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WASHINGTON, D.C. 20546

REPLY TO ATTN OF: GP

TO: USI/Scientific & Technical Information Division
Attention: Miss Winnie M. Morgan

FROM: GP/Office of Assistant General Counsel for Patent Matters

SUBJECT: Announcement of NASA-Owned U. S. Patents in STAR

In accordance with the procedures agreed upon by Code GP and Code USI, the attached NASA-owned U. S. Patent is being forwarded for abstracting and announcement in NASA STAR.

The following information is provided:

U. S. Patent No. : 3,556,048

Government or Corporate Employee : California Inst. of Tech. Pasadena, Calif.

Supplementary Corporate Source (if applicable) : JPL

NASA Patent Case No. : NPO-10331

NOTE - If this patent covers an invention made by a corporate employee of a NASA Contractor, the following is applicable:

Yes ☒ No ☐

Pursuant to Section 305(a) of the National Aeronautics and Space Act, the name of the Administrator of NASA appears on the first page of the patent; however, the name of the actual inventor (author) appears at the heading of Column No. 1 of the Specification, following the words ". . . with respect to an invention of . . . "

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Enclosure
Copy of Patent cited above

FACILITY FORM 602

N71-26701 (ACCESSION NUMBER) (THRU)

4 (PAGES) (CODE)

✓ (NASA CR OR TMX OR AD NUMBER) 09 (CATEGORY)

PATENTED JAN 19 1971

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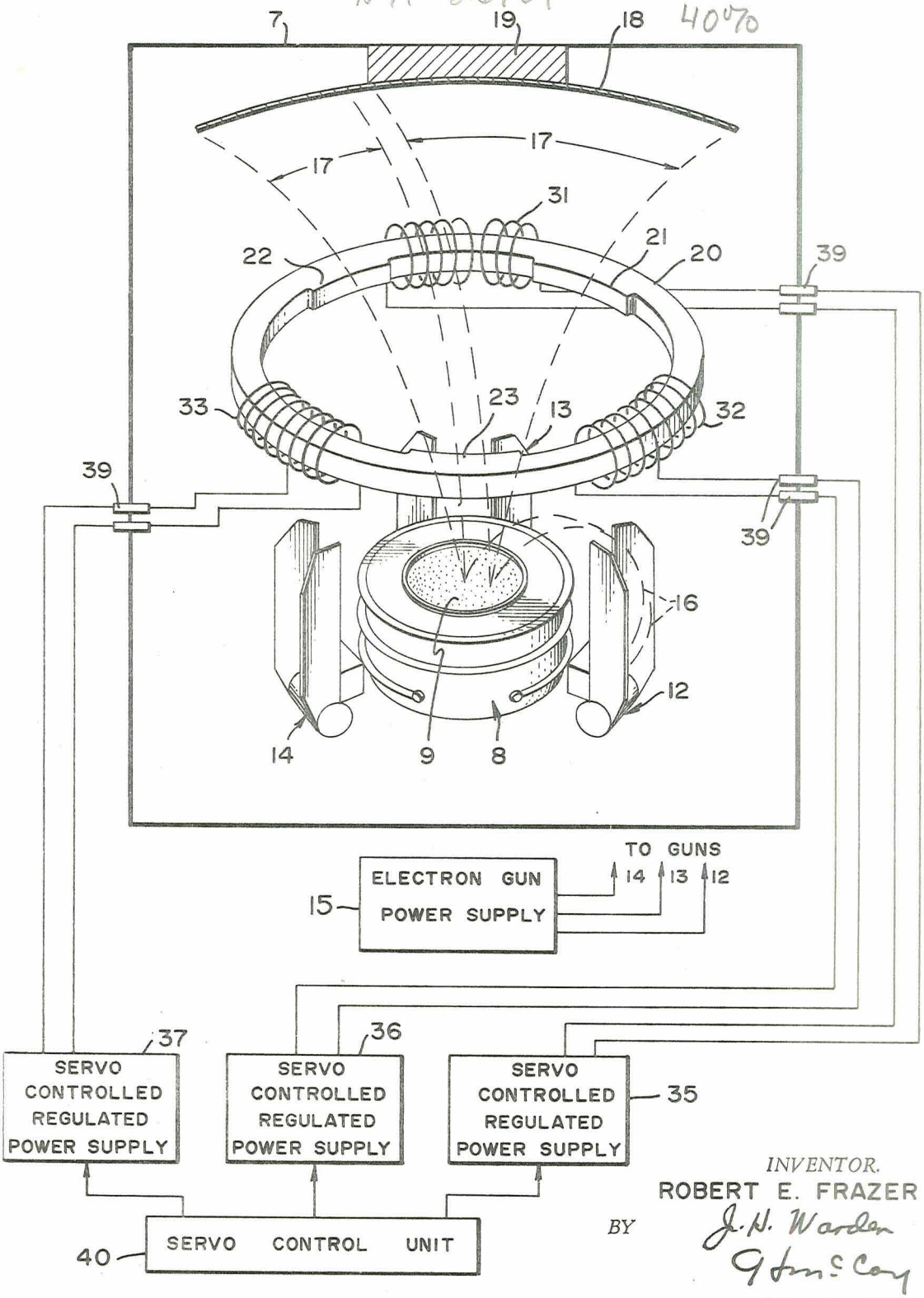

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United States Patent

[11] 3,556,048

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[21] Appl. No. **757,625**
[22] Filed **Sept. 5, 1968**
[45] Patented **Jan. 19, 1971**

[54] **VACUUM EVAPORATOR WITH ELECTROMAGNETIC ION STEERING**
9 Claims, 1 Drawing Fig.

[52] **U.S. Cl.** **118/49.5,** 204/298
[51] **Int. Cl.** **C23c 13/08**
[50] **Field of Search** 117/93.2, 106; 204/192; 118/49, 49.1, 49.5

[56] **References Cited**

UNITED STATES PATENTS

3,211,128	10/1965	Putter et al.	117/106
3,205,087	9/1965	Allen	117/106
3,117,022	1/1964	Bronson et al.	204/192
3,046,936	7/1962	Simons	117/106

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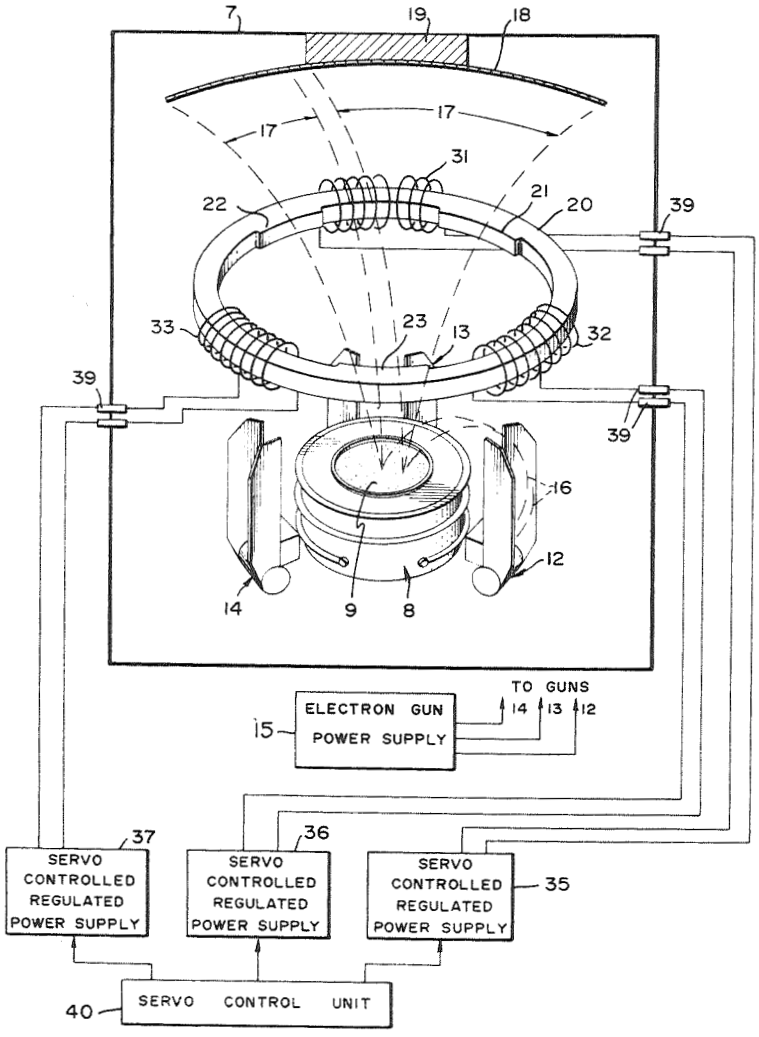
ABSTRACT: An apparatus for vaporizing material in a high vacuum chamber is disclosed. The apparatus includes an electromagnetic arrangement comprising a plurality of coils. The coils are controllably energized to produce a rotating magnetic field in the path of the vaporized material or ions to controllably steer them to selected points of the chamber's inner surface.



VACUUM EVAPORATOR WITH ELECTROMAGNETIC ION STEERING

ORIGIN OF INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention generally relates to an apparatus for evaporating substances in high vacuum and, more particularly, to improvements therein.

2. Description of the Prior Art

Many devices have been designed and developed to evaporate materials, for example, metals, in high vacuum to produce films. Typically, a container, often referred to as a crucible, supports the material to be evaporated in a vacuumtight housing. The material is evaporated by electron bombardment. The evaporated material, consisting of ions carrying neutral atoms, is used to coat a substrate, or simply condense over a selected surface to form a film. Generally, the area of the desired film surface is relatively small. Consequently, a single crucible may be employed to contain the material which, after evaporation, produces the film.

However, difficult problems arise whenever the surface to be coated is quite large. In the prior art, attempts have been made to produce a large deposited film by utilizing a plurality of crucibles (sources). Such an arrangement is satisfactory only if the uniformity of the film is not particularly critical. However, if film coating has to be of highly uniform thickness or has to meet specific thickness requirements, a multicrucible arrangement has been found to be of very limited use. The need for film coatings of relatively large surface area and of a high degree of uniformity, exists in both commercial and military applications. For example, the need is present whenever it is necessary to produce large diameter mirrors for solar simulators, solar energy converters, large antenna dishes, and the like.

OBJECTS AND SUMMARY OF THE INVENTION

It is a primary object of the present invention to provide a new improved apparatus for evaporating substances, such as metals and nonmetals, to produce a relatively large deposited film.

Another object of the present invention is to provide improvements in an evaporation apparatus in order to control deposition of evaporant onto a relatively large surface area.

A further object of the present invention is to provide highly reliable means which are easily controllable to control the deposition of vaporized films onto a relatively large surface area.

These and other objects of the invention are achieved by providing improved means in a vacuumtight housing in which a material is evaporated, in order to control the steering of the evaporated material towards a relatively large surface area to be coated therewith. Briefly, in one embodiment, the improved steering means consists of a plurality, such as three, coils wound around an annular ring which is placed above a crucible, in which evaporant is heated by electron bombardment. Ions, carrying with them neutral atoms, which are released from the hot material surface pass through the field of the coils. The coils are energized by a polyphase current to produce a controlled rotating magnetic field, whose rate of rotation and amplitude are controlled by controlling the phase and amplitudes of the currents, supplied to the three coils. It is the controlled rotating magnetic field which is used to steer the ions as they pass through the magnetic field so that they are controllably deposited to form the desired large surface film.

The novel features of the invention are set forth with particularity in the appended claims. The invention will best be understood from the following description when read in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWING

The FIG. is a combination block and modified cross-sectional diagram of a material deposition apparatus which incorporates the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the FIG., reference numeral 7 designates a vacuumtight housing in which a crucible 8 is securely positioned. The crucible is generally formed of a metal ceramic complex having excellent thermal insulating properties, with which the material 9, contained therein and which is to be evaporated, does not react. Material 9 may be hereafter referred to as the evaporant.

In the FIG., three electron beam guns 12, 13 and 14 are shown spaced approximately 120° from each other around crucible 8. The electron beams, supplied with power from an electron gun power supply 15, are designed to produce streams of electrons or electron beams which are aimed at the center of evaporant 9 in crucible 8. In order to simplify the drawing, the connections between power supply 15 and the various guns are deleted. Various commercially available electron guns may be employed. In one embodiment actually reduced to practice, each of guns 12, 13 and 14, consisted of a 10 kilowatt gun of the 270° bent beam type, manufactured by Airco Temescal, a Division of Air Reduction Company at Berkeley, California.

As is appreciated by those familiar with the art, the function of the electron beams is to heat evaporant 9, and cause it to evaporate. The vapor, in the form of ions carrying neutral atoms, which in the FIG. are designated by dashed lines 17, leaves crucible 8 and travels toward a substrate 18, shown supported in housing 7 by a support member 19. The vapor, upon striking the surface of substrate 18, which is assumed to be of a relatively large area, condenses to form a film thereon.

In accordance with the teachings of the present invention, in order to control the uniformity of the film deposited on the surface of substrate 18, an annular ring 20 is placed above crucible 8. The ring is provided with three inwardly directed projections, which are spaced approximately 120° apart, and serve as magnetic pole pieces 21, 22 and 23. Electrically conductive coils 31, 32 and 33 are wound around the annular ring 20, intermediate the inwardly directed projections. Coils 31, 32 and 33 are connected to respective servo controlled regulated power supplies 35, 36 and 37. The leads of the various coils extend through the walls of housing 7 and are insulated therefrom by vacuumtight insulators, generally designated by reference numeral 39. Power supplies 35, 36 and 37 are shown connected to a servocontrol unit 40.

The basic function of the annular ring 20, the three coils wound thereabout and the servocontrol power assembly, consisting of power supplies 35, 36, 37 and servocontrol unit 40, is to control the direction of the ions which pass through ring 20 so that when the ions strike the surface of substrate 18 a film of selected characteristics is deposited thereon. That is, the function of such means is to controllably steer the ions toward a controlled point on the surface of the substrate 18. The controlled steering is accomplished by controlling, by means of servocontrol unit 40, the amplitudes and the relative phases of the currents supplied to the three coils in order to produce a controlled rotating magnetic field about ring 20. By controlling the rate of rotation of the field, as well as the relative intensities of the magnetic fields produced by the three coils, ions are controllably steered to any selected point on the relatively large surface of substrate 18, thereby controlling the deposition thereon.

In one embodiment, actually reduced to practice, the servocontrol unit 40 was used to control the relative phases of the

three power supplies to produce a magnetic field rotating at a rate of three cycles per second. Such a field was used to steer ions emanating from a single crucible to form a deposit of aluminum on a 23 foot diameter surface for use as a solar simulator.

It should be appreciated by those familiar with the art that various servocontrol techniques may be employed in the design of servocontrol unit **40** in order to control the amplitudes in the relative phases of current supplied by a plurality, such as **3**, power supplies. Therefore, the unit **40** is not described in further detail.

There has accordingly been shown and described herein novel means for controllably steering vapor or ions towards a relatively large surface area in order to produce a film of selected controlled characteristics. The means include a plurality of windings which are energized to produce a rotating magnetic field. As the ions pass through the rotating magnetic field, their direction is affected thereby so that they strike the surface on which the film is to be formed at a controlled point.

It is appreciated that those familiar with the art may make modifications and/or substitute equivalents in the arrangements as shown. For example the coils **31**, **32** and **33** need not be positioned in a single plane as shown in the FIG. Rather they may be positioned in any desired configuration or relative positions with respect to one another. The only requirement is that the magnetic fields produced by the currents in the coils, when combined, result in a controllable magnetic field with which the ions passing therethrough are steerable towards the desired surface. Therefore, all such modifications and/or equivalents are deemed to fall within the scope of the invention as defined in the appended claims.

I claim:

1. Apparatus for producing a film of a vaporizable substance comprising:

a vacuumtight housing;

an open-topped crucible for holding a substance to be evaporated;

means for vaporizing said substance to convert at least a part thereof; and

electromagnetic means positioned in a plane above said crucible for providing a rotating magnetic field to control the direction of said vaporized substance toward a selected surface in said housing.

2. The apparatus as recited in claim **1** wherein said electromagnetic means for providing a rotating magnetic field surrounds an area through which flows said vaporized substance.

3. The apparatus as recited in claim **2** wherein said means for vaporizing include a plurality of electron guns, and means providing power to said guns to direct streams of electrons to heat and vaporize said substance by electron bombardment.

4. The apparatus as recited in claim **3** wherein said electromagnetic means include a plurality of coils disposed above said crucible, and servo controlled power supply means for controlling the amplitudes and relative phases of electrical current supplied to said coils to produce a magnetic field rotating at a preselected rate.

5. The apparatus as recited in claim **4** wherein said electromagnetic means include a ring disposed in said plane and said plurality of coils being wound and equidistantly spaced on said ring.

6. In a vacuum deposition apparatus for vaporizing a vaporizable material, means for vaporizing said material to form ions, the improvement comprising; electromagnetic means surrounding a portion of the path of said ions to provide a rotating magnetic field for controlling the directions thereof.

7. The apparatus as recited in claim **6** wherein said electromagnetic means comprise a plurality of windings surrounding an area in the path of said ions and means for energizing said windings to produce an electromagnetic field of selected characteristics which extends across said path to control the direction of flow of the ions passing therethrough.

8. The apparatus as recited in claim **7** wherein the number of windings is at least three, equidistantly spaced from one another.

9. The apparatus as recited in claim **8** wherein said means for energizing provide said three windings with a polyphase current to produce said rotating magnetic field.