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[54] **APPARATUS FOR EFFECTING DEPOSITION BY ION BOMBARDMENT**

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[30] **Foreign Application Priority Data**
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[52] **U.S. Cl.** 118/49.1; 117/93.3; 219/121 EB; 313/259

[51] **Int. Cl.** C23c 13/12

[58] **Field of Search** 118/49.1, 49.5; 117/93.3; 219/121 EB; 313/359, 360, 362

[56] **References Cited**

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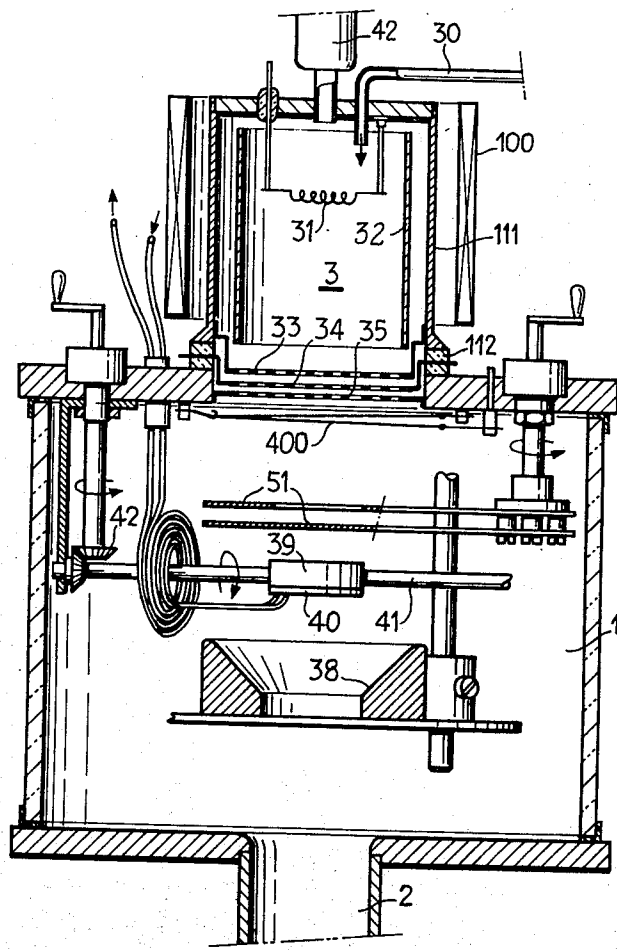
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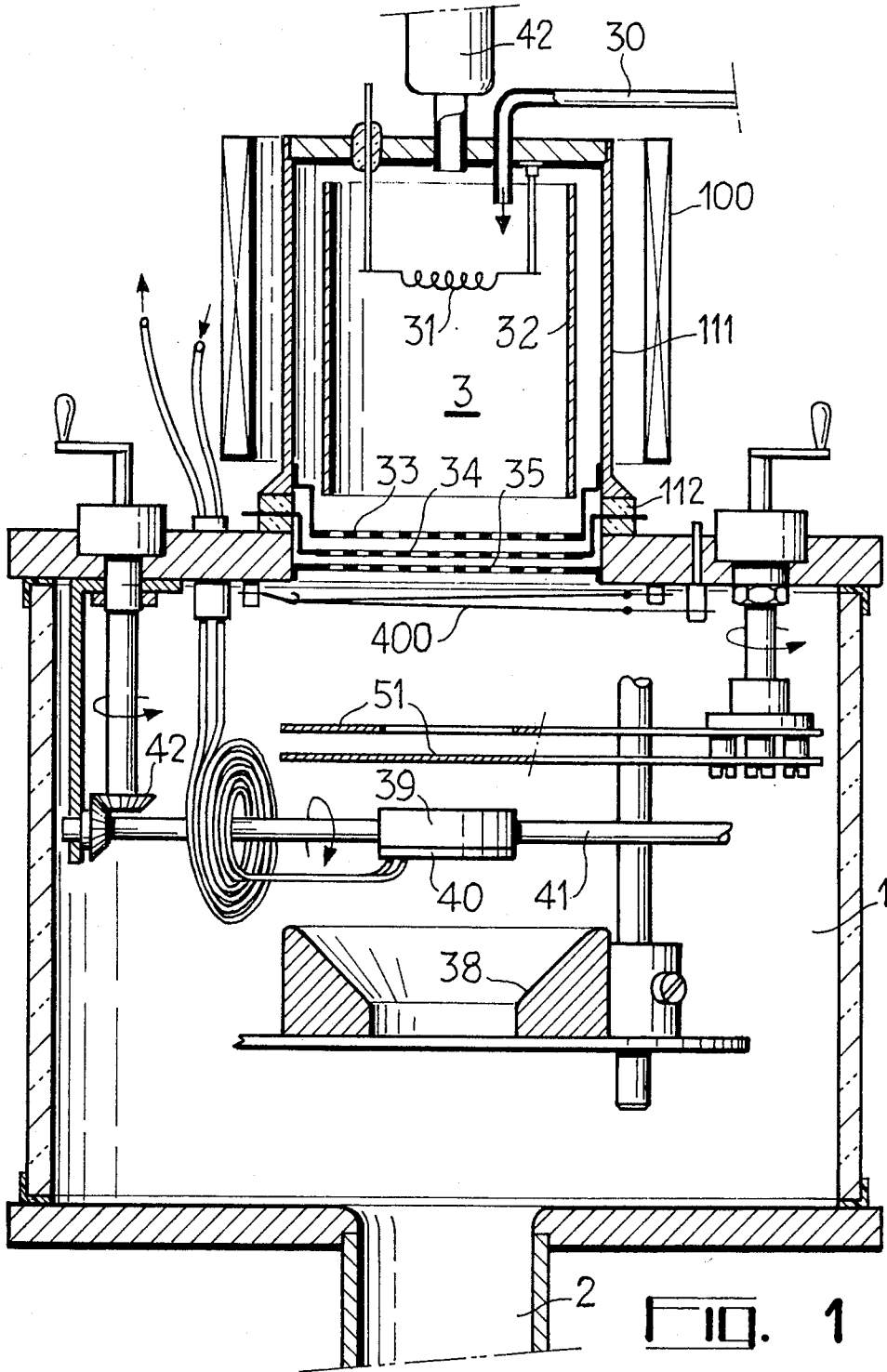
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[57] **ABSTRACT**

An apparatus for effecting deposition by ion bombardment comprises a multiple grid ion gun and a target with a hollow central portion. The substrate upon which the deposit is to be effected is carried by a support and can be successively and directly exposed to the ion beam in order to produce a suitable surface condition and to the atoms coming from the target when the latter is subjected to ion bombardment.

6 Claims, 4 Drawing Figures





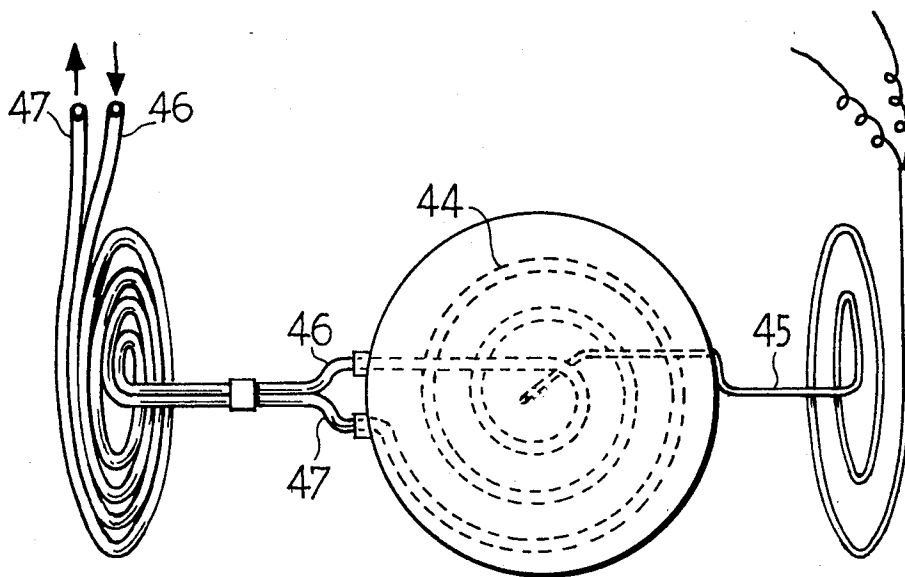


FIG. 2

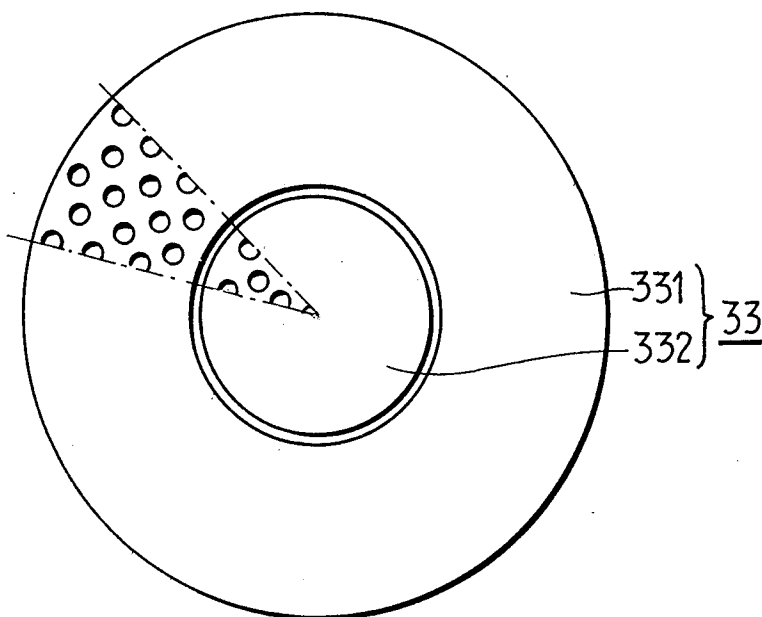


FIG. 3

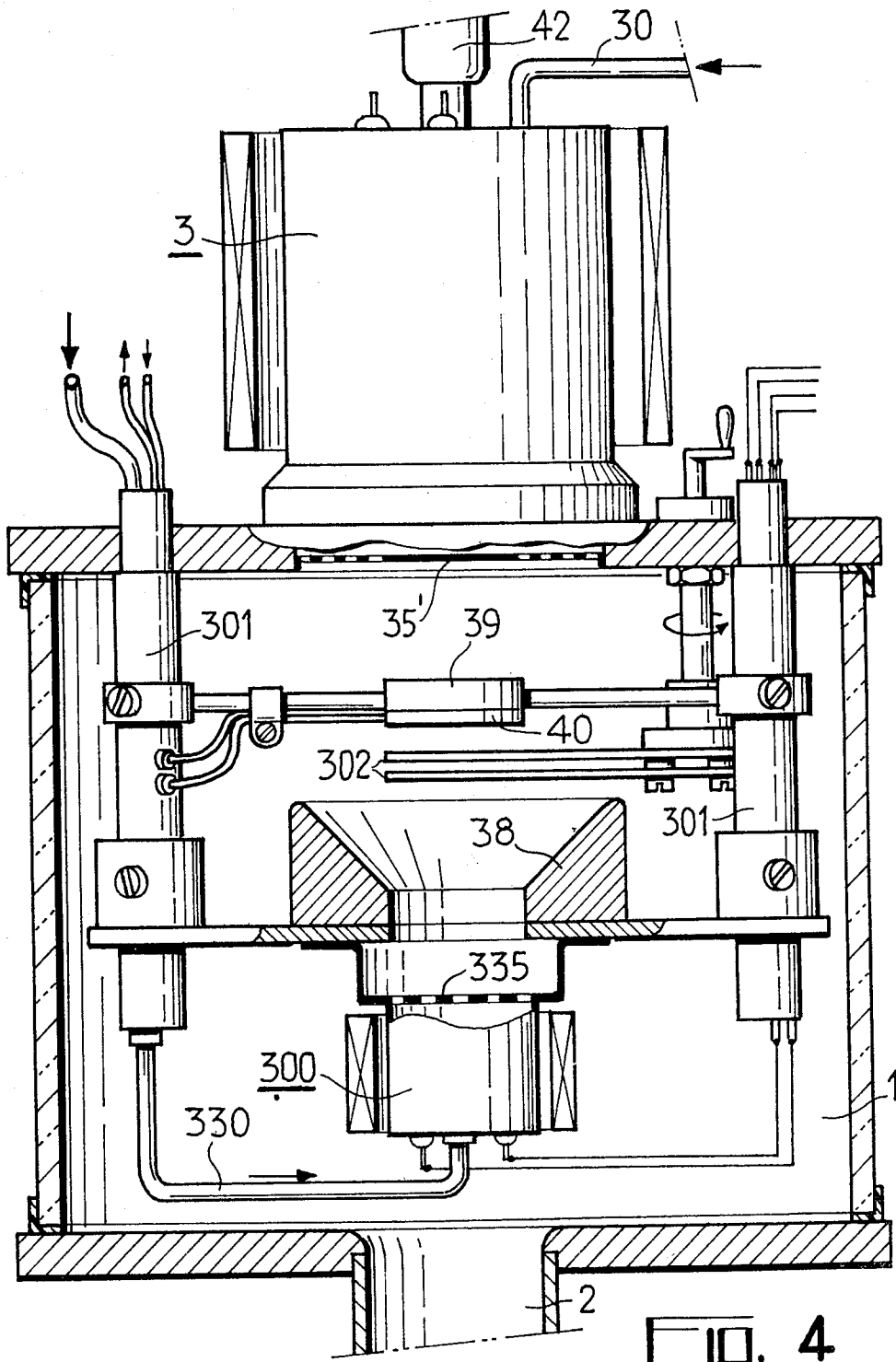


FIG. 4

APPARATUS FOR EFFECTING DEPOSITION BY ION BOMBARDMENT

To produce upon the surface of a substrate made for example of semiconductor material, a deposit of a pre-determined material which adheres very firmly and is extremely pure even at the interface, it is desirable to carry out the following operations:

maintain the substrate at a suitable temperature, that is to say to provide on the support on which the substrate rests, heating or cooling means;

beforehand clean the substrate, using ion bombardment for example, positive argon ions, the charges on which are neutralised by an electron cloud in order to prevent the formation of electrical charges at the insulating zones on the surface of the substrate, a phenomenon which might well occur, for example on a silicon wafer, certain zones of which are oxidised;

maintain within the enclosure, the lowest possible pressure in order to restrict contamination firstly of all the substrate surface which constitutes the future interface (whose purity condition is fundamental for example in the case of Schottky diodes), and secondly of the deposited layer or film.

The known kinds of apparatus for carrying out operations of this kind, are of the triode cathode-sputtering kind.

The assembly of target and substrate is located in a region of strong electric field. For the cleaning operation, a suitable potential is applied to the sample. For cathode sputtering, this potential is applied to the target. In the case of a substrate partially covered with an insulator, the surfaces of the insulator is positively charged by the arrival of positive ions, and the emission of secondary electrons, this giving rise to an ion concentration in the insulator-covered regions. Moreover, in apparatus of this kind, it is difficult to achieve a pressure much below 10^{-3} mmHg, in the neighbourhood of the substrate.

The object of the present invention is a novel apparatus for deposition by ion bombardment, which makes it possible to successively carry out cleaning by ion bombardment and the deposition upon the substrate of the material of the target, which method is free of the said drawback.

The ion bombardment apparatus in accordance with the invention comprises an evacuated enclosure and means for supplying inert gas therein; an ion-gun made up of an anode and multiple accelerator grids in order to accelerate the ions formed in the gun, a substrate holder and a target made of the material which is to be deposited, these latter being arranged in order to receive the accelerated ions, elements being provided in order to successively subject the substrate to the action of the accelerated ions, and to the stream of atoms stemming from the atomisation of said target by the ions.

The invention will be better understood from a consideration of the ensuing description and by reference to the attached drawings, in which:

FIG. 1 illustrates in transverse section a first embodiment of the invention;

FIG. 2 schematically illustrates the substrate holder and its accessory parts;

FIG. 3 illustrates one of the grids of the device shown in FIG. 1;

FIG. 4, in transverse section, illustrates a second embodiment of the invention.

The device shown in FIG. 1 comprises a vacuum-tight enclosure 1. This enclosure is evacuated through the pipe 2. It incorporates an ion gun 3 into which there opens a pipe 30 supplying the gas to be ionised, for example argon.

This known kind of gun comprises a tungsten filament 31 which emits electrons. The filament is supported by the top part of the gun 3, namely the part 111, this top part being placed at a potential in the order of 1000 V and being insulated from the remainder of the enclosure by an insulator ring 112, a vacuum gauge 42 controls the residual pressure in the gun, which should be in the order of 10^{-6} mmHg.

The gun moreover comprises an accelerating anode 32 placed at a slightly higher potential than the part 111 (around 1040 V); the tungsten filament 31, one terminal of which is connected to the enclosure 111, has its other terminal connected to a direct voltage source supplying a voltage in the order of 30V.

The portion 111 of the enclosure carries a grid 33 containing some hundreds of holes, and is electrically connected to it as well. Two other perforated grids, in which the holes are located opposite those in the grid 33, namely the grids 34 and 35, are also provided. The grid 34 is placed at a negative potential of the order of -200 V, whilst the grid 35 is grounded.

A solenoid 100 surrounds the part 111 and creates a magnetic field directed along the axis of the gun. Accordingly, the electrons emitted by the filament have their trajectories elongated and make it possible to effect total ionisation of the argon. The grid 34, which is at a negative potential, prevents the electrons emanating from a filament 31 from penetrating into the enclosure 1, and accelerates the ions.

The gun produces a uniform ion density in the order of 1 m A/cm^2 , of low energy (less than or equal to 1KeV).

In the enclosure 1, there is then encountered another tungsten filament 400. This, when heated, emits an electron cloud which compensates the positive charges on the ions leaving the gun 3.

This is followed by the object holder 39 carrying the substrate 40 which is to be covered. The substrate is arranged in order to be able to face the central part of the gun. The object holder is itself carried by a shaft 41 perpendicular to the ion gun axis, and can be rotated through 180° by a crank and a gear system 42. The substrate can thus, as required, be subjected to or removed from, the effect of ion bombardment. This shaft passes through the enclosure by virtue of a vacuum-tight seal. The target 38 of material, which is to be atomised, is arranged on the gun axis beyond the substrate holder. It takes the form of a hollow conical frustum, the smaller base of which has the same diameter as the object holder 39.

A retractable mask 51 makes it possible, before an operation, to adjust the gun whilst avoiding bombardment of the substrate.

FIG. 2 illustrates the sample holder which comprises a heater element 45 making it possible to raise it to a suitable temperature (600° or 700° for example) in order to degas the substrate, and a pipe system 44 through which a cooling fluid can be circulated in order to bring this temperature to a suitable level during bombardment. This pipe arrangement comprises at its

two ends noses 46 and 47 wound spiral fashion and capable of undergoing a rotation of 180° C.

The operation of the system is as follows:

After having attached the substrate to the object holder and placed the target in position, the vacuum is produced in the enclosure (pressure of 10^{-6} mm. Hg). The substrate, protected by the mask 51, is placed opposite the gun. The voltage is applied to the latter. Then, the argon pipe is opened, maintaining a pressure of 10^{-6} mm.Hg.

The plasma develops under the action of filament 31. After retraction of the mask, the substrate is bombarded by the A^+ ions and is cleaned.

The filament 400, in the electric field-free region, emits electrons which neutralise the positive charges on the ions and prevent the insulating zones of the surface of the substrate from becoming positively charged.

After cleaning, the object holder is rotated through 180° and the substrate is then opposite the target which is then bombarded by that part of the ion beam not blocked off by the substrate. The atoms which it liberates thus become deposited upon the substrate.

By way of non-limitative example, the respective dimensions and the currents utilised are as follows:

For the gun:

Beam diameter 100 mm. The current density is uniform to within 5 %, over 50 mm (central part).

Current density: $i = 10^{-3}$ A/cm².

Ion energy: $E = 10^3$ eV.

Diameter of the object holder: $\Phi = 40$ mm.

The deposition rates obtained are 200 Angstroms/minute for molybdenum and 1000 Angstroms/minute for gold.

In order, during deposition, to prevent the back of the substrate from being bombarded by the central part of the beam, it is possible to modify the gun by splitting the grid 33 into two sections, the central section 331 and the peripheral 332, as shown in FIG. 3, the grid here being shown in plan.

These two parts are insulated from one another; the part 332 is annular in form and the part 331 is of disc form. In the cited example, the internal part has a diameter of 40 mm, the external ring has an internal diameter of 42 mm and an external diameter of 100 mm.

During the first phase of cleaning the substrate by bombardment, the two sections 331 and 332 of the grid are raised to the potential 1000 V. This makes it possible to simultaneously clean the substrate and the internal surface of the target. When the object holder is rotated in order to expose the substrate to the deposition of the particles detached from the target, the central part 332 of the grid is placed at a potential slightly higher than the anode 32, the peripheral section 332 remaining at the potential 1000 V which prevents the extraction of ions from the central part of the gun and therefore prevents bombardment of the rear portion of the object holder.

FIG. 4 illustrates a second example of the invention. In this figure, similar references designate similar elements to those so marked in FIG. 1.

Only the output grid of the gun 3 has been shown. It contains holes only at its peripheral region. The gun 3 can therefore only bombard the target 38. The latter is hollow. At the other side of the hollow target, there is arranged a gun 300 supplied with argon from a pipe 330; only the output grid 335 has been shown. This has the same diameter as the substrate, the object holder is

fixed, the substrate is opposite the gun 300, and the assembly of gun 300 object holder 39 and target 38 is carried by a set of pillars 301 providing the electrical connections for the heater element of the object holder and the means of supplying it with cooling fluid. A retractable mask- 302 is arranged between the substrate and the gun 300. For example, this mask is rotatable about a vertical axis, and in one of its position, it is positioned for receiving the totality of the beam incoming from the gun 300.

Operation takes place in three phases:

a. Cleaning the substrate:

The gun 300 is supplied with a voltage, gun 3 is stopped the mask 302 is retracted. The ions coming from the gun 300 pass through the target 38 and clean the substrate;

b. Cleaning the target:

The gun 300 is stopped and the mask 302 protects the substrate against the impurities detached during cleaning of the target 38. The gun 3 has a voltage applied to it;

c. Deposition, the gun 3 remaining live:

The target 302 is retracted and the substrate is exposed to bombardment by the atoms coming from the target.

What I claim is:

1. An apparatus for effecting deposition by ion bombardment, comprising an evacuated enclosure and in said enclosure: an ion source comprising at least one ion gun producing a uniform beam, a target mounted below said source and made of the material which is to be atomised, an object-holder aligned with and disposed between said source and said target so that ions passing said object-holder impinge on said target and supporting a substrate having a surface to be bombarded means for moving said holder between a first position exposing said surface to be bombarded to said beam and a second position exposing said substrate to the stream of atoms emanating from the target and means for blocking a portion of said beam whereby said beam does not impinge on said object-holder when said object-holder is in said second position.

2. An apparatus as claimed in claim 1, wherein the target is hollow, and has an internal surface frustoconical with an axis corresponding to the axis of said gun in order to allow part of the ion beam to pass and thus bombard said object.

3. An apparatus as claimed in claim 1, wherein said means for moving comprises a shaft perpendicular to the gun axis, said object holder being mounted upon said shaft, and a mechanical system enabling said shaft to be rotated through 180°.

4. An apparatus as claimed in claim 1, wherein said object-holder has a heating system to raise it to a predetermined temperature and piping arrangements passing a cooling fluid at a suitable temperature.

5. An apparatus as claimed in claim 1, wherein said gun comprises grids containing mutually opposite holes, each grid possessing an annular and a peripheral portion, the grid closest to the accelerating anode having connections placing the central part at a higher potential than the peripheral part in order to effect said blocking of a portion of said beam.

6. An apparatus as claimed in claim 1, characterised in that at the exit of the ion gun there is a filament emitting electrons which neutralise the positive charges on the ions.