Oct. 1, 1946. H. OSTERBERG ET AL 2,408,529

APPARATUS FOR TREATING ARTICLES

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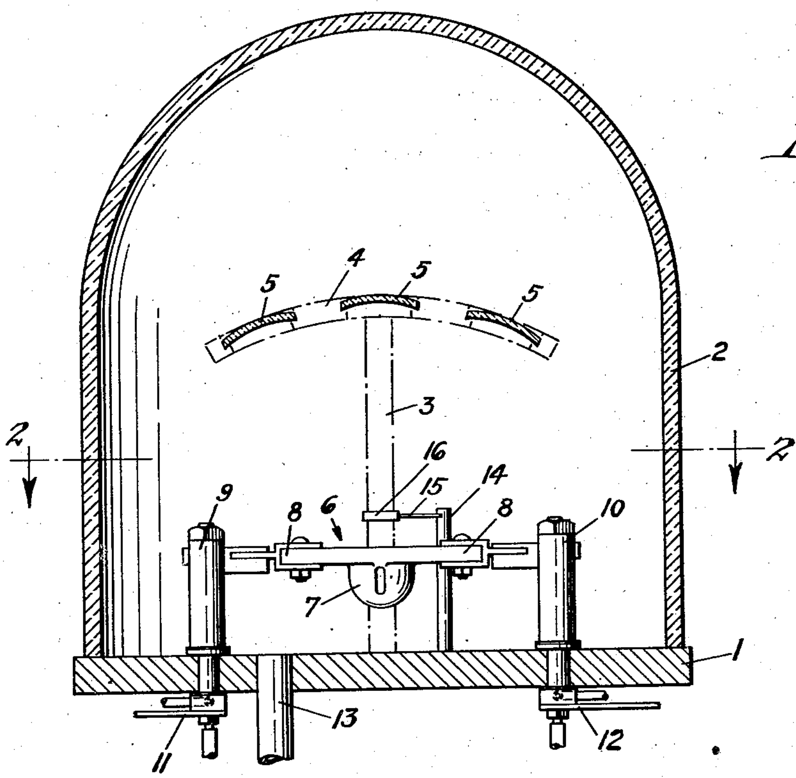

Fig. 1.

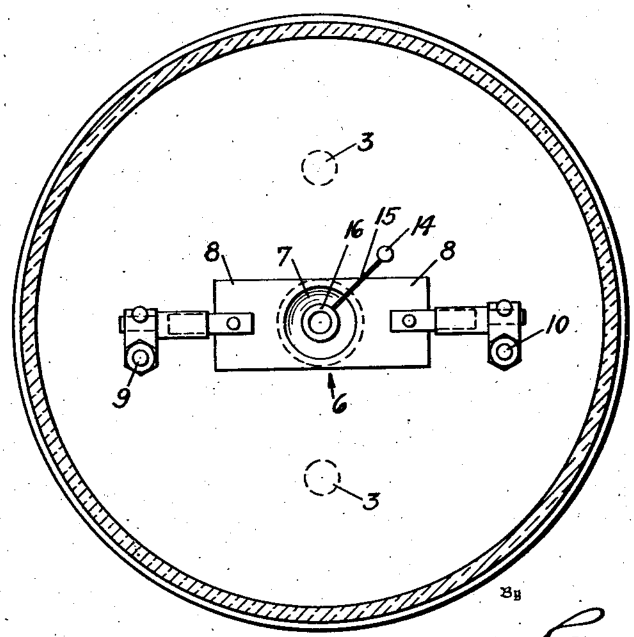

Fig. 2.

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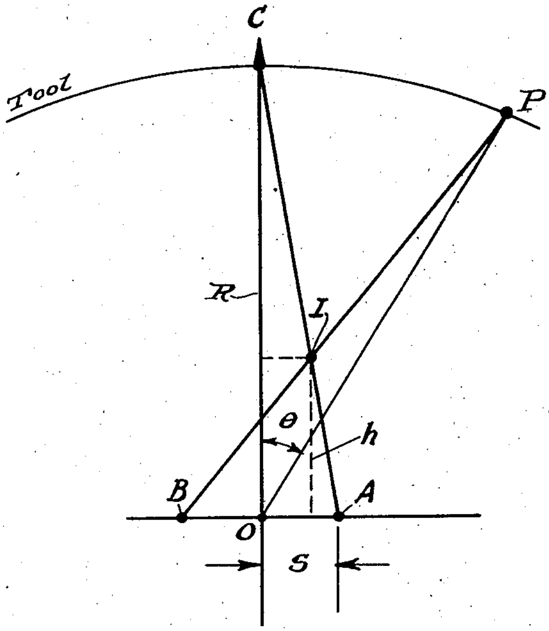

Fig. 3.

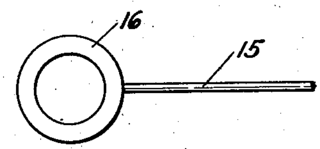

Fig. 4.

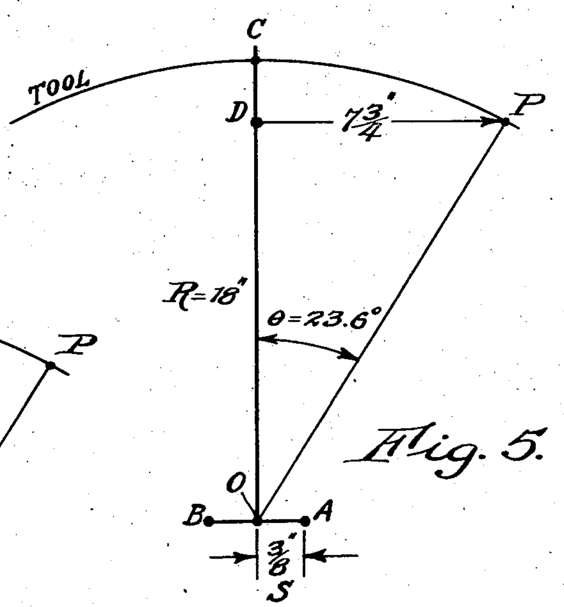

Fig. 5.

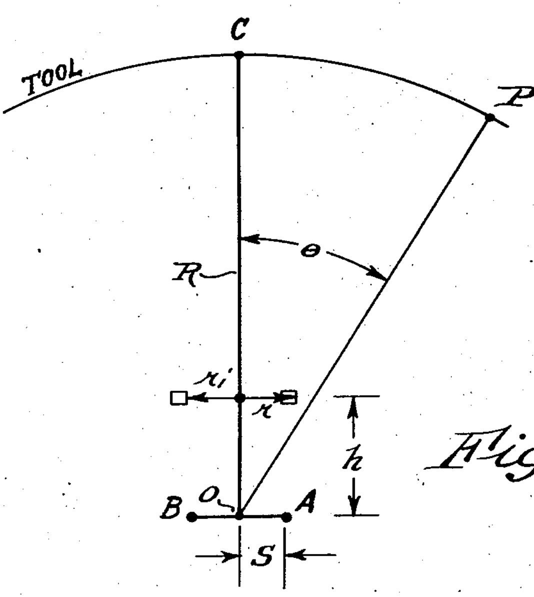

Fig. 6.

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UNITED STATES PATENT OFFICE

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APPARATUS FOR TREATING ARTICLES

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5 Claims. (Cl. 91—12.2)

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This invention relates to new and improved apparatus for treating the surfaces of articles and relates more particularly to the provision of coatings formed by vaporization of the coating material in a vacuum and the control of the deposition of said coating material to provide more uniform distribution thereof over the surface of the article or articles to be coated.

The present apparatus is shown applied to the forming of nonreflective coatings over the surfaces of light transmitting articles but its use is not so limited but it may be employed in connection with any arrangement for depositing coatings by evaporation in a vacuum where it is desired to obtain as uniform as possible distribution of said coating on the surface to be coated.

An object of the present invention is to provide new and improved apparatus of the type set forth with which a more uniform distribution of the coating material from the center to the edge will be obtained, especially where a non-point source of coating material is employed.

Other objects and advantages of the invention will be apparent from the following description taken in connection with the accompanying drawings. It will be understood that many changes may be made in the details of construction and arrangement of parts without departing from the scope of the invention as expressed in the accompanying claims. We, therefore, do not wish to be limited to the exact details of construction and arrangement of parts shown and described as the preferred forms have been shown by way of illustration only.

Referring to the drawings:

Fig. 1 is a side view of an apparatus embodying the invention;

Fig. 2 is a sectional view taken on line **2—2** of Fig. 1 looking in the direction of the arrows;

Fig. 3 is a diagrammatic view further illustrating the invention;

Fig. 4 is a top view of one form of blocking element which may be employed; and

Figs. 5 and 6 are diagrammatic views further illustrating the invention.

In the past considerable work has been done in connection with the providing of optical elements such as lenses, prisms, etc., with nonreflective coatings to prevent as far as possible reflection by said surfaces and also to increase the light transmission of said elements.

The method and apparatus usually employed for this purpose comprised the placing of the article to be coated in a vacuum in spaced relation with a source of coating material and then

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vaporizing said coating material to form a coating over the surface of said article which is disposed in the direction of the source of coating material. However, where the surface to be coated was large or where a number of articles were coated at the same time, it was found that the deposit of the coating material over the entire area was not uniform, that is, the thickness of the coating or deposit adjacent the center was considerably more than the thickness of the deposit at the outer edge and thus did not provide the same degree of non-reflectivity over the entire surface of a large article or over the surfaces of the various articles where a number of small articles were coated.

In the past attempts have been made to overcome this non-uniformity in the deposit. One of the methods involved the use of several sources of the material to be evaporated with the sources distributed so as to give an approximately uniform deposit. One of the difficulties with this technique was that it required many sources of the material to be evaporated and also that distribution of such sources must be varied from one set-up to another. Another technique which has been employed has been to interpose rotating sectors between the source of the material to be evaporated and the plate to be coated in such a manner as to increase the relative deposit at the outer edges of the plate. While this gave control for certain cases, it did not permit the use of one sector for several set-ups where articles of differently curved surfaces were coated and required different sectors for each set-up and the construction of such sectors involves laborious, time consuming calculations of sector dimensions for each set-up, and also this process slowed down the rate of coating and is hardly applicable to commercial use.

It is, therefore, an object of this invention to provide a new and improved apparatus for coating the surfaces of articles by vaporization of the coating material in a vacuum whereby the distribution of the coating material will be uniformly distributed from the center to the edge of the tool and which is simple, efficient and economical in construction and operation and therefore readily lends itself to commercial production.

The apparatus embodying the invention comprises a base **1** and bell jar or the like **2** forming the vacuum chamber.

Within the vacuum chamber are a pair of uprights **3** supporting the tool or disc **4** which supports the lenses **5**, and the surfaces of said lenses **5**, which are to be coated are positioned in the direction of the crucible 6 containing the material to be vaporized to form the coating, such as magnesium fluoride, cryolite, quartz or other suitable material for forming nonreflective coatings and where the method and apparatus is employed for other purposes such as for forming reflective coatings on reflectors, such material may be aluminum or other suitable reflective metal.

The crucible 6 comprises the bowl portion 7 adapted to contain the coating material and the integral extensions 8 adapted to be supported by and receive current through the posts 9 and 10 which extend through the base 1 and receive current through the leads 11 and 12 respectively, to vaporize the coating material by the resistance heating of said crucible 6.

The opening 13 through the base 1 is provided to allow the evacuation of the vacuum chamber by suitable vacuum pumps, not shown.

Within said vacuum chamber and adjacent said crucible 6 is provided a post or support 14 secured to said base 1 and extending upwardly therefrom.

This post 14 supports the wire or rod member 15 which member carries the blocking or vignetting member 16 and supports said member 16 in aligned, adjusted relation with said bowl portion 7 of said crucible member 6.

This blocking or vignetting member 16 has been found to provide more uniform coatings or films especially with a non-point source (and it is difficult to secure the equivalent of a point source located at the center of curvature of the tool or disc 4).

This vignetting member 16 is preferably in the form of an annular member of proper size and located in proper relation over the crucible. This member 16 is so positioned as to vignette the central portions of the tool 4 more than the edge of said tool, that is, so that the points at the edge of the field will not be vignetted but all other points will be vignetted in increasing amount up to the center of the tool.

It will be apparent that many types of variation in deposit may be obtained by using blocking or vignetting members 16 of suitable contour and form, but in order to get uniform distribution from the center of the tool to the edge of the tool a ring shaped stop is preferable.

This stop could however be of other configuration such as a spiral coil or a rectangular frame containing a plurality of cylindrical coils.

The annular member 16, as stated above, must be of proper outside diameter and inside diameter and must be positioned at the proper height from the source of material in the crucible.

Most sources used in the evaporation of magnesium fluoride, metals and other coating material obey the cosine law of molecular emission so that more evaporated particles are emitted along the normal to the source than in any other direction. Consequently when a tool such as shown in Fig. 3 is placed above the source S the greatest thickness of deposit of evaporated material will be at the mid point C of the tool with a gradual decrease in thickness to a point P at the edge of the tool. The decrease in thickness of the evaporated film from C to P is often as great as 15%. This 15% decrease in the thickness of the deposited coating is such as to interfere with the reflection reduction property of the coating over various parts of an article where a large article is coated or over different articles where a number of small articles is coated and is of such magnitude as to interfere with the efficiency of the nonreflecting film.

Referring to Fig. 3, this variation in thickness may be prevented and a uniform deposit obtained by blocking out a greater portion of the molecules reaching point C in the half cone CAO than in the corresponding half cone PBO. It is in fact desirable to use a ring stop or blocking member as previously described in such a position and of such an outer radius that the edge of this blocking member is located at the point I which is the intersection of the lines CA and PB where points A and B correspond to the outer boundary of the molten material in the crucible 7. The point I determines therefore both the outer radius r of the ring stop and the height h of the ring stop above the source of coating material. The location of I and hence r and h can be derived from purely geometrical considerations with the result that

$$h=\frac{2mR}{\frac{R}{S}+m}$$

$$r=S\frac{\frac{R}{S}-m}{\frac{R}{S}+m}$$

where

$$m=\frac{\cos\theta}{\frac{S}{R}+\sin\theta}$$

The angle θ appearing in the equation for m is the angle subtended at O the center of the source by the half tool CP namely angle COP. R is the radius of the tool. It is customary to place the molten material very close to the center of the tool. If the source S is not placed at the center of curvature of the tool, then with good approximation since the radius S is small as compared to the dimension CP of the tool R may be taken simply as the distance OC.

The point I and thus r and h may also be determined graphically from the intersection of lines CA and PB.

In Fig. 5 is shown an evaporation configuration such as may occur in practice in which the radius of the evaporating source is three-eighth inches, the distance OC eighteen inches and in which the evaporating tool has a half-chord PD equal to seven and three-quarters inches. The corresponding angle θ is found to be 23.6 degrees. When these values of R, S and θ are substituted into the above equations we find that h equals 1.56 inches and r equals 0.34 inch.

In Fig. 6 is shown the source S placed at the distance R below the mid-point C of the tool and a ring stop with outer radius r and height h as determined from previous considerations. The problem is to determine the inner radius r_1 of the ring stop such that the distribution of the evaporated materials will be uniform upon the tool.

First we determine the difference in the thickness of the deposition of the coating material between the center C of the tool and the edge of the tool P as obtained from a source without the ring stop. Calling the thickness at the center C unity, the thickness at the point P will be some quantity less than unity for example 0.85. L_0 is defined as the difference between unity and the ratio of the thickness of the deposited material at the edge P to the thickness of the deposited material at the mid-point C. This ratio is approximately equal to cosine θ so that, approximately, L=1-cosine θ. With L_0 determined either from experiment or mathematical calculations the inner radius r_i may now be calculated from the formula

$$r_i = r\left(1 - \frac{4S^2}{r^2}L_0\right)^{\frac{1}{2}}$$

in which r is the outer radius of the ring stop determined from previous consideration and in which S is the radius of the molten coating material in the crucible.

With the ring stop of the proper inner and outer radii determined as stated above and placed at the proper height from the source which height may be determined in a manner given above, we have found that the distribution over the entire tool is substantially uniform and that the variation between the center of the tool and the edge of the tool as previously given has been practically eliminated.

It is pointed out that with the prior methods not employing this ring stop that a variation such as the 15% example given above is in the case of nonreflecting magnesium fluoride films sufficient to cause the color of the evaporated film to vary from straw color at the edge to blue at the center. It will be apparent that this variation in color is accompanied by an undesirable variation in the efficiency of the nonreflecting film.

It is pointed out that where the article to be coated is but a single small article which may be readily positioned at the point C at the center of the tool a substantially uniform coating may be obtained over the entire surface but that where the article to be coated is large in surface or where it is desired to coat a number of small articles simultaneously such as is usual in production in commercial quantities that it is necessary that the angle θ of evaporation be greater than with the single small element as described above and it is in this case that the variation in the thickness of the deposited coating is encountered requiring the use of the ring stop to obtain a uniform thickness of the deposited coating. By the term "workpiece" as that term is used herein is meant a cluster of small lenses supported for coating simultaneously as well as a lens supported for coating individually.

The above formulas and examples have been given primarily for curved tools of the type shown and described. It is further pointed out that in the case of a flat tool or a flat article to be coated such as a large mirror or the like the above formula for determining r_i which is the inner radius of the ring stop again applies with almost the same precision. However in this case L_0 is approximately equal to $1-(\cos\theta)^2$.

Instead of the form of crucible shown, a porcelain crucible containing the coating material which is vaporized by a spiral or rectangular coil either immersed in or slightly above the coating material may be used.

S in the formulas above is the effective radius of the molten material and/or the molten material together with the vaporizing means.

From the foregoing it will be seen that we have provided simple, efficient and economical means and methods for obtaining all of the advantages of the invention.

Having described our invention, we claim:

1. Apparatus for coating a workpiece by vacuum distillation comprising means providing a vacuum chamber, means for supporting the workpiece within said chamber, means for vaporizing the coating material, said last mentioned means directing the vaporized material along a widening path toward the workpiece, and an annular vignetting member positioned in said path to alter the distribution of the vaporized material received by said workpiece by the shadow cast by said member, said shadow on said workpiece being partial centrally of said path and changing in intensity toward the outer portions thereof.

2. Apparatus for coating a workpiece by vacuum distillation comprising means for supporting a workpiece within an evacuated chamber, a source other than a point source of vaporized coating material and a vignetting member in the shape of an annulus positioned and arranged for casting a partial shadow substantially centrally along the path from said source to the workpiece, the overall diameter and the diameter of the central opening of said annulus being adjusted to the spacing of said annulus from said source for shading substantially all areas of the workpiece from a part but not all of said source for distributing the vaporized coating material substantially uniformly over the surface of the workpiece.

3. Apparatus for coating a workpiece by vacuum distillation comprising an evacuated chamber, means for delivering vaporized coating material along a path in said chamber in the form of a truncated cone, means for supporting a workpiece in said path, and a vignetting member positioned in said path in front of said workpiece in the form of an annulus of sufficiently small central opening to diminish the amount of vaporized coating material moving along the central portion of said path and of sufficiently small overall diameter so as not to substantially diminish the travel of vaporized coating material along the outermost portion of said path.

4. Apparatus for coating a workpiece by vacuum distillation comprising means providing a vacuum chamber, means for supporting the workpiece within said chamber, means for vaporizing the coating material and for directing the vaporized material along a widening path toward the workpiece, and an annular vignetting member positioned and arranged in said path for casting a partial shadow substantially centrally of said path and diminishing gradually outwardly for distributing the vaporized coating material substantially uniformly over the surface of the workpiece, said annular member having a sufficiently small overall diameter so that said shadow substantially disappears in the outermost portions of said path.

5. Apparatus for coating a workpiece by vacuum distillation comprising means providing a vacuum chamber, means for vaporizing coating material and for directing the vaporized material along a path in said chamber in the form of a truncated cone, means for supporting a workpiece in said path, and a vignetting member of circular outline positioned in said path in front of said workpiece, said vignetting member being of sufficiently small diameter relative to said truncated cone to cast only a partial shadow on said workpiece and being arranged at a distance from said vaporizing means such that said partial shadow gradually decreases in intensity from the axis of said cone to the outer portions of said workpiece.

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