

June 6, 1939.

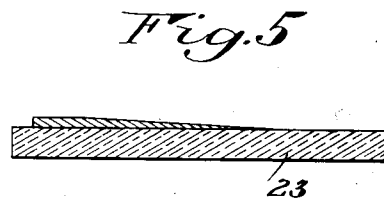
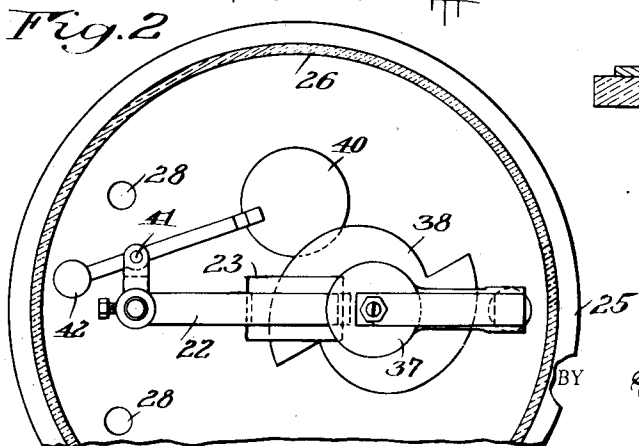
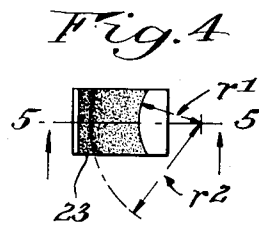
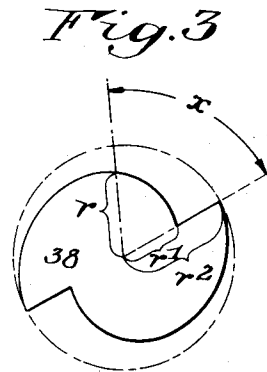
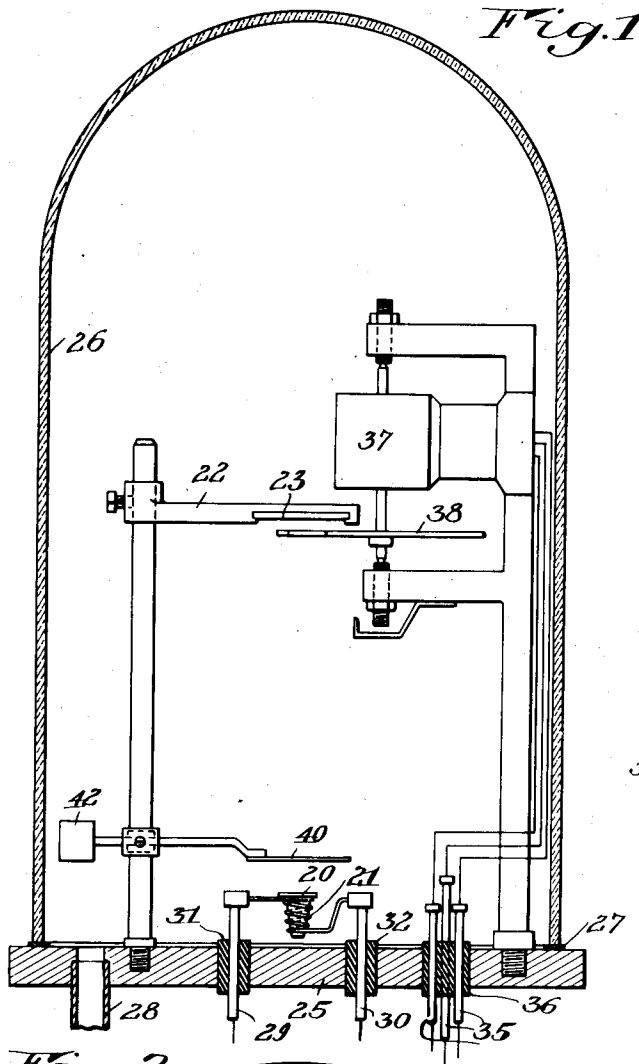
B. O'BRIEN

2,160,981

METHOD AND APPARATUS FOR PRODUCING THIN WEDGES

Filed Oct. 19, 1935

3 Sheets-Sheet 1



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METHOD AND APPARATUS FOR PRODUCING THIN WEDGES

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3 Sheets-Sheet 2

Fig. 6

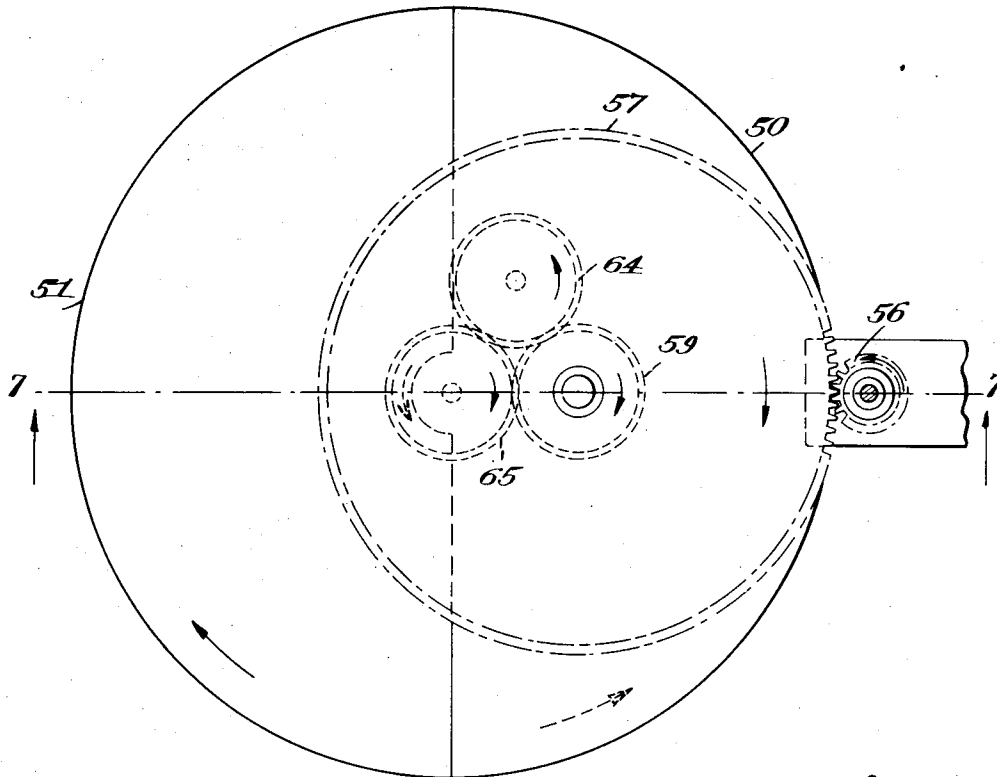
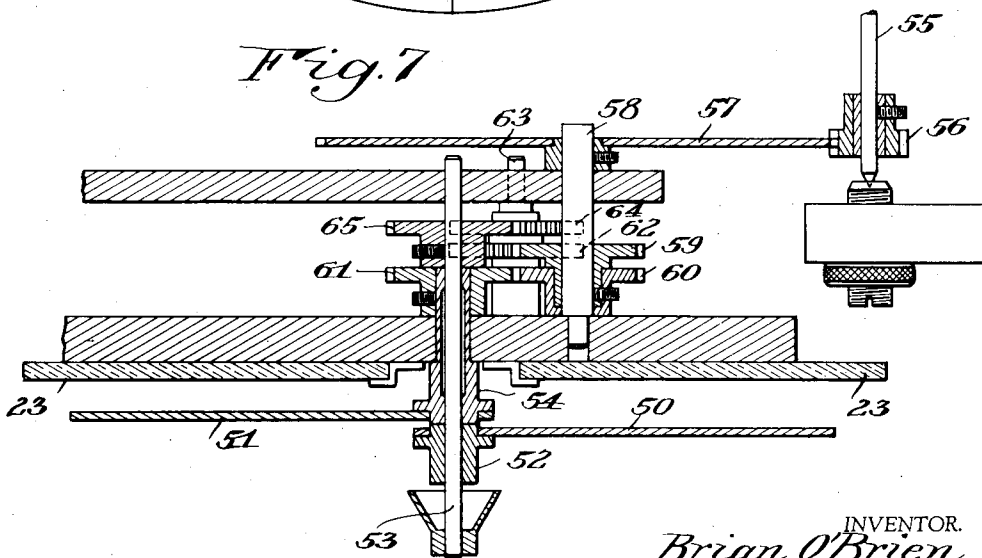


Fig. 7



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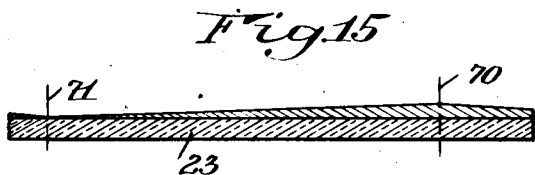
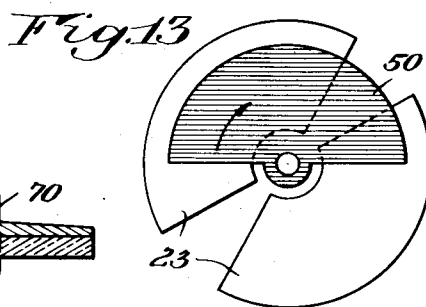
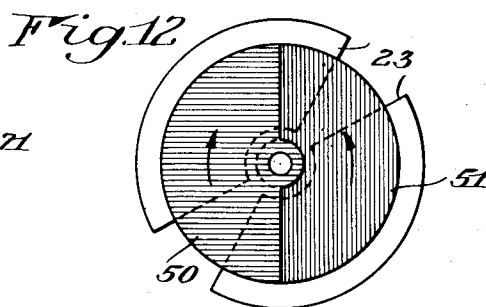
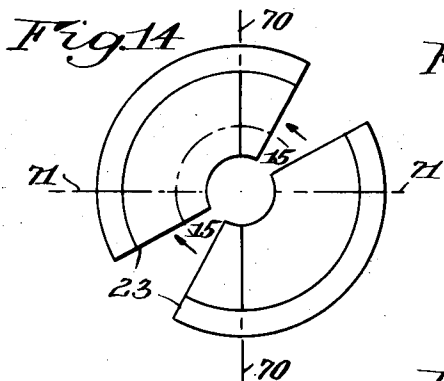
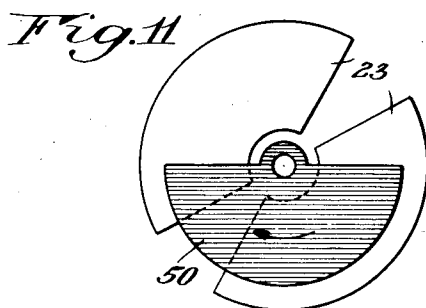
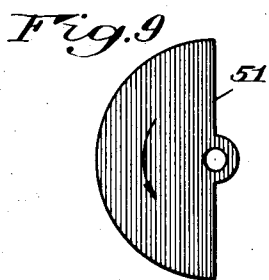
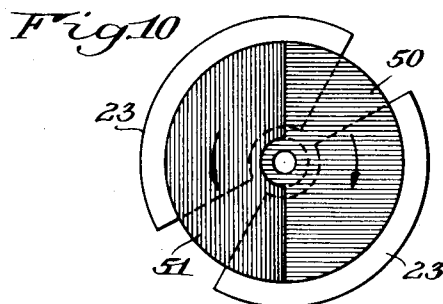
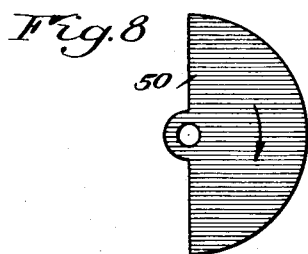
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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

2,160,981

METHOD AND APPARATUS FOR PRODUCING
THIN WEDGES

Brian O'Brien, Rochester, N. Y.

Application October 19, 1935, Serial No. 45,802

11 Claims. (Cl. 91—12.2)

This invention relates to the production of thin wedges, such, for example, as thin films of metal or metaloids, of non-uniform thickness, upon a base of glass, quartz, or other suitable substance, such wedges being useful, for instance, in optical apparatus of certain types.

An object of the invention is the provision of a greatly improved and more satisfactory method of producing such wedges, which method results in the production of more accurate and satisfactory wedges than those produced by prior methods.

Another object is the provision of simple, compact, and inexpensive apparatus for carrying out the method and producing the wedges.

A further object is the provision of a method and of an apparatus which enables the production of accurate wedges or films of non-uniform thickness, substantially independently of unavoidable variations in the rate at which the wedge-forming material is deposited upon its base or support.

To these and other ends the invention resides in certain improvements and combinations of parts, all as will be hereinafter more fully described, the novel features being pointed out in the claims at the end of the specification.

In the drawings:

Fig. 1 is a view partly in side elevation of a partly in vertical section, showing one form of apparatus constructed in accordance with the invention;

Fig. 2 is a plan thereof with parts in horizontal section;

Fig. 3 is a diagrammatic plan of the shutter shown in Figs. 1 and 2;

Fig. 4 is a plan view of the wedge produced by this apparatus;

Fig. 5 is a vertical section through the wedge shown in Fig. 4, substantially on the line 5—5 thereof, on an enlarged scale;

Fig. 6 is a plan of a modified form of shutter and operating mechanism;

Fig. 7 is a vertical section taken substantially on the line 7—7 of Fig. 6;

Fig. 8 is a plan of one of the sectors or shutter parts shown in Fig. 6 and Fig. 7;

Fig. 9 is a similar view of the other sector or shutter part shown in Figs. 6 and 7;

Fig. 10 is a view of the two sectors in one position;

Fig. 11 is a similar view showing the sectors in the second position;

Fig. 12 is a similar view showing the sectors in still another position;

Fig. 13 is a similar view showing the sectors in a fourth position;

Fig. 14 is a plan of the wedges made by the use of the sectors shown in Figs. 6 to 13, inclusive; and

Fig. 15 is a vertical section on a greatly enlarged scale through one of the wedges, taken in a circumferential direction substantially on the line 15—15 of Fig. 14.

The same reference numerals throughout the several views indicate the same parts.

The novel method of the present invention can best be understood in connection with a description of the apparatus and of the operation thereof, and will be so described in this specification.

Referring now to Figs. 1 to 5, inclusive, of the drawings, there is shown a small crucible 20 in which the metal or other material to be used in forming the wedge is placed. This crucible 20 is surrounded by a filament 21 of tungsten or similar material, or, if preferred, the metal may be placed directly on the heating filament without the use of a crucible. Arranged on a suitable bracket or support 22, conveniently above the heating filament 21, is the base or support 23 on which the wedge is to be formed, which base may be a piece of glass, quartz, or other suitable material. The base or surface to be coated may be placed at one side of, or even beneath, the heating filament if so desired, the position being determined by convenience.

The whole structure is supported by a suitable base 25 on which is placed a bell jar 26 of glass or other material. By the use of a suitable seal 27 of wax, rubber, or other suitable material, a vacuum tight seal is formed at the base of the bell jar, and a connection 28 is provided, leading to a high vacuum pump, by means of which the interior of the bell jar 26 is evacuated, preferably to a very high degree.

Lead wires 29 and 30 pass through vacuum tight seals 31 and 32 in the base 25, and carry electric current for energizing the heating filament 21. Other lead wires designated in general by the numeral 35 extend also to a vacuum tight seal 36 to a motor 37 within the bell jar, for operating a shutter or blocking member conveniently mounted on the armature shaft of the electric motor 37, the shutter being shown at 38.

If the pressure within the apparatus be reduced to a value such that the mean free path of a gas molecule is of the order of the dimensions of the apparatus or greater, the metal atoms from the heated filament or crucible will distill in substantially straight lines. If the metal be

solid and have a negligible vapor pressure at room temperature, the metal atoms will adhere to the glass or other surface on which they strike, within a distance of less than one micron from the point of impingence on the surface, and a uniform deposit may thus be built up.

If the distance between the distilling substance in the crucible 20 or on the filament 21, and the surface 23 to be coated, is several times the greatest dimension of the surface 23, and no intervening object lies between, the film of metal will deposit substantially uniformly in thickness over the surface 23. When, for example, aluminum is so deposited to a thickness of approximately one five-thousandth of a millimeter upon a surface of glass or quartz, the film will appear substantially gray when viewed by transmitted light, and will transmit only a few per cent of the light incident upon it.

If a plane shutter is placed between the filament 21 and the surface 23, close to the surface, and is slowly withdrawn during the distillation of the metal, a graded deposit of metal upon the surface 23 will result.

If the shutter is withdrawn with uniform velocity and the rate of distillation is constant, a uniformly graded or wedge-like deposit of metal will result. However, I have found that it is very difficult to maintain a uniform rate of distillation with metals such as magnesium, aluminum, silver, chromium, gold, copper, or other metals of comparatively high boiling point, so that the method of uniformly withdrawing a shutter does not result in an accurately uniform gradation of metal deposit.

I have also found that if a shutter be provided such that it may be replaced in front of the surface 23 and withdrawn therefrom uniformly, many times during the distillation, a uniformly graded deposit will result even with non-uniform distillation rate, since the insertion and uniform withdrawal of the shutter, repeated cyclicly many times, results in averaging such irregularities as may be unavoidably present in the distillation rate.

One form of such a shutter consists of a metal disk 38 having a profile cut in the form of an Archimedes spiral. This spiral is described by the well known equation $r=ax$, in which a is a constant, r is the radius, and x is the angle, as shown diagrammatically on Fig. 3. In such a spiral, the radius changes uniformly with the angle.

The shutter disk 38 is preferably mounted, as above stated, directly on the armature shaft of the electric motor 37 so that it may be rotated rapidly and uniformly throughout the distillation. The resulting metallic deposit on the surface 23 is uniform along circular arcs whose centers coincide with the axis of rotation of the shutter disk 38, and the deposit increases in thickness in a linear fashion with increase of radius. The deposit will have a linear wedge form when viewed in radial section as in Fig. 5. When viewed by transmitted light, the optical density will be constant along the circular arcs, but will increase along the radius, and the wedge may thus be used to vary the intensity of a beam of light in a known manner.

I have found that such wedges formed of aluminum or other metals deposits upon optically worked plates of quartz or glass, can be mounted before the slit of a spectrograph in the well known manner, to produce a wedge spec-

trum, and are of great value in quantitative spectrographic measurements.

Obviously the thinnest edge of the wedge will be at the distance r^1 (Fig. 3) from the center of rotation of the shutter disk 38, since all that part of the surface 23 which is closer to the center of rotation of the shutter disk than this radius r^1 will be covered at all times by the shutter and no metal will be deposited thereon. All parts of the base or support 23 which are farther from the center of rotation than the maximum radius r^2 will never be covered by the shutter at any time during its rotation, and thus will have the maximum deposit of metal thereon. The parts of the base 23 between the radius r^1 and the radius r^2 will have a deposit which is uniformly graded in thickness, due to the shape of the shutter disk 38, from zero thickness at the radius r^1 to maximum thickness at the radius r^2 .

If the metal is deposited upon a base 23 which is maintained, during the deposit, at normal room temperature, then it is found that the wedge or film near its thin edge (that is, near the radius r^1) does not have a uniformity of gradient of optical density. If, however, the base or support 23 is maintained, during the depositing process, at a temperature considerably below room temperature, then improved results are obtained and the linear law of optical density holds for a thinner portion of the wedge, closer to its thin edge. The base 23 may be maintained at the desired low temperature by suitable means such as a chamber cooled by liquid air supplied to the chamber through a suitable metallic tube system passing into the vacuum chamber in such manner as not to disturb the vacuum condition therein, this cooled chamber lying tightly against the back surface of the base 23 to cool it. If the base 23 be soldered to the metallic cooling chamber with Wood's alloy, then a better heat conductivity between the base 23 and the cooling chamber results. However, the gain in the character of the resulting wedge from an optical standpoint is not great, and in many practical cases it is unnecessary to cool the base in this manner.

The apparatus may also include a shutter 40 mounted to swing horizontally on a vertical pivot 41 and provided with a counter-weight 42 of iron or other magnetic material so that this shutter may be readily operated by means of an electromagnet or other magnet held near the counter-weight 42 outside of the bell jar 26. At the beginning of the distillation process the shutter 40 may be positioned directly over the metal being distilled so as to prevent any of the vapor reaching the base or support 23 until the distillation has proceeded to the point where impurities have been distilled off and only the pure substance is being boiled away. Similarly, toward the end of the distillation the shutter can be used to stop the deposit, but at other times, when it is desired to have the vapor of the distilled material reach the base 23, the shutter 40 is swung aside.

An alternative form of apparatus is illustrated in Figs. 6 to 13, inclusive, for making wedges of the form shown in Figs. 14 and 15. This apparatus, insofar as the vacuum chamber, the heating filament, and the base or support 23 are concerned, may be identical with that previously described, the only difference being in the form of shutter used, and in the form of wedge resulting therefrom.

The Archimedean spiral form of shutter shown in Fig. 3 results, as previously mentioned, in a wedge in which the thickness varies in a radial direction and is uniform in circumferential direction. Sometimes it is desired to have a wedge having a thickness uniform in a radial direction and varying in a circumferential direction. This form of wedge, illustrated in Figs. 14 and 15, can be made by the use of shutter mechanism such as shown in Figs. 6 to 13, inclusive.

Two semicircular shutter sectors 50 and 51 are employed, being mounted to turn in closely adjacent planes about a common axis. For example, the shutter 50 may be secured to a hob or boss 52 on a shaft 53, while the shutter 51 is secured to a sleeve 54 rotatable on the shaft 53.

These shutters are so geared that they rotate in opposite directions at uniform speed. For example, the armature shaft 55 of the electric motor carries a pinion 56 driving the gear 57 on the shaft 58 are two gears 59 and 60. The gear 60 meshes with a gear 61 fixed to the sleeve 54 and thus drives the sleeve. The other gear 59 on the shaft 58 meshes with a gear 62 on an idler shaft 63, and a second gear 64 on this same idler shaft meshes with a gear 65 fixed to the shaft 53, thus turning the shaft 53 at the same speed as the sleeve 54 but in an opposite direction.

The same opposite movement of the two shutter blades could obviously be obtained by suitable bevel gears, but it is preferred to use spur gears as shown, rather than bevel gears, for the reason that this gearing, in the high vacuum chamber, must operate substantially without lubrication. Properly designed spur gears have a simple rolling contact with each other, and consequently are better adapted to operate without lubrication than bevel gears, which never have a simple rolling contact but which always have at least to some extent a sliding contact with each other.

If these shutter sectors 50 and 51 are mounted with their mutual axis of rotation directly above the heating filament 21, and if a base or support 23 of glass, quartz, or other suitable material is placed immediately above the rotating shutter sectors, it is apparent that the base 23 will receive a maximum deposit of metal along a diameter corresponding to that at which the two semicircular shutter sectors meet when they do not overlap with each other at all, because along this diameter the flow of vapor toward the base 23 is obstructed half of the time of each rotation of the shutter, which is the minimum of possible obstruction with a semicircular shutter. It is also apparent that the base will receive its minimum deposit of metal along a diameter at right angles to the first mentioned diameter, since along this second diameter the shutters uncover the base 23 only momentarily during each rotation, keeping it covered at all other times. Assuming the shutter blades to be geared relatively to each other in the positions illustrated in Figs. 8 and 9, the diameter of maximum deposit would be along the lines 70 shown in Fig. 14, while the line of minimum deposit would be line 71. In between these two points the deposit would be of graded thickness varying uniformly in a circumferential direction from the minimum on the diameter 71 to the maximum on the diameter 70, as will be apparent from a study of various different successive positions of the shutter blades as shown diagrammatically in Figs. 10 to 13, inclusive.

Two wedges or even four wedges may be simul-

taneously produced by the use of these shutters, each wedge occupying one quarter of the circle.

When using this type of shutter, the base 23 may be cooled by liquid air or the like if desired, just as in the case of the previous form of shutter.

It is evident that the Archimedes spiral previously described may be changed to a spiral of other form if a different law of change of density or thickness of the wedge along the radius is desired. Also oscillating or reciprocating shutter mechanism may be used to vary the average intensity of a beam of distilling atoms or molecules in an evacuated space without departing from the scope of this invention. It is also evident that the mechanical inversions may be used, such as causing the base or receiving surface 23 to oscillate behind a fixed shutter, or to rotate behind a fixed spiral or other apertured plate, these inversions likewise falling within the scope of the invention.

If more convenient, the receiving surface 23 may be placed in a horizontal direction, or even beneath the distilling substance. It is evident also that the metal or substance to be deposited may be caused to leave the source in the form of particles larger than molecular dimensions, such as a spray of droplets, and that this procession of particles from source to target may be interrupted by a cyclicly operating shutter as above described.

Various forms and thicknesses of wedges or deposits of material of varying thickness may be produced by the method and apparatus of the present invention, for various uses. When metallic wedges for use with transmitted light in optical instruments are desired, their maximum thickness will usually not exceed two-tenths of a micron, but it is evident that much thicker deposits may be built up if desired, for other uses. For production of optical wedges, where high accuracy is desirable, it is preferred to carry on the process in a very high vacuum, for example, a vacuum such that the absolute pressure does not exceed about one ten-thousandth of a millimeter of mercury. Under low pressures of this magnitude, the molecules of the substance being distilled move in substantially straight lines over distances comparable to the dimensions of the apparatus (as for example a distance of 10 inches between the heating filament and the receiving surface) and thus produce sharper demarkation and more accurate grading of the wedge.

I claim:

1. The method of forming deposits of vaporizable material of graduated thickness, which comprises providing a support to receive the material, distilling the material in the vicinity of said support so that vapors of the material will tend to travel in substantially straight lines toward and to accumulate on said support, and repeatedly blocking and unblocking the path of travel of the vapors towards said support during the distilling operation, leaving one portion of the area of the support unblocked for a longer time than another portion thereof, to produce differences in thicknesses of material on different parts of said support.

2. The method of building up a deposit of varying thickness on different parts of a given area of a support, which comprises providing a support, causing material to be deposited to travel substantially continuously toward said support, and repeatedly blocking and unblocking the path of travel of the material toward said given area

of the support a multiplicity of times during the building up operation, one portion of the area of the support being left unblocked for a longer time than another portion thereof, during each repeated blocking and unblocking operation.

3. The method of forming metallic deposits of graduated thickness which comprises providing a support to receive a metallic deposit, distilling metal in the vicinity of said support so that the distilled metal will tend to travel in substantially straight lines toward and to accumulate on said support, and repeatedly blocking and unblocking the course of travel of the distilled metal toward said support in such manner as to allow the metal to travel toward one portion of the area of the support for a longer time than toward another portion thereof, to produce the desired gradations in thickness.

4. The method of building up a deposit of material of tapering thickness on a given area of a support, which comprises providing a support, causing the material to be deposited to travel toward said area of said support in approximately uniform quantity per unit of area of the support, and repeatedly blocking and unblocking the path of travel of the material toward said area of the support a multiplicity of times during the building up operation, in such manner that the paths of travel of material toward different parts of said given area are blocked during each repetition of the blocking and unblocking action for respective times which are inversely proportional to the respective thicknesses to be built up on those respective parts of said given area, the time of blocking varying gradually and progressively from minimum blocking in the path of travel toward the part of the area to receive maximum thickness of deposit, to maximum blocking in the path of travel toward the part to receive minimum thickness, the multiple repetition of the blocking and unblocking action serving to produce a finished deposit in which unavoidable variations in the rate of travel of the material toward said given area of said support during the building up operation are averaged, so that the finished deposit is smoothly tapered substantially independently of such variations.

5. The method of producing deposits of condensed vaporizable material of varying thickness on different parts of a support, which comprises providing an evacuated space having a support therein, vaporizing the material to be deposited in said evacuated space in the general vicinity of said support so that vapors of said material will tend to travel toward and condense upon said support, moving a blocking member between said support and the source of vapors to permit the vapors to reach a part of said support for a longer time than they may reach another part of said support, and repeating the movements of said blocking member a multiplicity of times during the depositing operation to average unavoidable variations in the rate of travel of the vapors toward the support.

6. A device for forming thin deposits of varying thickness on different parts of a support, comprising means for holding a support in stationary position, means in the vicinity of said support for vaporizing material in such manner that it will tend to travel in substantially straight lines toward said support, shutter means interposed between the support and said vaporizing means so as to block and unblock the path of travel of the vaporized material toward the support, and means

for repeatedly moving said shutter means a multiplicity of times during depositing operation.

7. A device for forming thin deposits of varying thickness on different parts of the same area of a support, comprising means for vaporizing material to be deposited in such manner that the vaporized material will tend to travel in substantially straight lines toward the support, means for holding a support in position to receive vapors of said material, shutter means interposed between said vaporizing means and said support for blocking the path of movement of the vaporized material toward said support, said shutter means having a cycle of movement during which a portion of the area of said support is exposed to receive vapors of material for a longer period of time than another portion of the area of said support, and means for repeatedly moving said shutter means through its said cycle of movement a multiplicity of times during a single complete depositing operation on the same area of said support.

8. A device for forming thin deposits of controllable varying thickness on different parts of the same area of a support, comprising means for vaporizing the material to be deposited in such manner that the vaporized material will tend to travel in substantially straight lines toward the support, means for holding a supporting element in position to receive vapors of said material, a blocking element interposed between said supporting element and said vaporizing means, said blocking element being shaped to uncover part of said area of said supporting element for a longer time than another part of said area during each cyclical movement of one of said elements relative to the other, and means for producing cyclical movement of one of said elements relative to the other repeatedly during a single vaporizing operation to produce variations in thickness of the material deposited on said supporting element by reason of said cyclical movement and to produce a deposit substantially independent of variations in the rate of vaporization from time to time by reason of the repetition of said cyclical movement.

9. A device for forming thin deposits of varying thickness on different parts of the same area of a support, comprising means for vaporizing the material to be deposited, means for holding a supporting element in position to receive vapors of said material, a blocking element interposed between said supporting element and said vaporizing means, said blocking element being shaped to uncover part of said area of said supporting element for a longer time than another part of said area during each cyclical movement of one of said elements relative to the other, means for producing cyclical movement of one of said elements relative to the other repeatedly during a single vaporizing operation to produce variations in thickness of the material deposited on said supporting element by reason of said cyclical movement and to produce a deposit substantially independent of variations in the rate of vaporization from time to time by reason of the repetition of said cyclical movement, and vacuum chamber means enclosing said supporting element, said shutter element, and said vaporizing means.

10. A device for producing optical wedges of metal of a thickness varying substantially uniformly along one path, which comprises means forming a vacuum chamber, means within said chamber for vaporizing metal, means also within said chamber for holding a transparent support-

ing element in position to receive metal vapors from said vaporizing means, rotary shutter means interposed between said transparent element and said vaporizing means, said shutter means being effective upon each rotation to uncover a part of the area of said transparent element for a longer time than another part of the area thereof, and means for repeatedly rotating said shutter means during the formation of a single optical wedge on said transparent element.

11. The method of producing deposits of condensed vaporizable material of varying thickness on different parts of a support element, which comprises providing a partially evacuated space having a support element therein, vaporizing the material to be deposited in said partially evacu-

ated space in the general vicinity of said support element so that vapors of said material will tend to travel toward and condense upon said support element, providing a blocking element between said support element and the source of vapors, moving at least one of said elements relatively to the other in such manner as to permit the vapors to reach a part of said support element for a longer time than they may reach another part of said support element, and repeating the movement of said one of said elements a multiplicity of times during the depositing operation to average unavoidable variations in the rate of travel of the vapors toward the support element.

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