

Description

The present invention relates to an MeV ion implantation apparatus provided with an external resonance circuit type RFQ (radio frequency quadrupole) accelerator.

FIG. 2A of the accompanying drawings shows a known example of an arrangement of an MeV ion implantation apparatus having an RFQ accelerator. An ion beam emitted from an ion source 1 is accelerated by an RFQ accelerator 2 up to an energy in the order of MeV, and thereby, ion implantation into a sample substrate 5 is performed. FIG. 2B of the accompanying drawings is a drawing for describing a detailed arrangement of the RFQ accelerator 2. The RFQ accelerator has four electrodes 2a - 2d shaped in an undulated form within its RFQ container 2. Radio frequency power in the range from tens to hundreds of MHz is introduced into the cylindrical container 2 so that a radio frequency high voltage is induced at the undulated quadrupole electrodes 2a - 2d, and the ion beam is accelerated by the radio frequency field thereby generated.

The ion beam is accelerated when it moves along the centre axis of the space surrounded by the quadrupole electrodes 2a - 2d.

A description of an apparatus similar to the example of FIG. 2, is disclosed in EP-A-163745 (JP-A-60-121656).

In the known example, of the various ion species emitted from the ion source, only a specific ion species is accelerated to be implanted into the sample substrate 5 and other ion species are generally diverged during their acceleration within the undulated quadrupole electrodes to collide with the electrodes. Hence, the electrode material (copper in general) is sputtered by the ion beam and particles of heavy metal are deposited onto the sample substrate 5 thereby contaminating it. When the sample substrate 5 is made from a semiconductor material, the contamination by heavy metal will frequently cause fatal defects in the semiconductor characteristics leading to fabrication of inferior products.

Meanwhile, in the known example as shown in FIG. 2B, it is not possible to use material other than copper or similar materials as the material for undulated quadrupole electrodes. This is because, if radio frequency power is introduced into a cylindrical container 2 made from material other than copper, its electrical resistance becomes high and heat loss becomes great, thereby making it difficult to generate a radio frequency high voltage within the cylindrical container. In fact, it is known that the generated voltage is inversely proportional to $1/2$ power of the electrical resistance r .

The known RFQ accelerator shown in FIG. 2 has a basic problem other than the problem of the contamination by heavy metal. That is, since the cylindrical container 2 in the known RFQ accelerator was formed so as to have a specific size constituting the so-called cavity resonator, the operating radio frequency was limited to a specific frequency, and therefore, when the ion species is determined, the accelerating energy is determined and, hence, there has been a problem that there is only one choice of accelerating energy. In order to have accelerating energy of variable values, it is required to have the exciting frequency made changeable at will. A known example whereby this object is attained is shown in FIG. 3 (refer to EP-A-163745 or JP-A-60-115199). Referring to the figure, undulated quadrupole electrodes 2a - 2d are contained in the container 2. This container, however, is not a specific size so as to function as a cavity resonator. A radio frequency high voltage supplied to the electrodes 2a - 2d is generated in an electric resonance circuit formed of an inductor 9 and a variable capacitor 10. Variable frequency is obtained by changing the value of the capacitance C or inductance L , thereby changing the resonant frequency. That is, the electrodes 2a - 2d are only supplied with the voltage. Therefore, the portion for which materials with low electric resistance should be used to facilitate generation of the high radio-frequency voltage is limited only to the external electric resonance circuit comprising the inductance L , capacitance C . This is different from the prior art example of FIG. 2 wherein the radio frequency current in the resonance circuit does not flow into the undulated quadrupole electrodes. In FIG. 3, generation of the radio frequency high voltage can be achieved by forming the variable capacitor 10, inductance coil 9, and wirings from such materials as copper optionally coated with silver. Therefore, it is not required to fabricate the undulated quadrupole electrodes 2a - 2d from a metal of particularly low electric resistance, but it may be made from materials not liable to cause contamination of the sample substrate 5 by heavy metal.

In the case of the known example of FIG. 2, since it adopted the cavity resonator structure, it was essentially necessary to use low electric resistance material such as copper or silver for fabricating the undulated quadrupole electrodes 2a - 2d, but such electrical restriction on the material of the quadrupole electrodes 2a - 2d was first removed by the known example of FIG. 3 of the accompanying drawings. However, in connection with the known example of FIG. 3, there is not any consideration or structure, to prevent the implanted sample substrate from being contaminated by heavy metal particles, or as to selection of the electrode

material and methods to prevent the contamination by heavy metal particles.

In a first aspect the present invention, provides an external resonance circuit type RFQ accelerator, comprising undulated quadrupole electrodes for accelerating a beam of ions towards a substrate and comprising a separate radio-frequency resonance circuit for supplying a radio-frequency high voltage to the electrodes;

wherein:

at least one of the components of the apparatus which is exposed to the ion beam has a surface coated with silicon, doped silicon or carbon on an electrically conducting base so as to reduce particle contamination on the substrate due to the ion beam sputtering of the electrically conducting base material.

It is preferred that the quadrupole electrodes and the radio-frequency resonance circuit are contained in separate containers, the container containing the quadrupole electrodes being evacuated and its internal surface coated with silicon, doped silicon or carbon so as to reduce particle contamination on the substrate due to the ion beam sputtering of the electrically conducting base material.

It is also preferred that a plasma deposition mechanism for providing a coating is added to a vacuum container containing the component or components to be coated.

In a second aspect, there is provided an external resonance circuit type RFQ accelerator comprising undulated quadrupole electrodes for accelerating a beam of ions towards a substrate, and comprising a separate radio-frequency resonance circuit for supplying a radio-frequency high voltage to the electrodes; wherein said electrodes are formed of silicon.

Another aspect of the present invention is an ion implantation apparatus with an accelerator according to the first or second aspect above.

Generally, the undulated quadrupole electrodes 2a - 2d have complicated shapes and their surfaces are required to be smooth to prevent dielectric breakdown from occurring between the electrodes upon application of the high voltage. While the so-called NC (numerical control) processing is used for obtaining such complex electrode forms, materials capable of being processed are limited to prevent warping or bending while the electrodes are processed and, hence, copper, aluminum, steel, etc. are normally used. Because of the complexity in the undulated form, the required smoothness of the surface, and the limitation of usable materials as described above, it is difficult in general to line the surface of the electrode mechanically with a sheet member of a different material using screws or the like. Hence, such a method as plating or CVD (chemical vapor deposition), or

physical surface coating with the use of an ion beam is effective to cover the surface of the undulated electrodes with a different substance. When quadrupole electrodes provided with surface coating through such a method is used, the contamination by heavy metal of the sample substrate can be greatly reduced even if the electrode surface is sputtered by the ion beam impinging thereon while the beam is accelerated. Further, since the coating formed as described above smoothes the finished surface, the dielectric breakdown between electrodes becomes less likely and a stabilized beam accelerating operation can result.

Embodiments of the present invention will now be described, by way of example, with reference to the accompanying drawings, wherein:

FIG. 1 shows an embodiment of the present invention, of which FIG. 1(A) is an explanatory drawing of the structure of a quadrupole electrode according to the present invention and FIG. 1(B) is an explanatory drawing of an MeV ion implantation apparatus provided with an external resonance circuit type RFQ accelerator;

FIG. 2 shows explanatory drawings of an ion implantation apparatus provided with a prior art RFQ accelerator, and has already been discussed;

FIG. 3 is an explanatory drawing of a prior art external resonance circuit type RFQ accelerator, and has already been discussed; and

FIG. 4 is an explanatory drawing of another embodiment according to the present invention.

With reference to FIG. 1, FIG. 1(A) shows an undulated electrode 2a' (whose material is copper) processed as in the past and uniformly coated with a silicon film 2a'' to a thickness of several μm - several 100 μm . The coating is performed by plasma deposition under vacuum. For the deposition, SiH_4 is used as the plasma discharge gas. A negative bias voltage is applied to the undulated copper electrodes whereby ions in the plasma are adapted to obtain energy to impinge on the electrodes while the silicon film is being formed. Thus, the adhesive strength of the formed film is greatly enhanced.

FIG. 1(B) shows an embodiment in which RFQ accelerator is constructed of the undulated quadrupole electrodes, surfaces of which are coated with the silicon film as described above, and incorporated into an MeV ion implantation apparatus. As the ion source 1, a microwave discharge type ion source was used. A boron ion (B^+) beam drawn out of the source was accelerated to the level of MeV and implanted into a silicon wafer sample substrate 5. The wafer 5 after the implantation was subjected to spectrum analysis of heavy metal ions in a secondary ion mass spectrometer (SIMS) and an Auger electron spectroscopic ana-

lyzer. Thereby, the contamination is compared between the cases where electrodes without silicon coating were used and where the electrodes of the present invention were used. When the prior art undulated quadrupole electrodes 2a - 2d without the surface coating were used, particles of heavy metal originating from the electrode material (copper in the case of the experiment) were detected in the region from the surface down to a depth of several μm in as high a concentration as over 1 ppm (corresponding to 10^{16} particles/ cm^3). In obtaining a B^+ beam, BF_3 gas is generally used as the material gas supplied to the ion source. Therefore, other than B^+ , various ion species such as F^+ , BF^+ , and BF_2^+ ions are simultaneously extracted from the ion source 1. In the RFQ accelerator, while the B^+ ion is accelerated to be implanted into the wafer 5, other ions are diverged and some of them bombard the quadrupole electrodes. Since large amounts of ions other than the B^+ ion are generated when the BF_3 gas is used, the contamination by heavy metal particles caused on the sample substrate was at such a high concentration level that it is sufficiently detected.

On the other hand, when ion implantation was carried out by accelerating the B^+ beam up to the MeV level by the use of the quadrupole electrodes coated with the silicon film 2a' of FIG. 1A, it was found that the contamination by heavy metal was of a level far below 1 ppm. Further, when the supports (made from a metal) supporting the quadrupole electrodes and the inner surface of the container 2 were also coated with a silicon film, the quantity of heavy metal particles originating from the electrode material, cylinder, and the like was decreased to the level barely detectable with the SIMS analyzer at the maximum sensitivity of the detector (corresponding to 10^{14} particles/ cm^3). When similar silicon coating is also applied to the surfaces of the piping midway between the cylinder 2 and the implantation chamber 3 and various internal components, the heavy metal particles were decreased so much that they became undetectable even at the detection level of maximum sensitivity.

When an MeV implantation of the B^+ ion into a silicon substrate was carried out according to the present invention, deterioration in the electrical characteristics and occurrence of inferior products due to contamination by heavy metal was sharply decreased.

It is known that contamination by such particles as carbon (C) does not affect and deteriorate semiconductor characteristics so much as the contamination by heavy metal such as copper and iron does. Hence, we prepared quadrupole electrodes coated with carbon instead of silicon as another embodiment and conducted experiments with

them. Also in this case, it was found that deteriorated products by contamination by heavy metal particles were not produced.

FIG. 4 is an explanatory drawing of another embodiment according to the present invention. When an external resonance circuit type RFQ accelerator according to the present invention (an accelerator incorporating undulated quadrupole electrodes overlaid with surface coating with an external resonance circuit added thereto) was operated for a long time, a problem was encountered that the coating film subjected to the sputtering beam became gradually thinner and the base metal came to the surface. The embodiment shown in FIG. 4 provides an RFQ apparatus incorporating a plasma generating device whereby the coating film can be reapplied to solve the above described problem. More particularly, this embodiment incorporates a separate radio frequency power source 13 (using 13.56 MHz) for generating plasma, and radio frequency power is supplied therefrom to a discharge coil 12. A discharge gas supply system 14 is used to introduce SiH_4 gas into the container 2 wherein plasma is generated, and thereby, a silicon film (up to a thickness of 100 μm) is deposited on the quadrupole electrodes 2a', 2c'. Thus, it becomes possible to operate the apparatus again without replacing the quadrupole electrodes and it has become unnecessary to stop the operation of the accelerator on account of its coating film coming to the end of its life. While the film is deposited, the acceleration of the beam is stopped.

Although a silicon film has been considered as the material for the surface coating in the above described embodiment, it is apparent from the purpose and structure of the present invention that a silicon film doped with a small amount of boron, phosphorous, or arsenic will also be applicable. In actual examples, SiH_4 gas with a small amount of BF_3 , PH_3 , or AsH_3 mixed therein was used and the above described silicon film doped with boron, phosphorous, or arsenic was obtained. Although the case where surface coating was applied to the quadrupole electrodes made from copper or steel has been described in the foregoing description of the present invention, it is, apparently, effective even if the electrodes themselves are formed of silicon.

Therefore, by constructing a high energy ion implantation apparatus of an MeV class using an external resonance circuit type RFQ accelerator, according to the present invention, ion implantation causing small heavy metal contamination on a sample substrate may be obtained and great effects can be obtained therefrom when it is put into practical use.

Claims

1. An external resonance circuit type RFQ accelerator, comprising undulated quadrupole electrodes (2a,2b,2c,2d) for accelerating a beam of ions towards a substrate and comprising a separate radio-frequency resonance circuit for supplying a radio-frequency high voltage to the electrodes;

characterised in that:

at least one of the components of the apparatus which is exposed to the ion beam has a surface coated with silicon, doped silicon or carbon on an electrically conducting base so as to reduce particle contamination on the substrate due to the ion beam sputtering of the electrically conducting base material.

An accelerator according to claim 1 wherein the quadrupole electrodes and the radio-frequency resonance circuit are contained in separate containers, the container (2) containing the quadrupole electrodes (2a,2b,2c,2d) being evacuated and its internal surface coated with silicon, doped silicon or carbon so as to reduce particle contamination on the substrate due to the ion beam sputtering of the electrically conducting base material.

3. An accelerator according to claim 1 or claim 2 wherein the electrodes and at least part of any metallic supports therefor and power supply lines have a surface coated with silicon, doped silicon or carbon so as to reduce particle contamination on the substrate due to the ion beam sputtering of the electrically conducting base material.

4. An accelerator according to any one of the preceding claims wherein said surface is coated with silicon doped with small amounts of boron, arsenic or phosphorus.

5. An accelerator according to any one of the preceding claims, wherein a plasma deposition mechanism for providing said coating is added to a vacuum container (2) containing the component or components to be coated.

6. An external resonance circuit type RFQ accelerator comprising undulated quadrupole electrodes (2a,2b,2c,2d) for accelerating a beam of ions towards a substrate, and comprising a separate radio-frequency resonance circuit for supplying a radio-frequency high voltage to the electrodes;

characterised in that:

said electrodes are formed of silicon.

7. An ion implantation apparatus, comprising an accelerator according to any one of the preceding claims and an implantation chamber (3) for implantation of ions into a silicon semiconductor substrate (5).

Patentansprüche

1. RFQ-Typ-Beschleuniger mit externem Resonanzschaltkreis, der wellenförmige Quadrupolelektroden (2a, 2b, 2c, 2d) zur Beschleunigung eines Ionenstrahls zu einem Substrat hin umfaßt und einen eigenen Radiofrequenzresonanzschaltkreis zum Zuführen einer Hochspannung im Radiofrequenzbereich zu den Elektroden umfaßt;

dadurch gekennzeichnet, daß:

zumindest einer der Bestandteile der Vorrichtung, der dem Ionenstrahl ausgesetzt ist, eine Oberfläche aufweist, die mit Silizium, dotiertem Silizium oder Kohlenstoff auf einer elektrisch leitenden Basis beschichtet ist, sodaß die Teilchenkontamination auf dem Substrat aufgrund des Ionenstrahlputterns des elektrisch leitenden Basismaterials verringert wird.

2. Beschleuniger nach Anspruch 1, worin die Quadrupolelektroden und der Radiofrequenzresonanzschaltkreis in getrennten Behältern enthalten sind, wobei der die Quadrupolelektroden (2a, 2b, 2c, 2d) enthaltende Behälter (2) evakuiert ist und seine Innenfläche mit Silizium, dotiertem Silizium oder Kohlenstoff beschichtet ist, um die Teilchenkontamination auf dem Substrat aufgrund des Ionenstrahlputterns des elektrisch leitenden Basismaterials zu verringern.

3. Beschleuniger nach Anspruch 1 oder 2, worin die Elektroden und zumindest ein Teil jeglicher Metallträger dafür und Stromzufuhrleitungen eine Oberfläche aufweisen, die mit Silizium, dotiertem Silizium oder Kohlenstoff beschichtet ist, um die Teilchenkontamination auf dem Substrat aufgrund des Ionenstrahlputterns des elektrisch leitenden Basismaterials zu verringern.

4. Beschleuniger nach einem der vorhergehenden Ansprüche, worin die genannte Oberfläche mit Silizium beschichtet ist, das mit kleinen Mengen an Bor, Arsen oder Phosphor dotiert ist.

5. Beschleuniger nach einem der vorhergehenden Ansprüche, worin ein Plasmaabscheidungsmechanismus zum Schaffen des genannten Überzugs einem Vakuumbehälter (2)



hinzugefügt ist, der den oder die zu beschichtenden Bestandteil oder Bestandteile enthält.

6. RFQ-Typ-Beschleuniger mit externem Resonanzschaltkreis, der wellenförmige Quadrupolelektroden (2a, 2b, 2c, 2d) zur Beschleunigung eines Ionenstrahls zu einem Substrat hin umfaßt und einen eigenen Radiofrequenzresonanzschaltkreis zum Zuführen einer Hochspannung im Radiofrequenzbereich zu den Elektroden umfaßt;
dadurch gekennzeichnet, daß
die genannten Elektroden aus Silizium gebildet sind.
7. Ionenimplantationsvorrichtung, die einen Beschleuniger nach einem der vorhergehenden Ansprüche und eine Implantationskammer (3) zur Implantation von Ionen in ein Siliziumhalbleitersubstrat (5) umfaßt.

Revendications

1. Accélérateur par quadrupôle en radiofréquence à circuit résonant extérieur, comprenant des électrodes quadrupôles ondulées (2a, 2b, 2c, 2d) pour accélérer un faisceau d'ions vers un substrat et comprenant un circuit de résonance de radiofréquence séparé pour fournir une tension élevée de radiofréquence aux électrodes; caractérisé en ce que :
au moins l'un des composants de l'appareil, qui est exposé au faisceau d'ions présente une surface revêtue avec du silicium, du silicium dopé ou du carbone sur une base électriquement conductrice de façon à réduire une contamination de particules sur le substrat due à la pulvérisation du faisceau d'ions du matériau de base électriquement conducteur.
2. Accélérateur selon la revendication 1, dans lequel les électrodes quadrupôles et le circuit de résonance de radiofréquence sont contenus dans des conteneurs séparés, le conteneur (2) contenant les électrodes quadrupôles (2a, 2b, 2c, 2d) à l'état vide et sa surface interne est revêtue avec du silicium, du silicium dopé ou du carbone de façon à réduire une contamination des particules sur le substrat due à la pulvérisation du faisceau d'ions du matériau de base électriquement conducteur.
3. Accélérateur selon la revendication 1 ou la revendication 2, dans lequel les électrodes et au moins une partie de n'importe quels supports métalliques pour celles-ci et les lignes d'alimentation en puissance présentent une surface revêtue avec du silicium, du silicium

dopé ou du carbone, de façon à réduire une contamination des particules sur le substrat due à la pulvérisation du faisceau d'ions du matériau de base électriquement conducteur.

4. Accélérateur selon l'une des revendications précédentes, dans lequel ladite surface est revêtue avec du silicium dopé avec des petites quantités de bore, d'arsenic ou de phosphore.
5. Accélérateur selon l'une des revendications précédentes, dans lequel un mécanisme de dépôt de plasma pour réaliser ledit revêtement est ajouté à un conteneur à vide (2) contenant le composant ou les composants à revêtir.
6. Accélérateur par quadrupôle en radiofréquence du type à circuit résonant extérieur comprenant des électrodes quadrupôles ondulées (2a, 2b, 2c, 2d) pour accélérer un faisceau d'ions vers un substrat, et comprenant un circuit de résonance de radiofréquence séparé pour fournir une tension élevée de radiofréquence aux électrodes;
caractérisé en ce que :
lesdites électrodes sont réalisées en silicium.
7. Appareil d'implantation d'ions, comprenant un accélérateur selon l'une des revendications précédentes et une chambre d'implantation (3) pour l'implantation des ions dans un substrat semi-conducteur en silicium (5).

