. The operating pressure within the tank is brought down to vacuum levels by the pump **3**. Enclosed within a stainless steel housing **4** are up to four effusion cells **5** arranged equidistant from a hot ionizing surface **8** which has a high work function. For the sake of simplicity, only one cell is shown in detail. The effusion cells contain the evaporant which is vaporized when the temperature in the cell has reached the vaporizing point of the particular evaporant. The temperature is raised by passing current through high resistance wires **6** mounted therein by any suitable means and connected to some electrical source. The vapor pressure of each effusion cell is controlled by using a conventional saturable core reactor or current controller **7** to control the amount of current passing through the high resistance wires.

Exit orifices **9** are positioned to be on the side of each effusion cell facing the ionizing surface **8**. The dimensions of the exit orifices are very small in order to cause a molecular beam to be formed as the gas molecules exit through the orifice **9**. The molecules will tend to follow straight line paths as they exit from their respective effusion cells because of the low pressure within the ion source assembly **1**.

The effusion formula derived from the kinetic theory of gases gives the rate of effusion of the gas molecules through a small orifice, thereby enabling one to produce a molecular beam of known density. According to the kinetic theory of gases the gas in a low pressure effusion cell will move into an evacuated space (vacuum atmosphere) with velocities of the same magnitude and direction that they had upon passing through the effusion cell orifice. It should be noted that the pressure in the effusion cell is considered to be low when the mean free path of a molecule is large compared to the dimensions of the orifice. Therefore, the effusion formula describes the behavior of a molecular flow at a low pressure where the number of molecules effusing through an orifice **9** is equal to the number of molecules striking an area within the housing **4**. It is presumed that the effusion cell wall is of infinitesimal thickness at the edges of the orifice. The effusion formula can be written as:

$$Nn=\frac{N_oP}{\sqrt{2\pi MRT}}\ \frac{\text{molecules}}{\text{cm}^2\ \text{sec}}$$

where the elements of the above expression are defined as:

P—Vapor pressure
No—Avogrados number
M—Molecular weight
R—Universal gas constant
T—Absolute temperature
Nn—Number of effused molecules

It can be seen from the above relationship that the number of molecules effusing from a cell can be controlled or varied by the temperature in the effusion cell, thus allowing one to determine and control the desired ratio of several species of gas molecules as they effuse from different cells to form a total molecular beam. The number of molecules per cell (Nc) arriving at the ionizer **8** is:

$$Nc=\frac{N_oP}{\sqrt{2\pi MRT}}\left[\frac{A_1A_2}{S^2}\right]\frac{\text{molecules}}{\text{sec}}$$

where:

A1—effusion cell orifice area
A2—exposed ionizing area
S—distance from the cell orifice to the ionizer.

In the instant case, since there are four effusion cells, it can be seen that the composition of the molecular beam to be ionized is a summation of the molecules arriving at the ionizing surface **8** from each effusion cell.

There are several methods of producing ions; the method utilized in this invention is known as surface contact ionization. Ionization occurs by directing a material with a low ionizing potential i.e., below 6.3 ev. into contact with a hot metal surface having a high work function such as tungsten or rubidium. The ionizing surface is heated by passing current through it. The current is controlled by a core reactor or current controller **14**. The amount of ionization, or said in another manner, the ionization efficiency for each molecular specie must be controlled in order to have a controlled ion beam with specific molecular ion species for purposes to be disclosed. The surface ionization process depends primarily upon the difference between the work function $\theta 1$ of the ionizing surface **8** and ionization potential $\theta 2$ of the neutral atom. The greater $\theta 1$ is over $\theta 2$, the less energy required to detach the valence electron from the neutral atom. The ratio of the

number of atoms ionized by the ionizing surface **8** to the number of atoms directed to the surface **8** is given quantitatively by the Saha, Langmuir equation.

$$\frac{Ni}{N}=\frac{\phi 1-\phi 2}{{}_{e}KT}$$

where:

Ni—number of ionized molecules

N—number of molecules arriving at the ionizing surface.

Therefore, the ratio of a particular ion specie with respect to the total ion beam, can be controlled simply by controlling the temperature of the ionizing surface **8** and the temperature of the respective effusion cells.

The ions created at the ionizing surface **8** are subject to the forces of an electric field because of their positive charge. Therefore, an electric field is set up in the chamber by the electrostatic grid **15**. The grid which is negative with respect to the chamber causes the positively charged ions to move toward and pass through the grid and on through a three element electrostatic converging lens **11** for focusing into a narrow high intensity beam **10**. The central element of the electrostatic lens is biased by a variable potential source and the two outside elements are at ground potential. The electrostatic lens potential can remain fixed once the desired ion beam intensity is obtained. The ions, upon passing through the converging focusing lens, are further accelerated by the accelerating electrode **12** which is biased at a negative potential with respect to the ions. The ions upon passing through the accelerating electrode, because of the speed and direction, diffuse into the substrate **13**.

I claim:

1. An ion implantation device comprising a gastight tank, a substrate supported within said tank and in which ions are to be implanted, means for evacuating said tank, an ion chamber disposed in said tank and terminated at one end with an electrostatic extracting grid which is at a potential negative with respect to said chamber, an ionizing surface within said chamber having a high work function and means for controlling the temperature of said ionizing surface, a plurality of gas effusion cells positioned equidistant from said ionizing surface, each effusion cell containing an evaporant and having independently controlled means for heating by which to control the vapor pressure within each effusion cell, said effusion cells each having an exit orifice directing gas molecules into contact with said ionizing surface so as to cause the ionization of the neutral atoms, a converging focusing lens for receiving ions that pass through said extracting grid, an accelerating electrode biased negative with respect to the ions for accelerating the ions whereby to implant said ions in said substrate.