Jan. 9, 1968 V. E. HAMILTON 3,362,848

APPARATUS AND METHOD FOR EVAPORATIVE COATING

Filed March 3, 1964 3 Sheets-Sheet 1

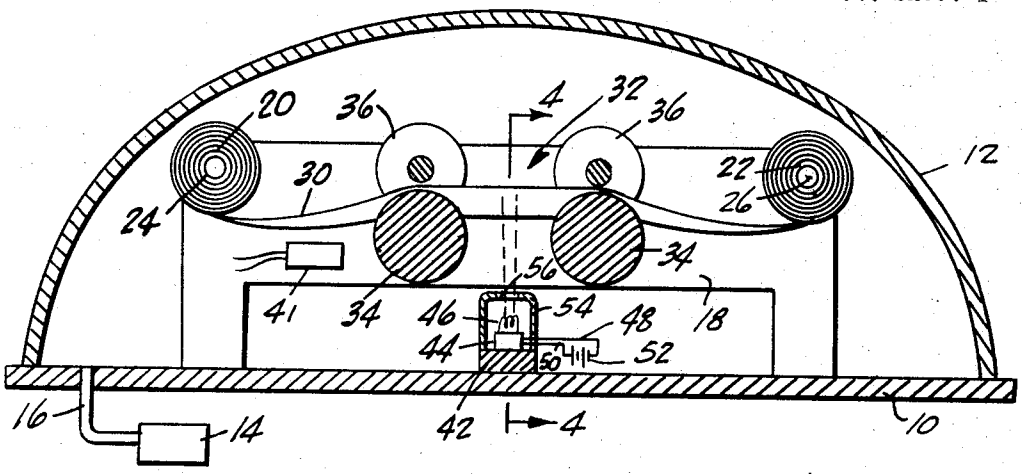


Fig. 1

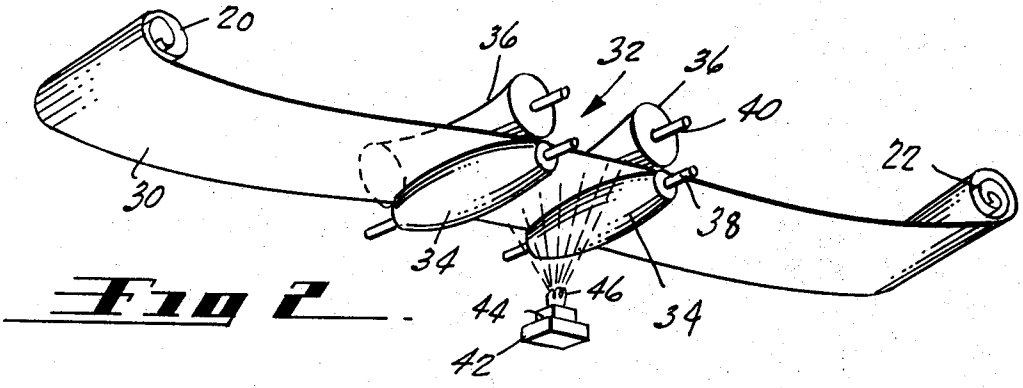


Fig. 2

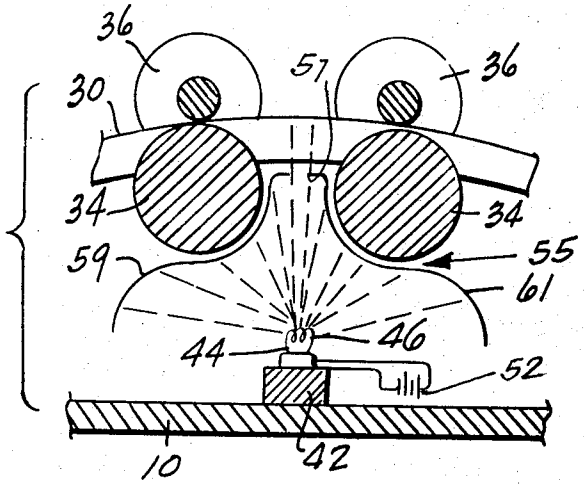


Fig. 3

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Jan. 9, 1968 V. E. HAMILTON 3,362,848

APPARATUS AND METHOD FOR EVAPORATIVE COATING

Filed March 3, 1964 3 Sheets-Sheet 2

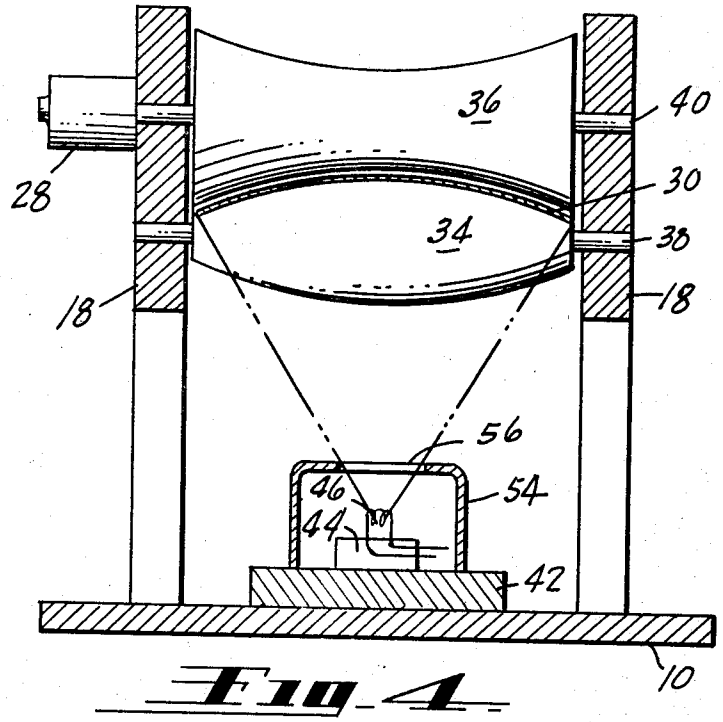


Fig. 4

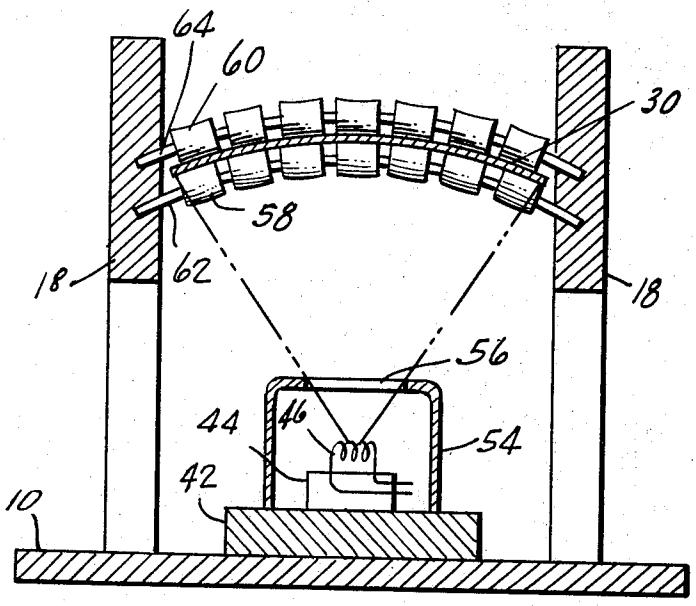


Fig. 5

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Jan. 9, 1968 V. E. HAMILTON 3,362,848

APPARATUS AND METHOD FOR EVAPORATIVE COATING

Filed March 3, 1964 3 Sheets-Sheet 3

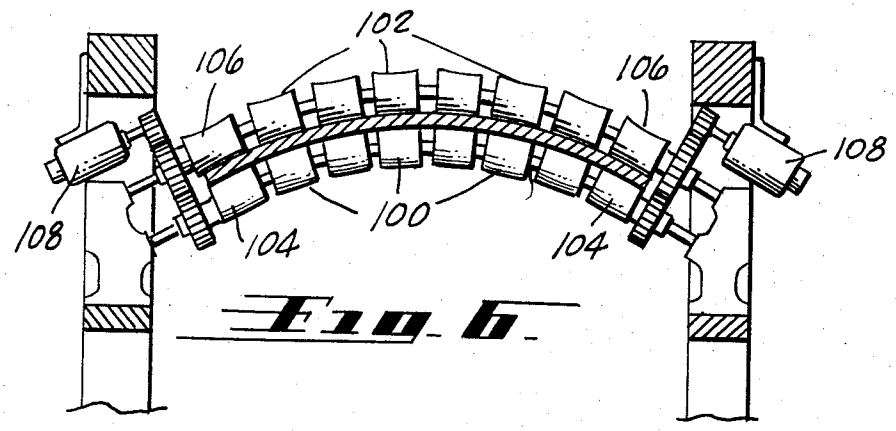


Fig. 6

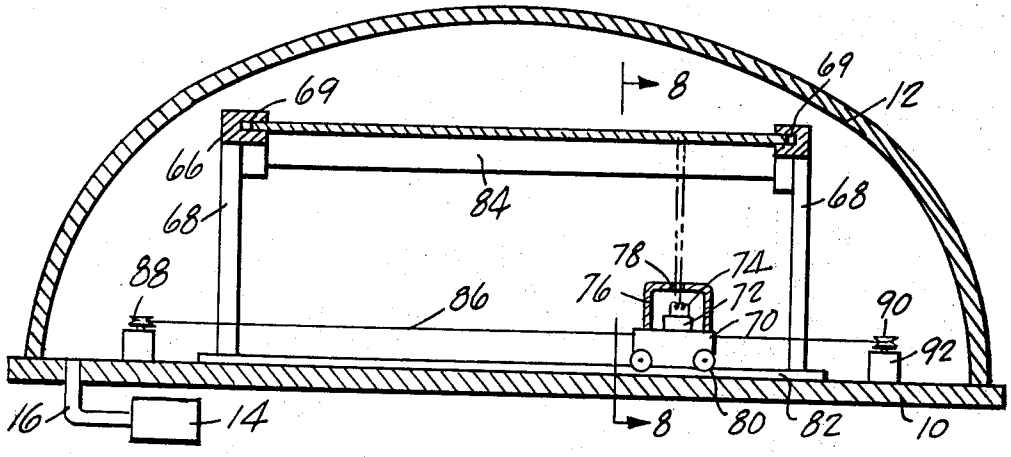


Fig. 7

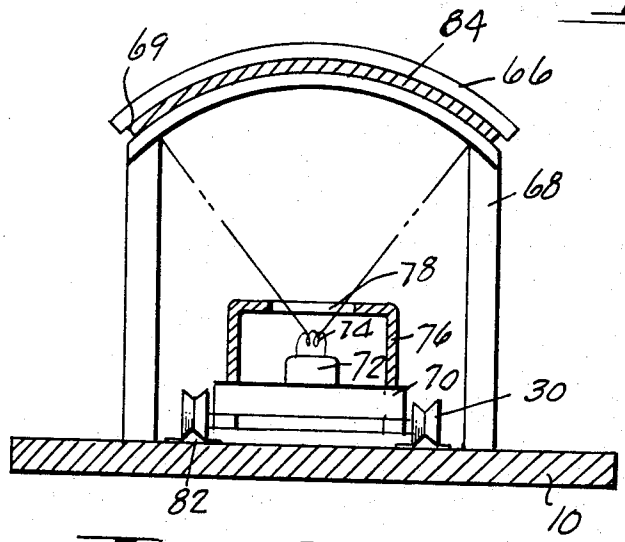


Fig. 8

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APPARATUS AND METHOD FOR EVAPORATIVE COATING

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19 Claims. (Cl. 117—106)

ABSTRACT OF THE DISCLOSURE

Apparatus includes means to move a long thin strip of flexible material in the direction of its length within a vacuum chamber and means to form it into a roof-like portion of a cylinder in the processing zone. A single concentrated source of evaporative coating material is located in the zone at the axis of the cylinder. The source is activated to emit particles in the form of a thin fan in a plane at right angles to the axis so that every portion of the film is at the same distance from the source as it passes through the zone. Thicker sheets are held stationary and the source moves along the axis of the cylinder.

This invention relates to the art of depositing evaporated coatings, particularly on sheet stock, and is directed primarily to the problem of depositing such coatings in a layer of uniform thickness.

In many fields the uniformity of thickness of a deposited layer is not critical and the only requirement is that all parts of the area be coated. Aluminized polyester film such as Mylar, for example, is used largely in the decorative field and the thickness of the coating may vary by several hundred percent so long as there is complete coverage which gives the impression of high quality chrome plate. Reasonable thickness control is desirable in order to minimize the total amount of metal deposited and thus minimize the cost, but high uniformity of thickness is not required for appearance or utility.

One example of a critical thickness control problem is the deposition of a low-reflection layer on plastic sheets which are cemented to the faces of the cathode ray tubes of television receivers to form safety glass combinations. The use of a low-reflection layer on the sheet increases light transmission by several percent and also greatly reduces specular reflection off the first surface of the complete tube face. This layer, as is well known, must be exactly some multiple of one quarter wave length thick ($\frac{1}{4}\lambda$; $\frac{1}{2}\lambda$; $\frac{3}{4}\lambda$), the wave length typically being chosen for the color or colors which produce the most substantial reflections in the visual region, such as the yellow-green central portion of the spectrum.

Common practice in evaporative coating of plastic sheet material such as Mylar is to feed a long web of suitable width from a supply reel to a take-up reel in a straight line through a processing zone, the material being planar from reel to reel. In the processing zone a sputtering device is located at a point displaced from the plane of the passing web on a line which extends through the center line of the web and perpendicular to its plane. When the material is sputtered from this localized point, the material along the center line of the web receives the heaviest coating because it is the shortest distance from the source. The paths from the source to laterally more remote portions of the web become longer and more angularly displaced, and the amount of deposition in a given time becomes less and less. Consequently, the best that can be accomplished is to coat the margin with the minimum permissible thickness and let the central areas coat thicker than necessary. As mentioned above, this is good enough for many purposes but unsatisfactory for optical work such as the production of low-reflection coatings.

The present invention solves this problem in a simple but very ingenious fashion by providing an arrangement in which all portions of the area to be coated pass through the processing zone at the same distance from a single concentrated source and substantially normal to the line of the shortest path from said source.

In one form of the invention, considered generically, at least a portion of the length of the base material, in the processing zone, is formed and maintained in the form of a part of a cylinder during the processing. A single concentrated source of evaporative coating material, magnesium fluoride being one example, is located on the axis of the cylinder. By the use of a slit mask or other suitable device, the sputtered material is confined and directed to radiate out in a fan formation toward the web in a plane normal to the axis of the cylinder, the angular extent of the fan corresponding to the angular extent of the web. Thus all of the particles of evaporated material are projected radially toward their particular target and all path lengths are substantially identical. At any one moment the particles coat a narrow line extending laterally of the length of the web, and all portions of the line receive a coating of uniform thickness. In order to coat a large area with this same uniform thickness, the source and the length of base material are moved relative to each other in directions parallel to the axis of the cylinder. In effect, the lateral coating line is spread out longitudinally of the length of material.

In the presently preferred embodiment of the invention, the apparatus is mounted in a vacuum chamber having a processing zone at an intermediate location. The base material to be coated is an elongate web of thin, transparent, plastic material carried by a pair of spaced supply and take-up reels, extending generally horizontally between them and passing through the processing zone. At upstream and downstream sides of the processing zone are concavo-convex guide means which form and retain the web in a roof-like arch which forms part of the wall of a cylinder having a longitudinal axis near the floor of the vacuum chamber.

The concentrated source of evaporative material is mounted on a stationary base and the source itself is located at the axis of the cylinder. A mask or other pattern control means directs the emitted particles in a fan formation toward the material in a plane normal to the cylinder, thus producing a narrow coating line of uniform thickness extending laterally of the longitudinal axis of the web. At least the take-up reel is provided with a power drive to draw the web between the guide means and through the processing zone at a constant rate of speed. Since each increment of area of the web is equidistant from the source as it is subjected to the coating action and is exposed for the same length of time, the result is a uniform coating of the entire area.

While the guide means may be simple slots in panels extending laterally of the path of travel of the web, it is preferred to use rollers to minimize resistance to movement of the web. In one form, a single barrel or olive roller and a single hour-glass roller constitute the guide means at each side of the processing zone. In another form, each set includes a series of small olive rollers on an arched support and a series of small hour-glass rollers on a correspondingly arched support.

A modified form of the invention is particularly suited for processing material which is too thick or rigid to conveniently be rolled up on supply and take-up reels. The material is cut into suitable sized sheets for processing in this form. The apparatus is mounted in a vacuum chamber similar to that used with the form previously described. The same source is used but in this case the base is mounted on rollers to travel back and forth in

a straight line along the floor, with the source traveling along the axis of the cylinder formed by the material.

The base material support comprises a pair of arches spaced from each other and located above the floor at about the ends of the path of travel of the source. Each arch has an open channel facing toward the other arch, and a sheet of base material of the appropriate length may be mounted with its ends fitting in the channels. The height and curvature of the channels are such that the sheet of base material will be formed and held in a roof-like arch to comprise a part of the wall of a cylinder with its axis parallel to the floor and passing through the source. Motor means is provided to move the source from end to end of the sheet so that it coats the sheet uniformly in the same way as in the form first described.

Various other advantages and features of novelty will become apparent as the description proceeds to conjunction with the accompanying drawings in which:

FIGURE 1 is a sectional view in elevation of the presently preferred form of the apparatus;

FIGURE 2 is an idealized representation in perspective of the apparatus of FIGURE 1;

FIGURE 3 is a view similar to FIGURE 1 showing a modified form of masking means;

FIGURE 4 is a sectional view taken on the line 4—4 of FIGURE 1, showing the guide roller form and the means for directing the emitted particles;

FIGURE 5 is a view similar to FIGURE 4, showing a modified form of the rollers;

FIGURE 6 is a view similar to FIGURE 5, illustrating a power drive for some of the rollers;

FIGURE 7 is a view similar to FIGURE 1, showing the modified form of apparatus; and

FIGURE 8 is a sectional view taken on the line 8—8 of FIGURE 7.

In the form of the invention disclosed in FIGURES 1, 2, and 4, the apparatus as a whole includes a vacuum chamber having a floor **10** and a removable, sealable hood **12**, together with a conventional vacuum pump **14** communicating with the vacuum chamber by means of conduit **16**. The apparatus of particular interest, which is mounted within the chamber, comprises a pair of spaced, upright, longitudinally extending standards **18** carrying between them near their ends a supply reel **20** and a take-up reel **22**, mounted on shafts **24** and **26** respectively. At least the shaft **26** of the take-up reel is driven by a geared motor **28**, FIGURE 4, or other suitable means to draw the web of material **30** to be coated through the apparatus.

The general mid-portion, as seen in FIGURE 1, is established as a processing zone in which the shape of the web is specifically controlled and the coating is applied. At the general upstream and downstream borders of this zone, support and guide means are provided for the web to support it at the proper distance from the coating source and to maintain it in a cylindrical shape while passing through the zone. These means may be laterally extending panels with arcuate, slot-like passages therethrough but, as illustrated in FIGURE 1, they consist of two sets of rollers, each set including a convex roller **34** and a concave roller **36** having shafts **38** and **40** respectively mounted for rotation in standards **18**. The shafts are shown in plain friction bearings for simplicity, but in practice they are supported in anti-friction bearings to minimize any tendency for their surface to drag on the surfaces of the web. The surfaces of the two rollers of each set are spaced apart slightly more than the thickness of the material to provide clearance while maintaining the web between the sets in the form of a roof-like arch forming a portion of the surface of a cylinder. A corona discharge device **41** of any well known type is mounted close to the under surface of the web upstream of roller **34** to remove residual gas molecules adhering to the surface.

A base **42** is mounted on the floor of the chamber in the lower part of the processing zone, and supports an insulator **44** which carries the concentrated source of evaporative material in the form of a coiled filament **46** having conductors **48**, **50** connected to a suitable source of electric power illustrated as a battery **52**. As best shown in FIGURE 4, the source is at the axis of the cylinder formed by web **30** of the material to be coated and consequently, in a lateral plane, it is equidistant from all points of the material. Thus, when power is applied, the sputtered material fans out radially and is evenly deposited along a narrow line extending laterally of the longitudinal axis of the web. Mask **54** is provided with an elongate narrow slit **56** to confine and direct the evaporated material in the fan-form path shown. Any suitable known type of sputterer with direction control may be submitted for the exemplary type illustrated herein.

The mask may be considerably modified so long as it accomplishes the intended purpose. Thus, in FIGURE 3, mask **55** may be well spaced from the source **46** and may have a slit **57** near the web. The extensive aprons **59** and **61** prevent the sputtered material from reaching the web except in the intended area.

FIGURE 2 best illustrates the roof-like arched section of the web in the processing zone and the narrow lateral line of coating which is deposited at any one moment in the process.

To carry out the complete coating operation with the apparatus just described is very simple and straightforward. Web **30** is threaded from supply reel **20** between the sets of rollers **34**, **36** through the processing zone and attached to reel **22**. Hood **12** is sealed on base **10** and vacuum pump **14** is operated to produce the proper vacuum. If necessary, the material is passed from supply reel to takeup reel and back one or more times past discharge device **41** to scrub the surface and remove substantially all residual gaseous molecules adhering thereto. Source **46** is then activated by applying power thereto and sputtering begins. Motor **28** is activated to draw the web through the processing zone at a constant rate so that effectively a narrow lateral coating line is moved longitudinally of the web and the same thickness of coating is deposited on every increment of its area.

It is obvious that there is a substantial difference in the peripheral speeds of the guide rollers at their centers and at their ends which will result in rubbing the surfaces of the web. This is not a serious matter because of the clearance provided. However, to reduce such variations to a minimum the modification illustrated in FIGURE 5 may be used. All elements of this modification are the same as in the form previously described except the rollers and their mountings. Rollers **58** and **60** are still convex and concave but are very short laterally, and each roller is separately rotatably mounted on the arched support bars **62** and **64**, which in turn are rigidly fixed in standards **18**. The variation in peripheral speeds of the various parts of any one roller are very small and, since they are independently mounted, there is no build-up of variation. They can, of course, be made as short as desired.

Since the coating must be uniform longitudinally as well as laterally, the sputtering rate is kept constant and the rate of feed of web **30** through the processing zone is also kept constant. Since the material diameter on reel **22** continually increases as the machine operates, the speed of shaft **26** must be reduced to compensate for the change. Any suitable known sensing and control device may be used to read the speed of the web and vary the speed of shaft rotation to keep the web speed constant.

It is also possible to use a slip drive on shaft **26** so that the driving shaft rotates more rapidly than shaft **26**. The speed of the latter is then controlled by the rate at which the web reaches the reel. When this system is used, the constant speed control is exercised at the processing zone. FIGURE 6 illustrates a suitable arrangement, in

which the rollers shown are substantially the same as those of FIGURE 5, and are the takeup rollers on the downstream side of the zone. The intermediate rollers **100** and **102** are preferably freely rotatable as before, but end rollers **104** and **106** are geared together and driven by constant speed motors **108**. Shaft **24**, FIGURE 1, is retarded by a conventional friction drag and thus the web **30** will be taut and smooth in the processing zone and will pass through it at the desired constant speed.

The modified form of the invention illustrated in FIGURES 7 and 8 is particularly suited for processing material which is too thick or too rigid to be conveniently rolled up on supply and take-up reels. It operates on the same principles as the forms previously described including the relative motion of the sheet and the source in directions parallel to the axis of the cylinder.

In this construction, the vacuum chamber is identical to the one already described. Identical arches **66** are mounted in spaced relation and above the floor of the chamber by columns **68**. An arcuate channel is formed in each arch in that face which directly opposes the other arch, and these channels are open at their ends to permit a sheet of material **84** to be coated to be slid into position as shown where it forms a roof-like arch in the form of a portion of a cylinder having an axis spaced above floor **10** of the chamber.

Base **70** carries insulator **72** which in turn carries the concentrated source **74** of evaporative material. A mask **76** with slit **78** is mounted on the base to operate in the same way as mask **54**. The base is carried by grooved rollers **80** which travel on tracks **82** extending longitudinally of the apparatus to such an extent that the base can travel from end to end of sheet **84**. The ends of a cable **86** are secured to the base and pass over pulleys **88** and **90** and other pulleys, not shown, to constitute an endless cable drive mechanism for the base. Pulley **90** is driven by a geared motor **92**. Source **74** is spaced above the floor the proper distance to move along the axis of the cylinder. In operation, the base and source are located at one end of their travel, the source is activated, and is then moved longitudinally on the axis of the cylinder at a constant speed to the other end of its travel, with the result that every increment of area of the sheet **84** receives a coating of the same thickness.

It will be apparent to those skilled in the art that various changes and modifications may be made in the method and apparatus as disclosed without departing from the spirit of the invention, and it is intended that all such changes and modifications shall be embraced within the scope of the following claims.

I claim:

1. A method of depositing on a length of thin base material a thin layer of evaporated material of uniform thickness, comprising: positioning a concentrated source of evaporative coating material at a selected locus on the axis of an imaginary cylinder; arranging at least a portion of said length of base material in cylindrical form at the surface of said imaginary cylinder; activating said source to discharge particles of evaporative coating material toward said base material in the shape of a fan lying in a plane normal to the cylinder axis; and moving said source and said length of base material relative to each other in directions parallel to the cylinder axis while continuing the discharge of said evaporative coating material.

2. A method of depositing on a length of thin base material a thin layer of evaporated material of uniform thickness, comprising: positioning a concentrated source of evaporative material at a selected locus on the axis of an imaginary cylinder; arranging at least a portion of said length of base material in cylindrical form at the surface of said imaginary cylinder in a processing zone; activating said source to discharge particles of evaporative coating material toward said base material in the processing zone in the shape of a fan lying in a plane normal to the cylinder axis; maintaining said source stationary; and moving said length of base material through said processing zone parallel to the cylinder axis while continuing the discharge of said evaporative coating material; the portion of said base material passing through said zone at any time being maintained in said cylindrical form.

3. A method of depositing on a length of thin base material a thin layer of evaporated material of uniform thickness, comprising; arranging said length of base material in arcuate form to constitute a portion of the periphery of a cylinder; positioning a concentrated source of evaporative coating material at the axis of said cylinder; activating said source to discharge particles of evaporative coating material toward said base material in the shape of a fan lying in a plane normal to the cylinder axis; and moving said source along said axis from end to end of said length of base material while continuing the discharge of said evaporative coating material.

4. Apparatus for depositing on a length of thin transparent material a low-reflection layer of evaporated material of uniform thickness, comprising: a horizontally elongate vacuum chamber having a generally horizontal floor; a supply reel and a take-up reel mounted at opposite ends of said chamber for rotation about horizontal axes to transfer thin transparent material from one to the other in a generally horizontal plane; a generally central portion of said chamber constituting a processing zone through which said material passes; supporting and guide means mounted upstream and downstream of said processing zone shaped and arranged to support between them an intermediate portion of the length of said material arched to form a roof-like portion of a cylinder having its axis in the vicinity of and substantially parallel to said floor; a concentrated source of evaporative coating material located at the axis of said cylinder and supported by said floor; means to activate said source to discharge particles of evaporative coating material upward toward said transparent material in the processing zone; means to direct the discharge in a fan formation lying in a vertical plane normal to the axis of the cylinder; and means to move said material through said processing zone in a direction parallel to the axis of the cylinder.

5. Apparatus as claimed in claim **4**; said supporting and guide means comprising upper rollers having concave surfaces and lower rollers having convex surfaces; the surfaces of the rollers cooperating to define guide paths for the material which are of predetermined arcuate shape in cross-section.

6. Apparatus for depositing on a length of thin transparent material a low-reflection layer of evaporated material of uniform thickness, comprising; a vacuum chamber; a supply reel and a take-up reel mounted in said chamber and spaced apart in the same general plane to transfer thin transparent material from one to the other in the same general plane passing through a processing zone at an intermediate locus; guide rollers mounted upstream and downstream of the processing zone to contact both surfaces of said length of material as it passes between them and shaped and arranged to constrain said material to an arcuate shape across its width as it passes through the processing zone, thus defining a portion of the periphery of a cylinder; a concentrated source of evaporative coating material located at the axis of said cylinder; means to activate said source to discharge particles of evaporative coating material toward said transparent material; means to direct the discharge in a fan formation lying in a plane normal to the axis of the cylinder; and means to drive at least the take-up reel to move the transparent material through the processing zone.

7. Apparatus as claimed in claim **6**; the guide rollers on one side of said material being convex and the guide rollers on the other side being concave.

8. Apparatus as claimed in claim **6**; the guide rollers

comprising two sets; and each set comprising a plurality of convex rollers mounted on an arcuate support for independent rotation and a plurality of concave rollers mounted on an arcuate support for independent rotation.

9. Apparatus as claimed in claim 6; the guide rollers comprising two sets; and each set comprising a single convex roller and a single concave roller.

10. Apparatus for depositing on a length of thin flexible material a thin layer of evaporated material of uniform thickness, comprising; a vacuum chamber; concavo-convex support and guide means mounted in said chamber and spaced apart to define between them a processing zone; said support and guide means being shaped and arranged to support between them a length of thin flexible material arched to form a portion of a cylinder; a concentrated source of evaporative coating material located at the axis of said cylinder; means to activate said source to discharge particles of evaporative coating material toward said flexible material in said processing zone in a fan formation lying in a plane normal to the axis of the cylinder; said source being normally stationary; and said flexible material being movable through said support and guide means in a direction parallel to the axis of said cylinder.

11. Apparatus for depositing on a length of thin base material a thin layer of evaporated material of uniform thickness, comprising: a vacuum chamber; supporting means mounted in said chamber and shaped and arranged to support between them a length of thin base material arched to form a portion of a cylinder; a concentrated source of evaporative coating material located at the axis of said cylinder; means to activate said source to discharge particles of evaporative coating material toward said base material; and means to confine the discharge to a fan formation lying in a plane normal to the axis of the cylinder; said base material and said source being movable relative to each other in directions parallel to the axis of said cylinder.

12. Apparatus for depositing on a length of thin base material a thin layer of evaporated material of uniform thickness, comprising; a vacuum chamber; supporting means mounted in said chamber and shaped and arranged to support between them a length of thin base material arched to form a portion of a cylinder; a concentrated source of evaporative coating material located at the axis of the cylinder; means to activate said source to discharge particles of evaporative coating material toward said base material; and a control mask located between said source and said base material to confine the discharge to a fan formation lying in a plane normal to the axis of the cylinder; said mask comprising a member of imperforate material having a narrow slit extending in a direction at right angles to the direction of the axis of the cylinder; said base material and said source being movable relative to each other in directions parallel to the axis of said cylinder.

13. Apparatus for depositing on a length of thin base material a thin layer of evaporated material of uniform thickness, comprising: a vacuum chamber having a generally horizontal floor; supporting means shaped and arranged to support between them a length of thin base material arched to form a roof-like portion of a cylinder having its axis in the vicinity of the substantially parallel to said floor; a concentrated source of evaporative coating material located at the axis of the cylinder and supported by said floor; means to activate said source to discharge particles of evaporative coating material upward toward said base material; and means to confine the discharge to a fan formation lying in a vertical plane normal to the axis of the cylinder; said base material and said source being movable relative to each other in directions parallel to the axis of said cylinder.

14. Apparatus for depositing on a length of thin base material a thin layer of evaporated material of uniform thickness, comprising: a vacuum chamber; support means mounted in said chamber and spaced apart to define between them a processing zone; said support means comprising arches provided with arcuate channels opening toward each other to receive the ends of a length of base material and hold it stationary with its original plane arched to form a portion of a cylinder; a concentrated source of evaporative coating material located at the axis of the cylinder; means to activate said source to discharge particles of evaporative coating material toward said base material in said processing zone in a fan formation lying in a plane normal to the axis of the cylinder; and said source being movably mounted to travel along the axis of the cylinder from end to end of the length of base material.

15. Apparatus for depositing on a length of thin base material a thin layer of evaporated material of uniform thickness, comprising: a vacuum chamber having a generally horizontal floor; supporting means shaped and arranged to support between them a length of thin base material arched to form a roof-like portion of a cylinder having its axis in the vicinity of and substantially parallel to said floor; a support carried by said floor for movement parallel to the axis of the cylinder; a concentrated source of evaporative coating material mounted on said support at said axis of the cylinder; means to activate said source to discharge particles of evaporative coating material upward toward said base material in a fan formation lying in a vertical plane normal to the axis of the cylinder; and means to move said support back and forth parallel to the axis of the cylinder from end to end of said base material; whereby said source will travel along said axis and deposit a uniform coating on the surface of said base material.

16. Apparatus as claimed in claim 15; said supporting means comprising a pair of arches spaced from each other and extending in vertical parallel planes; each arch being provided with an arcuate channel opening toward the opposite arch to receive one of the ends of the base material.

17. Apparatus as claimed in claim 16; said channels being formed in the opposing faces of said arches.

18. Apparatus as claimed in claim 16; said channels being open at least at one end of each to facilitate insertion of a length of material.

19. Apparatus as claimed in claim 16; said floor being provided with a pair of tracks extending parallel to said axis; and said support being provided with a plurality of rollers adapted to travel on and be guided by said tracks.

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