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COATING APPARATUS EMPLOYING ROTATING AND RECIPROCATING FILAMENT

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FIG. 1

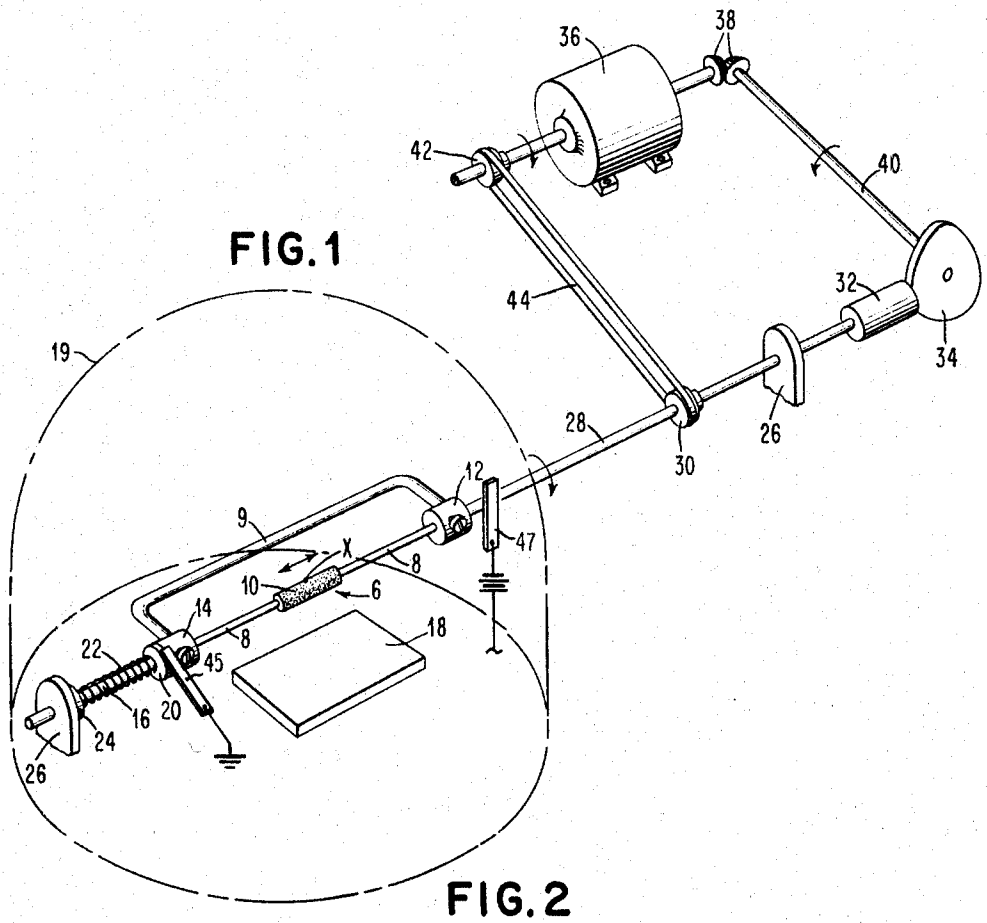
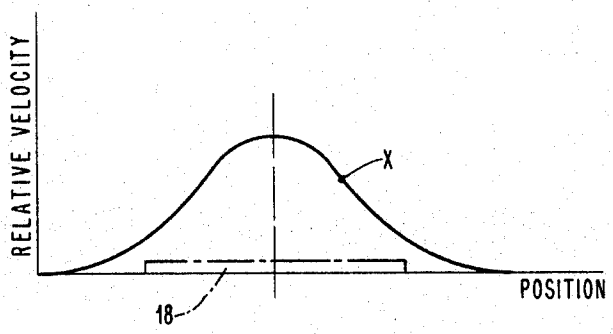


FIG. 2



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COATING APPARATUS EMPLOYING ROTATING AND RECIPROCATING FILAMENT

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This invention relates to an apparatus and method for evaporating a thin film on a substrate, and more particularly, to an apparatus and method for evaporating on a substrate a thin film of substantially uniform thickness.

In the art of vacuum deposited thin films, uniformity of film thickness is often required to maintain the electrical characteristics of the film constant throughout. This is especially true with thin film resistors, since the resistivity of such a resistor varies radically with changes in its thickness. Since any large production of thin film devices, e.g., resistors, requires that their electrical values be kept within certain tolerances it is obvious that the film thickness must be closely controlled.

Two types of sources of material to be deposited (evaporant) are often utilized. The first is generally referred to as a point source. Condensation from such a source on a plane surface has been found to be proportional to the cosine of the vapor incidence angle and inversely proportional to the square of the distance from the source. In other words, a point source deposits its vapor on a plane surface in the form of a hill, with the apex of the hill being at the point nearest the source. The second type of filamentary source (cylindrical) deposits its vapors over a greater surface area than the conventional point source. This, of course, enables it to produce greater quantities of thin film devices. However, the filamentary source also exhibits a similar but not as exaggerated, thickness distribution of coating as is evident from a point source. That is, assuming that the filament and plane surface are of equal length, the thickness of the coating on a plane surface is found to be greatest at the point on the surface which is closest to the center of the filament and gradually decreases in the form of a probability or "bell" curve as either end of the plane surface is reached. This type of thickness distribution has been demonstrated and is described in the book "Vacuum Deposition of Thin Films" by L. Holland, copyright 1961 by Wiley and Sons, at pp. 159–161. This phenomena can be explained by realizing that the ends of the filament are the controlling factors. Thus, while the fan shaped vapor evaporating from the center of the filament contributes to film buildup in the center portion of the substrate, the center buildup is also aided by the vapor which evaporates near the filament ends (a double contribution). The substrate edges do not experience such a double deposition from the ends of the filament, with the result that a thinner coating appears thereon.

To overcome these end effects, either the filament must be made long (e.g., 3–5 times the length of the substrate) and/or placed at a relatively long distance from the substrate. The problem with a relatively high ratio of filament to substrate length when the substrate is in itself long, is that the filament then does not fit into the vacuum system. Moreover, such a long filament is impractical due to the loss of the undeposited evaporant from the filament ends. It is also impractical to place the filament far from the substrate, due not only to the fact that the vacuum system becomes too large, but also because the deposition rates upon the substrate are too slow.

Present large quantity production techniques call for the utilization of a filament type source of evaporant; however, due to the aforementioned thickness variation

in the deposited film, the substrate edges are clipped and discarded, and only the relatively flat central portion is utilized. Needless to say, the yield from such techniques is not satisfactory.

Accordingly, it is an object of this invention to provide an apparatus and method for depositing a thin film of relatively constant thickness on a substrate.

Another object of this invention is to provide a method and apparatus for enabling a filamentary source of evaporant to deposit a relatively constant thickness thin film on a substrate.

A further object of this invention is to provide an economical method and apparatus for depositing a relatively constant thickness thin film from a filamentary source.

Still another object of this invention is to provide apparatus for depositing a relatively constant thickness thin film from a filamentary source which requires neither a long filament to substrate distance nor a large ratio of filament length to substrate length.

Another object of this invention is to provide a method and apparatus for depositing a relatively constant thickness thin film on a substrate which allows the use of a filamentary source which is shorter than the substrate.

Yet another object of this invention is to provide a method and apparatus for depositing a thin film from a filamentary source, which compensates for any inhomogeneities around the circumference of the source.

In accordance with the above stated objects, a short filamentary source of evaporant is displaced from and oriented longitudinally with the axis of a substrate to be coated. A relative nonuniform axial reciprocating motion is then initiated between the substrate and the filament with the relative speed between the elements being greatest when the filament is substantially centered over the substrate and least when the filament is over the substrate edges. An additional relative rotational motion is simultaneously imparted between the filament and substrate to integrate any inhomogeneities in the filament coating.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of a preferred embodiment of the invention, as illustrated in the accompanying drawings.

In the drawings:

FIG. 1 is a diagram showing a preferred embodiment of the invention.

FIG. 2 is a curve showing the variation of velocity of the filamentary source with its position.

Referring now to FIG. 1, a filamentary source **6** includes a resistive wire **8**, around a portion of which there is coated an evaporable substance **10**. If thin film resistors are being manufactured, substance **10** may be chromium, rhodium or some other resistive material. The resistive wire **8** is held by clamps **12** and **14** which are in turn held apart by nonconductive strut **9**. When clamped in place, the axis of filament **6** is coincident with the long axis of substrate **18**. The deposition apparatus is contained within vacuum bell jar **19** (shown in phantom) which provides the required vacuum atmosphere to carry out the process.

The relative length of the coated portion **10** of filament **6** with respect to the length of substrate **18** is variable; however, it has been found that a filament which is shorter than the length of substrate **18** is completely satisfactory. The reason for this will be explained in more detail hereinafter.

Shaft **16** extends from clamp **14** through washer **20**, spring **22**, washer **24** and support **26**. Shaft **16** is both slidably and rotatably mounted in support **26** so that it

is free to reciprocate and rotate therein. Extending from clamp **12**, is shaft **28** upon which pulley **30** and cam follower **32** are fixedly mounted. Shaft **28**, as is shaft **16**, is both slidably and rotatably mounted in support **26**. Either end of spring **22** is attached to a washer, e.g., **20**, **24**, which acts as a bearing surface. Spring **22** acting through washers **20** and **24** thereby biases clamp **14** away from support **26** in such a manner as to cause strut **9** and shaft **28** to firmly hold cam follower **32** in place on cam **34**.

Motor **36** acting through gearing arrangement **38** and shaft **40** imparts a rotational movement to cam **34**. Additionally, motor **36** acting through pulley **42**, belt **44** and pulley **30** imparts a rotational motion to shaft **28** and filamentary source **6**.

The electrical energization for filamentary source **6** is provided via brushes **45** and **47** which are in turn connected to suitable potential sources. Means (not shown) electrically isolate the driving portions of the system from the filament **6** and its power source. It should be realized that the techniques shown for energizing filamentary source **6** are schematic and are included only for illustrative purposes.

As aforestated, film deposition from a stationary filament on a planar substrate has a thickness characteristic resembling a bell-shaped curve with the greatest thickness appearing at the point on the substrate nearest the mid-point of the filament. In order to eliminate the aforementioned thickness variation in the deposited film, a nonlinear reciprocating motion of the type shown in FIG. 2 is imparted to filament **6** by cam **34**. In FIG. 2, the velocity of the mid-point X of filament **6** is plotted versus its position over substrate **18**. When mid-point X is centered directly over the center of substrate **18**, the velocity of filament **6** is greatest. Furthermore, as mid-point X approaches either extremity of substrate **18**, the velocity rapidly decreases to zero and the direction of travel of the filament reverses. This motion which, to a first approximation, is a simple harmonic function, smooths out the film coating by exposing the substrate areas (edges) which would normally have the thinnest film thickness to filament **6** for a proportionately greater time than the areas which would normally obtain the thicker coating (center). The exposure of the center portion of the substrate is thus decreased and the edges increased. The result of these relative speed variations is that a substantially uniform film thickness is obtained. Of course, depending upon the configuration of the substrate and the filament, some variations in relative motion which depart from simple harmonic may be empirically determined to be necessary, but the principle remains the same.

By virtue of the nonlinear reciprocating motion which is imparted to filament **6**, the coating portion **10** is made relatively short with respect to the length of substrate **18**. This is made possible due to reciprocating motion (described above) which gives all areas of the substrate substantially identical exposure to the evaporant. By additionally imparting the rotational motion to filament **6** through pulley **30**, any nonconcentricities, nonhomogeneities, or other nonconsistencies that may be intrinsic to the filament are integrated and smoothed.

In operation, filament **6** is first secured in place by clamps **12** and **14** and an electrical heating current is passed therethrough causing resistive wire **8** to heat and begin evaporating coating **10** (connections not shown). Motor **36** is energized imparting rotational motion to cam **34** and pulley **30**. While pulley **30** imparts a continual rotational motion to filament **6**, cam **34** pushes follower **32**, shaft **28**, strut **9** (and filament **6**) to the left causing a compression of spring **22**. When the high point of cam **34** passes follower **32**, spring **22** expands, holding follower **32** firmly against the bearing surface of cam **34**. In this manner, the displacement characteristic of cam **34** is imparted to filament **6** providing the desired nonlinear relative motion. If preferred, spring **22** can be replaced with an opposed cam driven in the same manner as cam **34**.

While the invention has been particularly shown and described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention.

What is claimed is:

1. An apparatus for evaporating a film on a substrate in a vacuum atmosphere comprising:

a filamentary source of vaporizable material which may have noncylindrical symmetry because of surface imperfections or departures from a circular cross section, spaced from said substrate, said source having an axis which is substantially parallel to the length of said substrate; and

means for providing relative rotation between said substrate and said source about the axis of the latter while simultaneously providing a predetermined nonuniform reciprocating relative motion between said substrate and said source along said axis, thereby producing on said substrate during the evaporation of said material from said source, a film having a desired thickness characteristic.

2. An apparatus for evaporating a film on a substrate in a vacuum atmosphere comprising:

a filamentary source of vaporizable material which may have noncylindrical symmetry because of surface imperfections or departures from a circular cross section spaced from said substrate, said source having an axis which is substantially parallel to the length of said substrate; and

means for providing relative rotation between said substrate and said source about the axis of the latter while simultaneously providing a substantially simple harmonic reciprocating relative motion between said substrate and said source along said axis, thereby producing on said substrate during the evaporation of said material from said source a film having a desired thickness characteristic.

3. An apparatus for evaporating a film on a substrate in a vacuum atmosphere comprising:

a filamentary source of vaporizable material which may have noncylindrical symmetry because of surface imperfections or departures from a circular cross section spaced from said substrate, said source having a length which is shorter than and an axis which is substantially parallel to the length of said substrate; and

means for providing relative rotation between said substrate and said source about the axis of the latter while simultaneously providing a substantially simple harmonic reciprocating relative motion between said substrate and said source along said axis, thereby producing on said substrate during the evaporation of said material from said source a film having a desired thickness characteristic.

4. An apparatus for evaporating a film on a substrate in a vacuum atmosphere comprising:

a filamentary source of vaporizable material which may have noncylindrical symmetry because of surface imperfections or departures from a circular cross section spaced from said substrate, said source having a length which is shorter than and an axis which is substantially parallel to the length of said substrate; and

means for providing relative rotation between said substrate and said source about the axis of the latter while simultaneously providing a predetermined nonuniform reciprocating relative motion between said substrate and said source along said axis, thereby producing on said substrate during the evaporation of said material from said source a film having a desired thickness characteristic.

5. An apparatus for evaporating a film on a substrate in a vacuum atmosphere comprising:

a filamentary source of vaporizable material which may have noncylindrical symmetry because of surface imperfections or departures from a circular cross section spaced from said substrate, said source having a length which is shorter than and an axis which is substantialy parallel to the length of said substrate; and

means for providing relative rotation between said substrate and said source about the axis of the latter while simultaneously providing a reciprocating relative motion between said substrate and said source along said axis, said relative motion being greatest when said source is centered over said substrate and is least when said source is over an edge of said substrate, thereby producing on said substrate during the evaporation of said material from said source, a film having a desired thickness characteristic.

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