

[54] **LOW TEMPERATURE SPUTTERING
DEVICE**

3,410,775 11/1968 Uratny 204/298
3,616,450 10/1971 Clark 204/298

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[57] **ABSTRACT**

[30] **Foreign Application Priority Data**

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[52] U.S. Cl. 204/298; 204/192

[51] Int. Cl. C23c 15/00

[58] Field of Search 204/192, 298

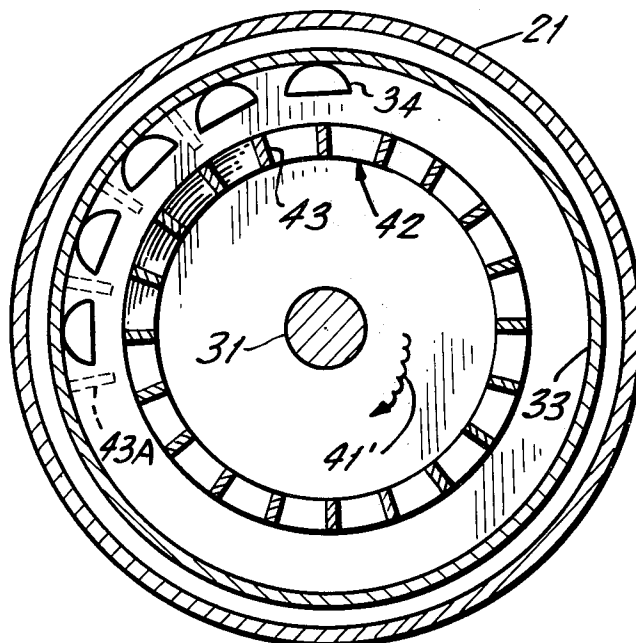
A sputtering device comprises a plurality of thin metal plates between the cathode and a holder for holding a plurality of objects on which the material of the cathode should be sputtered. The device further comprises a coil for providing magnetic field perpendicular to the electric field for producing a gas discharge for the sputtering. Alternatively, the device further comprises means for providing local electric or magnetic fields between the metal plates. The metal plates receive electrons produced during the sputtering and having their paths varied either by the coil magnetic field or by the local electric or magnetic fields.

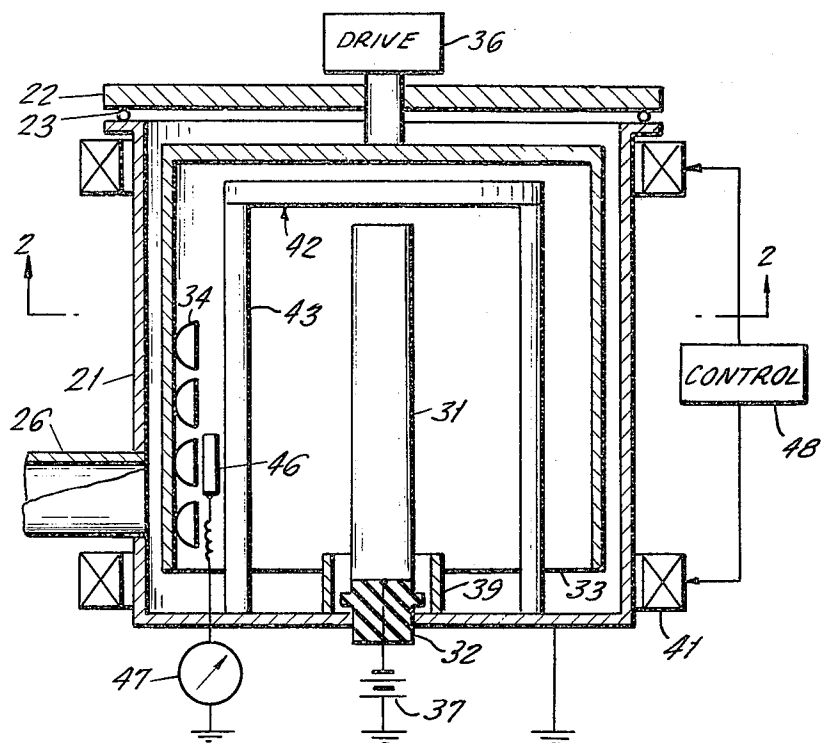
[56] **References Cited**

UNITED STATES PATENTS

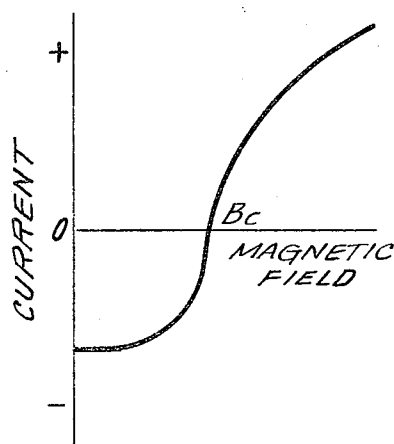
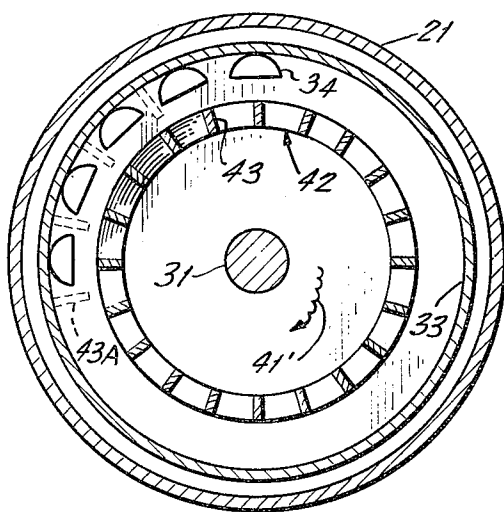
3,324,019 6/1967 Laegreid et al. 204/298

15 Claims, 15 Drawing Figures





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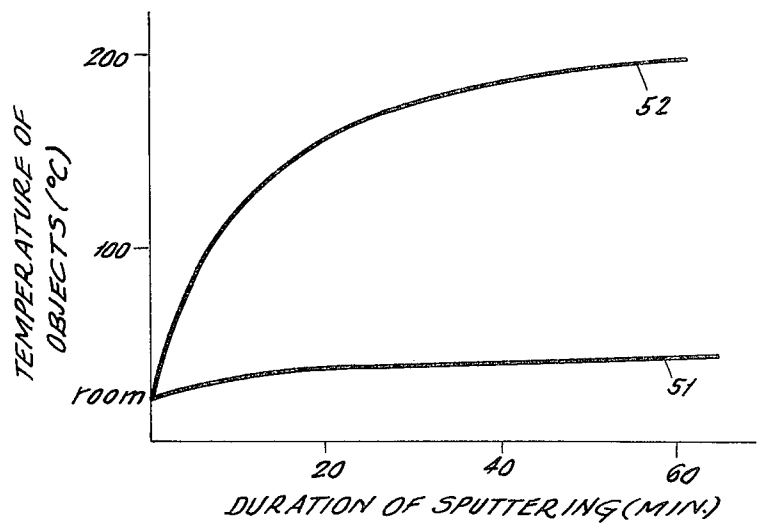


FIG. 4.

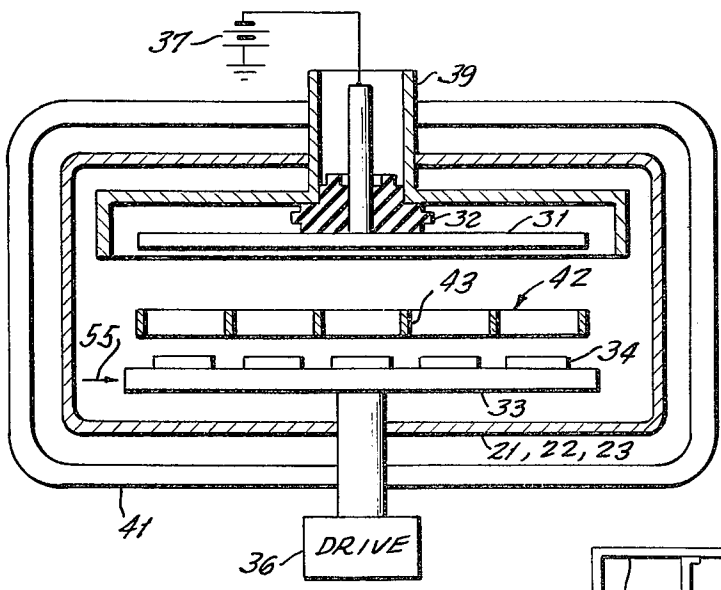


FIG. 5.

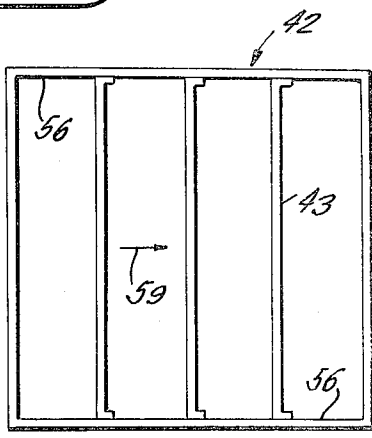


FIG. 6.

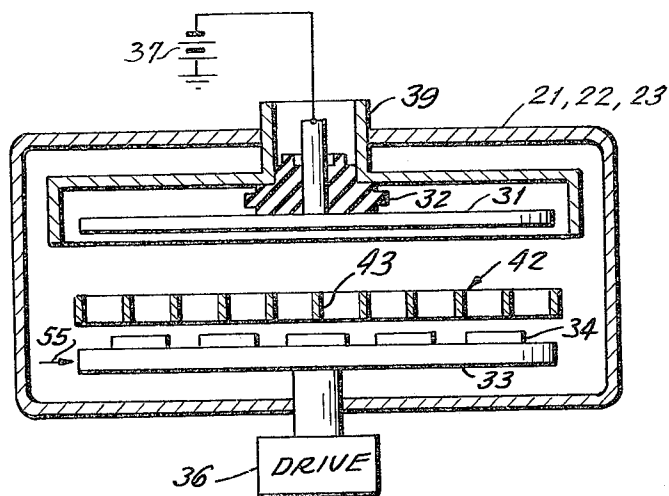


FIG. 7.

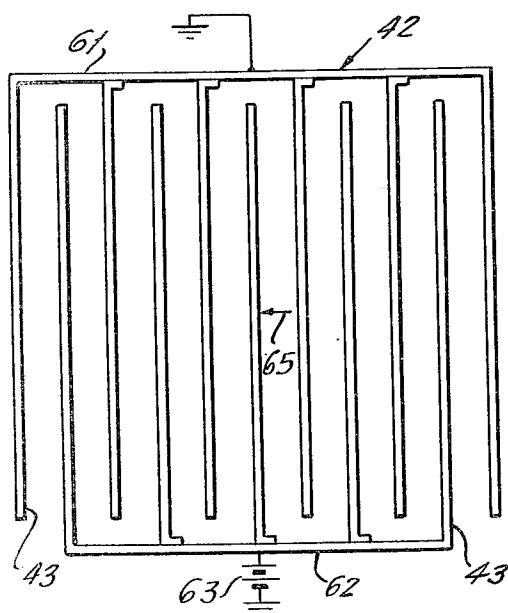


FIG. 8.

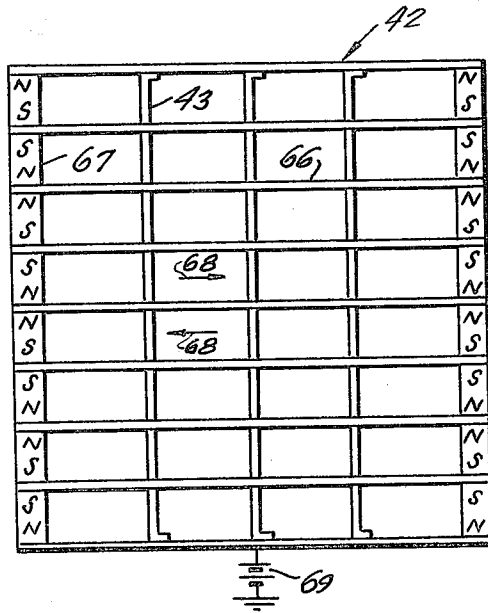


FIG. 9.

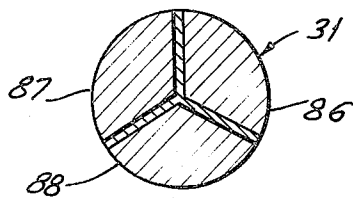


FIG. 15.

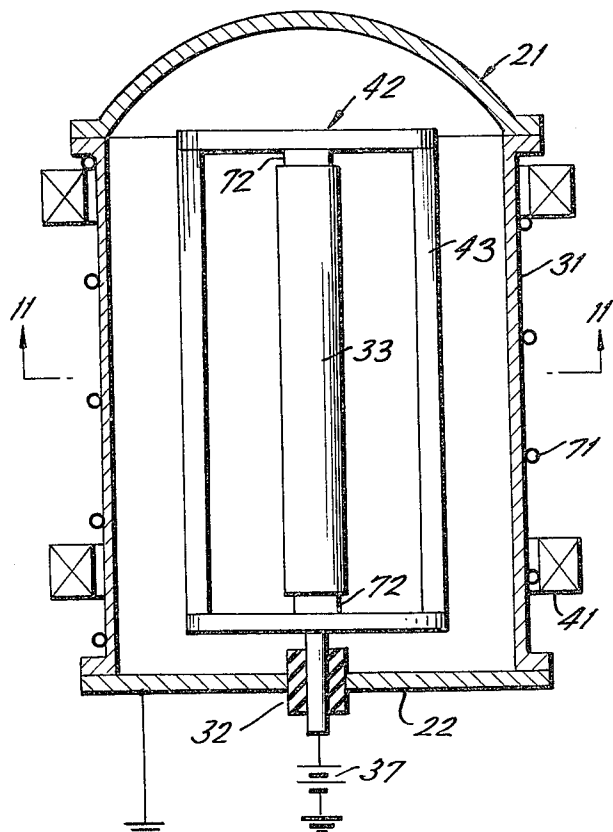


FIG. 10.

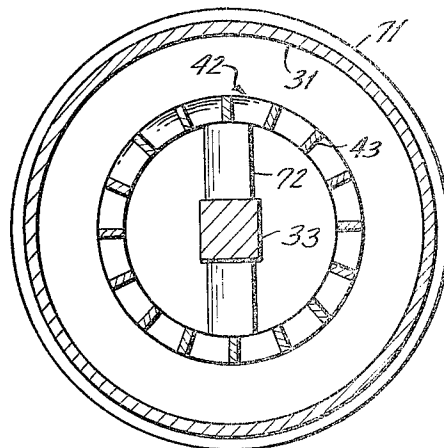


FIG. 11.

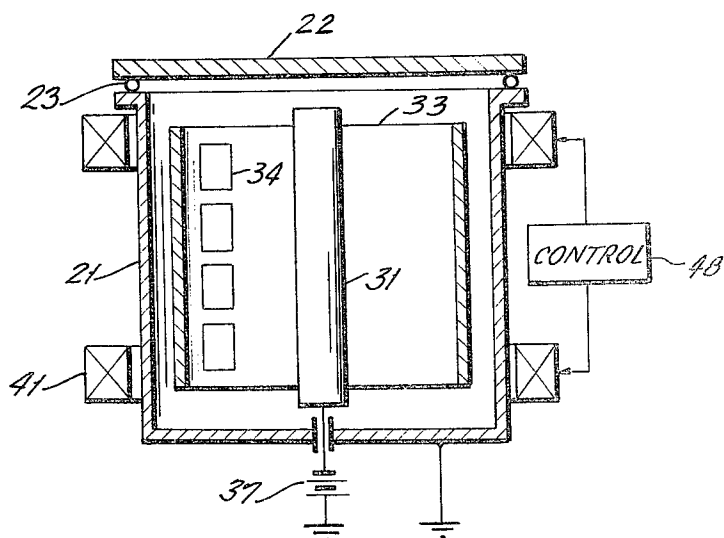


FIG. 12.

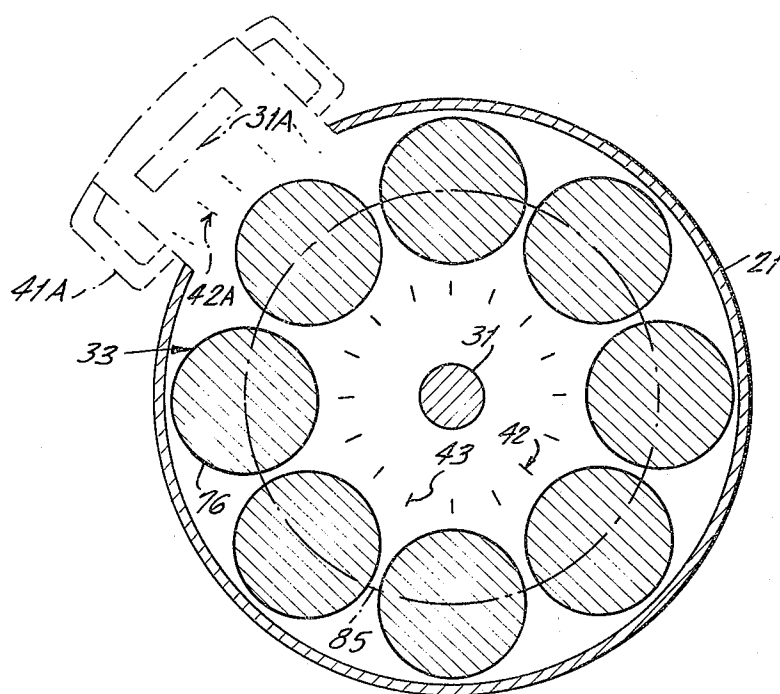
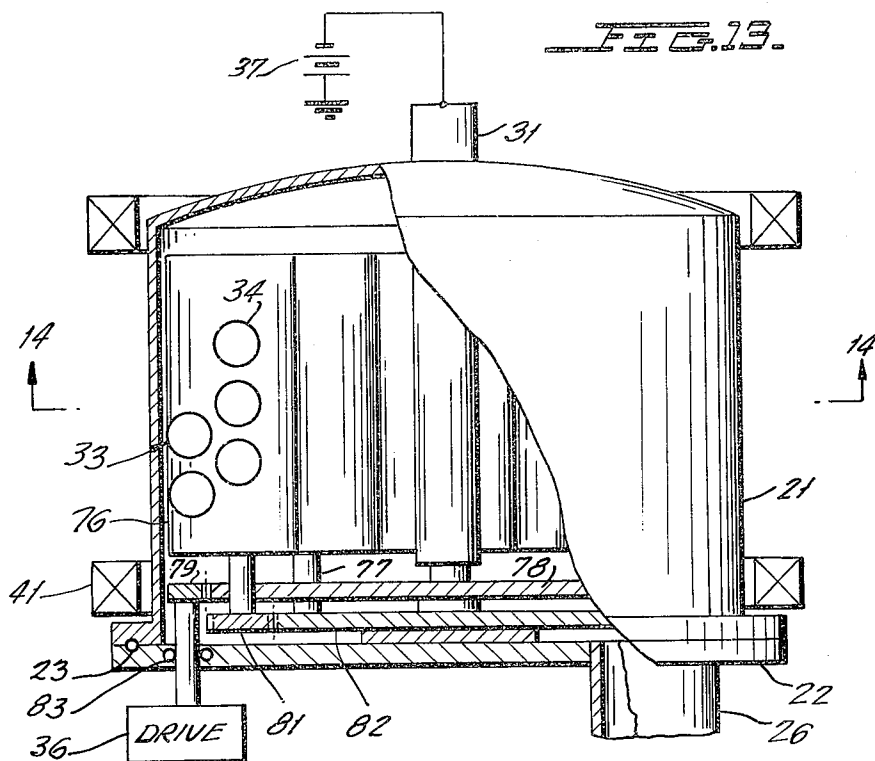


FIG. 14.

LOW TEMPERATURE SPUTTERING DEVICE

BACKGROUND OF THE INVENTION

This invention relates to a device comprising a cathode and a holder for holding a plurality of objects disposed in a gas-filled chamber for sputtering the material of the cathode onto the objects by providing an electric field between the cathode and the holder.

In a conventional sputtering device, the objects are heated by electrons produced either in the gas-filled chamber by the discharge for carrying out the sputtering or from the cathode as bombarded by positive ions produced by the discharge. It has therefore been impossible to carry out the sputtering onto the objects having a low capability of withstanding a high temperature, such as plastic or paper objects, photoresist films, or low-melting point alloy objects. It has also been impossible to carry out the sputtering onto the objects that are sensitive to the bombardment by the electrons, such as semiconductor substrates.

The objects, however, should be heated to a high temperature particularly in cases where the objects are capable of withstanding a relatively high temperature. This is necessary in order to avoid release of gasses from the objects subjected to the sputtering and has been carried out either by an infrared lamp or a heater wire arranged in the gas-filled chamber adjacent to the holder and energized by the a.c. power source widely available in laboratories and factories. The use of such a heater device is undesirable because the glow discharge produced at the terminal and lead wire portion of the heater device releases further gases from such portions and sputters the material of such portions onto the objects. A shield has been employed to preclude the undesired sputtering but this has resulted in a complicated structure of the sputtering device. When an infrared lamp is used, the material of the cathode is also sputtered onto the lamp surface to reduce the heating capability. In the case of a heater wire, the foreign substance deposited onto the wire surface is evaporated on preheating the objects.

A conventional sputtering device often called a concentric sputtering device comprises a cathode of a cylindrical shape and a holder for holding the objects in concentric relation to the cathode with a view to increasing the number of the objects simultaneously subjected to the sputtering. It is, however, desirable to further increase the number under some circumstances.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a sputtering device capable of carrying out the sputtering onto objects having a low capability of withstanding a high temperature.

It is another object of this invention to provide a sputtering device capable of carrying out the sputtering onto objects sensitive to the bombardment by electrons produced during the sputtering.

It is still another object of this invention to provide a sputtering device comprising no specific heating device and yet capable of preheating objects to be subjected to the sputtering.

It is yet another object of this invention to provide a sputtering device capable of accommodating a great number of objects to be simultaneously subjected to the sputtering, with the uniformity of the sputtered films even raised.

In the manner known in the art, a sputtering device according to this invention also comprises a cathode disposed in a gas-filled chamber, first means for holding a plurality of objects to be subjected to the sputtering in the chamber, and second means for providing an electric field between the cathode and the first means to produce a gas discharge in the chamber for carrying out the sputtering. In accordance with this invention, the device comprises third means disposed between the cathode and the first means and fourth means for varying the paths of electrons produced during the sputtering and accelerated by the electric field at least at first towards the first means, the third means being capable of receiving a major proportion of the electrons having the paths varied by the fourth means.

The fourth means may comprise means for providing a magnetic field substantially perpendicular to the electric field. In this case, the third means comprises a plurality of thin metal plates, each having a width in the direction of the electric field and a length in the direction of the magnetic field. Alternatively, the third means may comprise a plurality of substantially equally spaced thin metal plates, each having a width in the direction of the electric field. In the latter case, the fourth means may comprise means for providing local electric fields between the metal plates. Again in the latter case in which the thin metal plates are arranged substantially parallel, the fourth means may comprise a plurality of pole pieces substantially perpendicularly intersecting the metal plates and a plurality of bar magnets, each interconnecting the corresponding ends of adjacent two of the pole pieces, with a pair of bar magnets disposed at both ends of each of the pole pieces being similarly directed.

According to an aspect of this invention, the fourth means may comprise means for providing a magnetic field substantially perpendicular to the electric field and means for reducing the magnitude of the magnetic field substantially to zero on starting the sputtering.

In the manner also known in the art, the cathode may be of a cylindrical shape. In accordance with another aspect of this invention, the first means comprises a plurality of cylinders rotatable around the respective axes and means for rotating the cylinders around the cathode.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic vertical sectional view of a first embodiment of the instant invention;

FIG. 2 is a schematic horizontal sectional view of the first embodiment taken on lines 2—2 of FIG. 1;

FIG. 3 shows the electron current flowing into a metal piece used in a modification of the first embodiment and depicted in FIG. 1;

FIG. 4 shows how the temperature of objects subjected to the sputtering varies with time;

FIG. 5 is a schematic vertical sectional view of a second embodiment of this invention;

FIG. 6 is a top view of an electron trap used in the second embodiment;

FIG. 7 is a schematic vertical sectional view of a third embodiment of this invention;

FIG. 8 is a top view of an electron trap used in the third embodiment;

FIG. 9 is a top view of a modified electron trap used in the third embodiment;

FIG. 10 is a schematic vertical sectional view of a fourth embodiment of this invention;

FIG. 11 is a schematic horizontal sectional view of the fourth embodiment taken on line 11—11 of FIG. 10;

FIG. 12 is a schematic vertical sectional view of a fifth embodiment of this invention;

FIG. 13 is a schematic vertical sectional view of a sixth embodiment of this invention;

FIG. 14 is a schematic horizontal sectional view of the sixth embodiment taken on line 14—14 of FIG. 13; and

FIG. 15 is a schematic cross-sectional view of a modified cathode.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1 and 2, a sputtering device comprises a cup-shaped vessel 21, a cover 22 for the vessel 21, an O-ring 23 for hermetically sealing the cover 22 to the vessel 21, an exhaust pipe 26 for the vessel 21, a cylindrical shaped cathode 31 mounted on the bottom of the vessel 21 by means of an insulator 32 and extending in the vessel 21 along the axis thereof, a hollow cylindrical holder 33 disposed in the vessel 21 rotatable around the cathode 31 for holding a plurality of objects 34 subjected to the sputtering, driving means 36 for rotating the holder 33, and electric means 37 for supplying a d.c., a.c., or h.f. high tension of negative polarity to the cathode 31 with respect to the holder 33 to provide an electric field between the cathode 31 and the holder 33. The device may comprise a shield 39 for the cathode 31. The space enclosed by the vessel 21 and the cover 22 is evacuated to a high vacuum, such as 10^{-7} Torr, and filled with argon at the pressure of from 0.002 to 0.005 Torr. A gas-filled chamber is thus provided, in which a gas discharge is produced by the high tension.

In accordance with the present invention, the device depicted in FIGS. 1 and 2 comprises coil means 41 for providing a magnetic field substantially perpendicular to the electric field to cause the electrons produced either in the gas-filled chamber by the gas discharge or from the cathode 31 as bombarded by positive ions produced by the discharge and accelerated by the electric field at first towards the holder 33 to move along cycloidal or trochoidal paths 41'. Coil means 41 thus serves as means for varying the paths of the electrons. Also, it is thus possible to reduce the energy of the electrons, if any, bombarding the objects 34. The device further comprises an electron trap 42 interposed between the cathode 31 and the holder 33 and comprising a plurality of thin metal plates 43, each having a width W in the direction of the electric field and a length L in the direction of the magnetic field where $L > W$ as can be seen from FIGS. 1 and 2. The metal plates 43 are electrically connected together at their respective ends and to the holder 33 by means not shown and receive a major proportion of the electrons having their paths varied by the magnetic field to reduce the electrons reaching the objects 34 substantially to zero.

In accordance with a modification of the first embodiment of this invention illustrated with reference to FIGS. 1 and 2, the device comprises a metal piece 46 disposed in the adjacency of the holder 33 and electrically connected to the holder 33 through a meter 47. The metal piece 46 may be mounted on the holder 33.

The electrons, if any, flowing into the objects 34 or to the holder 33 flow also into the metal piece 46. Incidentally, the device comprises means 48 for controlling the magnitude of the magnetic field.

Referring to FIG. 3, the current measured by the meter 47 is negative when the magnetic field is zero. As the magnetic field is strengthened, the current increases. It is preferable that the sputtering is carried out with the controlling means 48 adjusted to provide a zero reading of the meter 47, in which case the coil means 41 provides a magnetic field of a threshold magnitude B_c . The sputtering may be carried out with the magnetic field of the magnitude exceeding the threshold value B_c .

By way of example, a plurality of plastic pieces 34 were subjected to the sputtering by a device according to this invention to provide reflectors for car headlights. Use was made of a cathode 31 of aluminium 70 mm in diameter and 800 mm long. With a d.c. high tension of an electric power of 3 kW, 1500-A thick aluminium films were quite satisfactorily formed upon the plastic pieces 34 in about twenty minutes. The temperature of the plastic pieces 34 rose only about 20°C above the room temperature. The plastic pieces 34 that begin to deform at about 70°C experienced no thermal damages. In contrast, similar plastic pieces were subjected to the sputtering by a conventional sputtering device with the same electric power. The plastic pieces began to deform in about four minutes, without formation of appreciably sputtered aluminium films.

Referring to FIG. 4, the temperature rise of the objects 34 is only about 50°C as illustrated with a curve 51 even though the sputtering is continued for sixty minutes with a sputtering device according to this invention. In contrast, the temperature rises to more than 150°C with a conventional sputtering device in twenty minutes of continued sputtering as illustrated by curve 52.

Referring to FIG. 5, a second embodiment of this invention comprises similar parts designated with like reference numerals as in FIGS. 1 and 2. In the second embodiment, the cathode 31 is of a planar shape and the coil means 41 provide a magnetic field in a direction perpendicular to the plane of the drawing. Preferably, the second embodiment comprises means (not shown) for moving the objects 34 in the direction illustrated with an arrow 55. The second embodiment need not comprise the driving means 36.

Referring to FIG. 6, an electron trap 42 comprises a plurality of parallel thin metal plates 43 connected by a pair of similar metal plates 56 at both ends. The paths of the electrons flowing generally towards the holder 33 are varied by the magnetic field to be directed principally as shown with an arrow 59. The metal plates 43 need not necessarily be straight but may meander with equal spacing between each pair of adjacent metal plates 43. Alternatively, the metal plates 43 may be arranged concentrically, with the distance between the metal plates 43 kept constant or varied with the distance from the center. In any event, the metal plates 43 receive a major proportion of the electrons having their paths varied by the magnetic field provided by the coil means 41.

Referring to FIGS. 7 and 8, a third embodiment of this invention comprises parts similar to those illustrated with reference to FIGS. 1 and 2 and designated with like reference numerals. It is to be noted that the

third embodiment comprises no coil means 41. Instead, the third embodiment comprises an electron trap 42 comprising a plurality of parallel thin metal plates 43, with every other one being connected together by an end metal plate 61 while the remaining ones of which are similarly connected together by another end metal plate 62. An electric source 63 supplies a d.c. voltage between the end plates 61 and 62 to provide local electric fields between the parallel plates 43. One of the end plates 61 and 62 may be connected to the holder 33 as indicated with ground. With the third embodiment, the paths of the electrons accelerated towards the holder 33 by the main electric field provided by the electric means 37 are varied by the local electric field as designated with an arrow 65. The electrons having the paths thus varied are received in most part by the metal plates 43. Although not shown in FIG. 7, the third embodiment may further comprise the coil means 41.

Referring to FIG. 9, a modified electron trap 42 for use in the third embodiment comprises a plurality of parallel thin metal plates 43, a plurality of pole pieces 66 substantially perpendicularly intersecting the metal plates 43, and a plurality of bar magnets 67, each interposed between the corresponding ends of adjacent two of the pole pieces 66 with the bar magnets 67 disposed at both ends of each pole piece 66 similarly directed. The paths of the electrons accelerated towards the holder 33 are varied by the local magnetic fields provided by the bar magnets 67 as indicated with arrows 68. The electrons are thus received by the metal plates 43 having their faces perpendicular to the arrows 68. The electron trap 42 may further comprise an electric source 69 for reinforcing the path varying function of the local magnetic fields.

Referring to FIGS. 10 and 11, a fourth embodiment of this invention is a sputtering device often referred to as a sputtering device of the inverted magnetron type and comprises parts similar to those illustrated with reference to FIGS. 1 and 2 and designated with like reference numerals. It is to be noted that the cup-shaped vessel here serves also as the cathode 31 having means 71 for cooling the same and that the holder 33 is carried by the electron trap 42 by stays 72. Operation and features of the fourth embodiment will be clear from the foregoing description.

Referring now to FIG. 12, a fifth embodiment of this invention comprises similar parts designated with like reference numerals as in FIGS. 1 and 2. It should be understood that the electron trap is omitted from this figure merely for clarity of illustration. According to this embodiment, the magnetic field is reduced to zero on starting the sputtering to direct the electrons towards the holder 33 and objects 34 to preheat the objects 34. It is possible to use any one of the embodiments comprising the coil means 41 and the controlling means 48 therefor to preheat of the objects 34. In addition, it is possible to have the third embodiment having the electron trap 42 illustrated with reference to FIG. 8 and means (not shown) for controlling the electric source 63 for similar operation. In accordance with the fifth embodiment, it is also possible to keep the temperature of the objects 34 at a temperature at which a balance is held between the heating effected by the electron bombardment on the objects 34 and the natural or forced cooling thereof. According to the results of ex-

periments, it was feasible to control the temperature within $\pm 1^\circ\text{C}$.

Referring to FIGS. 13 and 14, a sixth embodiment of this invention comprises parts similar to those illustrated with reference to FIGS. 1 and 2 and designated with like reference numerals. In these figures, the cup-shaped vessel 21 is shown as a bell jar and the cover 22, as a base plate therefor. Here, the cathode 31 is of a cylindrical shape and the holder 33 comprises a plurality of cylinders 76 for the objects 34 rotatable around their respective axes 77 arranged in the manner later described along a circle having the center on the axis of the cathode 31. The driving means 36 drives a turn table 78 through a gear 79 to revolve the cylinders 76 around the axis of the cathode 31. The cylinder axes 77 extend through the turn table 78 and are carried by gears 81, respectively, engaging with a center gear 82 fixed to the base plate 22. An O-ring 83 is disposed around the axle of the gear 79. It is possible with the sixth embodiment to simultaneously carry out the sputtering onto the objects 34 about three times as much in number as the objects dealt simultaneously with a single cylindrical holder having the surface along a line depicted with dot-dash line 85 in FIG. 14. In addition, it is possible to have uniform films sputtered onto the objects 34 having a complicated shape, particularly indents, because the objects 34 are directed towards the cathode 31 at one time during the operation and aslant thereto at another time as a result of rotation of the cylinders 76 about their respective axes.

Referring further to FIG. 14, one or more cathodes 31A may be disposed around the holder 33 to provide a sputtering device of the inverted magnetron type. The coil means 41A and the electron trap 42A thereof may be arranged as shown. It is possible with a plurality of cathodes 31A arranged in this manner to sputter a plurality of substances successively onto the objects 34 without the objects 34 being removed from the holder 33 and without the vacuum broken throughout the successive sputtering. With a similar arrangement, it is possible to sputter an alloy of the cathode materials onto the objects 34.

Finally referring to FIG. 15, a cylindrical cathode 31 may comprise sectors 86, 87, and 88 of different materials to sputter a ternary-system alloy of the materials onto the objects 34.

While the present invention has thus far been described, it should be understood that various modifications are possible. For example, the metal plates 43 of the electron trap 42 for the first embodiment may directly be attached to the holder 33 as shown at 43A with dash-dot lines in FIG. 2. The electron trap 42 and/or other parts may be forcibly cooled by means not shown. In addition, it is possible to combine in various manner the parts described in conjunction with several embodiments of this invention.

What is claimed is:

1. A device for sputtering the material of a cathode means onto an object, said device including a chamber, means for supplying a sputtering gas to said chamber, first means disposed in said chamber a spaced distance from said cathode means for holding said object and second means for providing electric fields between said first means and said cathode means to produce a gas discharge in said chamber, wherein the improvement comprises third means disposed in said chamber adjacent to said first means and fourth means for varying

the paths of electrons produced during the sputtering and initially accelerated by said electric fields towards said first means, said third means comprising a plurality of thin metal plates located substantially between said cathode means and said first means for receiving a major proportion of the electrons having the paths varied by said fourth means, each of said metal plates having a width substantially in the direction of the electric field at the location of each metal plate and extending in the direction of the electric field to collect electrons deviating from their initial path of movement towards said first means.

2. A device as claimed in claim 1, wherein said first means comprises a plurality of cylinders for holding said objects, said cylinders being rotatable around their respective axes arranged on a cylindrical surface, and means for rotating said cylinders around said respective axes and around the axis of said cylindrical surface.

3. A device as claimed in claim 2, wherein said cathode means comprises a plurality of cathodes arranged around said first means.

4. A device as claimed in claim 3, wherein said second means is capable of providing said electric fields simultaneously between said cathodes and said first means.

5. A device as claimed in claim 3, wherein said second means is capable of providing said electric fields successively between said cathodes and said first means.

6. A device as claimed in claim 2, wherein said cathode means is of a cylindrical shape arranged along said cylindrical surface axis and comprises a plurality of sectors, each having a length in the direction of said cylindrical surface axis.

7. A device as claimed in claim 1, wherein said fourth means comprises fifth means for adjustably varying the

paths of said electrons whereby the temperature of said objects is controlled.

8. A device as claimed in claim 7, further comprising a metal piece disposed adjacent to said first means for receiving a portion of said electrons, said fifth means being capable of adjustably varying the paths of said electrons in response to the amount of the electrons received by said metal piece.

9. A device as claimed in claim 8, wherein said metal piece is mounted on said first means.

10. A device as claimed in claim 7, wherein said fifth means is capable of adjustably providing a magnetic field substantially perpendicular to said electric fields.

11. A device as claimed in claim 7, wherein said fifth means comprises means for adjustably providing local electric fields between said metal plates.

12. A device as claimed in claim 1, wherein said fourth means comprises means for providing a magnetic field substantially perpendicular to said electric fields and wherein said thin metal plates have a length extending generally in the direction of said magnetic field.

13. A device as claimed in claim 12, wherein said thin plates are attached to said first means.

14. A device as claimed in claim 1, wherein said fourth means comprises a plurality of pole pieces substantially perpendicularly intersecting said metal plates and a plurality of bar magnets, each interconnecting the corresponding ends of adjacent two of said pole pieces, with a pair of said bar magnets disposed at both ends of each of said pole pieces similarly directed.

15. A device as claimed in claim 1, wherein said fourth means comprises means for providing local electric fields between said metal plates.

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