Oct. 5, 1948. W. H. COLBERT ET AL 2,450,855

METHOD OF COATING BY EVAPORATING METALS

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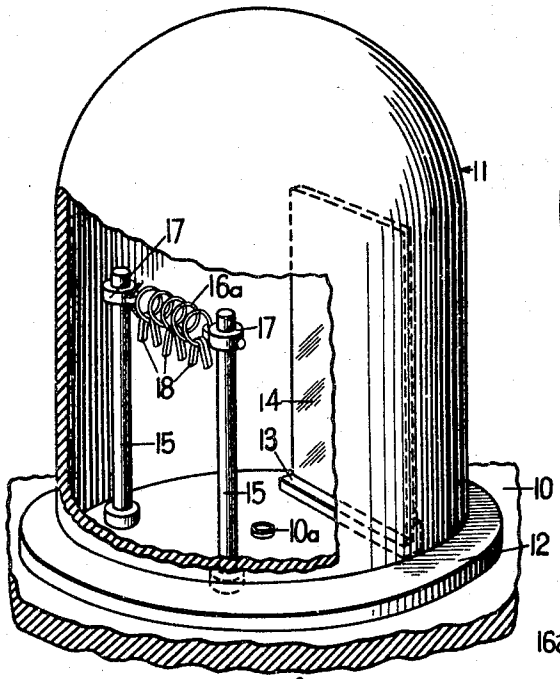


Fig. 1

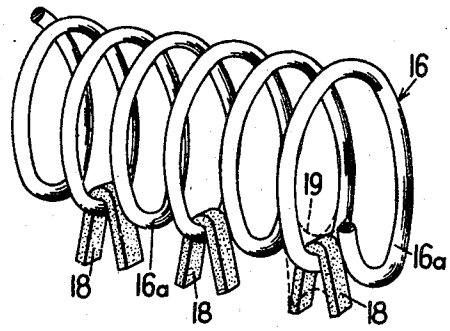


Fig. 2

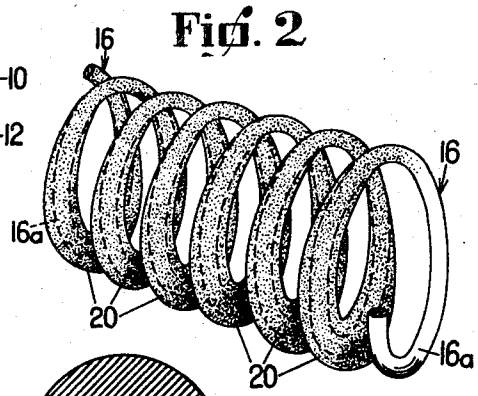


Fig. 3

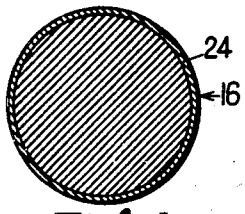


Fig. 4

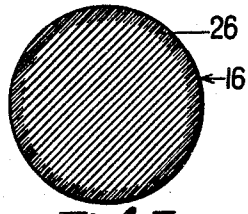


Fig. 5

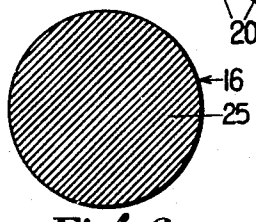


Fig. 6

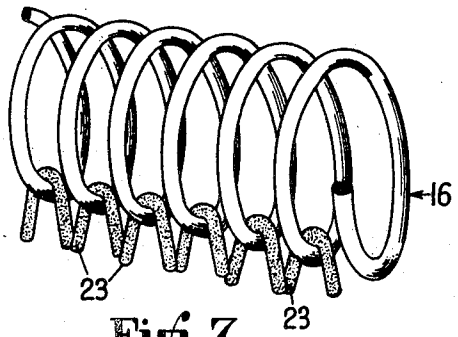


Fig. 7

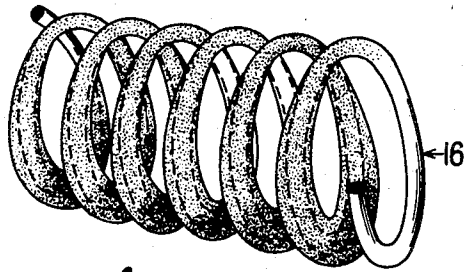


Fig. 8

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METHOD OF COATING BY EVAPORATING METALS

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Application December 3, 1946, Serial No. 713,701

14 Claims. (Cl. 117—107)

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Our present invention relates to a novel method of coating by evaporating metals. It has to do, more particularly, with the coating or wetting, by capillary attraction, of a filament which, for example, may be formed from a coil of ordinary tungsten wire, tantalum, molybdenum or columbium wire, by various metals in the form of an alloy with small amounts of chromium, which metals to be evaporated in pure form normally do not wet these metallic filaments, and the application of said metals or metal alloys by deposition resulting from thermal evaporation, to the face or surface of an article, such as a piece of glass, porcelain, plaster, metal, plastic, Cellophane, paper, or the like, to provide a reflective or metallized surface coating for said article. The invention also has to do with securing wetting and with thermal evaporation of such metals from tungsten, tantalum, molybdenum, or columbium filaments alloyed or coated with chromium by the application to the filaments of the pure metals desired to be evaporated.

This application is a continuation-in-part of our co-pending application, Serial No. 552,290, filed September 1, 1944, now Patent No. 2,413,606.

Methods and apparatus have previously been employed to apply coatings of metals by thermal evaporation to the faces or surfaces of such articles to produce mirrors, reflectors or metallized materials for other purposes. In these methods it is desirable to effect the thermal evaporation of the metal, such as silver, copper, gold or aluminum, by applying the metal directly to an electrically energized and thus heated tungsten or other metallic filament which is preferably located within a vacuumized chamber. The metals which may be used as filaments for such evaporations must obviously be of high melting point and also of low vapor pressure at the elevated temperatures at which the metals applied to the filaments evaporate. Thus, tungsten, tantalum, molybdenum and columbium have represented the only practical materials for such use. Platinum also has been used to a small degree but its high cost is generally prohibitive. While iron and nickel are of relatively low vapor pressure, they are of such relatively low melting point that filaments made from them rapidly burn out.

With these filaments many of the metals can be readily evaporated. Thus, for example, aluminum, magnesium, vanadium, barium, strontium, iron, nickel, cobalt, manganese, thorium, chromium, and titanium, when applied to filaments of tungsten, tantalum, molybdenum or

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columbium, will on heating in a vacuum, melt and spread over the filament by capillary attraction and satisfactory evaporation of these metals then occurs from the large amount of surface which the molten metal covers.

However, with a large number of metals which it is desirable to be able to themally evaporate and which from their vapor pressure at elevated temperatures should readily evaporate, it has been found difficult, if not impossible, to carry out satisfactory deposition of such coatings by thermal evaporation. Thus, for example, silver and copper while readily lending themselves to thermal evaporation from a crucible, cannot be evaporated readily from a coil of tungsten, tantalum, molybdenum or columbium when applied to a filament of these metals and heated by electrical resistance. The silver or copper on melting shows no affinity for the metallic filaments and almost immediately after melting collects into a drop and falls off of the filament. This lack of ability to wet tungsten, tantalum, molybdenum and columbium occurs also with the metals, gold, zinc, tin, antimony, cadmium, bismuth, lead, thallium and indium. With each of these metals the use of the four available coil filaments as a means of evaporating these metals has not been possible, and less desirable means of heating have been necessary where it became necessary to evaporate these under practical conditions repeatedly in the commercial production of mirrors and metallic coated articles. As each of these metals, after melting, pulls together into droplets and falls off the filaments, there has resulted a wastage of the metal whenever it has been attempted to evaporate them from these filaments and there have been continuous failures of the apparatus to function due to the loss of the metals from the heated wires; and where any metal has been evaporated the amounts so evaporated have always been uncertain and without control.

We have found that we may use tungsten, tantalum, molybdenum or columbium as filaments for the evaporation of metals which do not wet these filaments by causing them to wet such filaments by the application to such filaments, or the forming thereon, of alloys of those metals which we desire to evaporate with small amounts of chromium, such as amounts ranging from 0.1% to 5%, which is characterized in that it will also form an alloy with tungsten, tantalum, molybdenum and columbium in the presence of the metal we desire to evaporate. Thus, for example, we may add small amounts of chromium to silver and when such alloys are melted on a tungsten

filament, the silver will be found to wet the tungsten filament and to spread itself by capillary attraction over the surface of the tungsten wires. In the absence of the chromium the silver melts, draws itself into a droplet and falls off the filament wire because it does not wet the same. Not all metals have been found to act in this manner. Alloying the normally non-wetting metals among themselves, such as adding lead to silver, does not seem to bring about any desirable improvement in the wetting characteristic. In each case, however, it is found that the chromium readily forms alloys with tungsten, tantalum, molybdenum and columbium and also forms alloys with copper, silver, gold, zinc, tin, antimony, cadmium, bismuth, lead, indium and thallium. It has also been found that chromium when heated reduces tungsten oxide, molybdenum oxide, tantalum oxide, and columbium oxide, to the metals, and that the removal of coatings of these oxides, normally present upon filaments composed of tungsten, molybdenum, tantalum, or columbium, aids in securing the desired wetting since silver, copper, gold, zinc, tin, antimony, cadimum, bismuth, lead, thallium, and indium do not wet the oxide-coated filament. Thus, the chromium readily brings about the desired wetting and it appears clearly that this is accomplished through the reduction of the oxide coating upon the filament and upon the mutual alloying tendency which these metals possess. The chromium may also be added to the filament either as an alloy with the tungsten, tantalum, molybdenum or columbium, or preferably it may be employed as a surface coating or surface alloy with such filaments. Filaments containing small amounts of chromium are found to wet readily when the pure otherwise non-wetting metals are fused thereon. Thus the wetting is brought about in the presence of the chromium, and it is immaterial as to whether the chromium is supplied in an alloy applied to the filament or exists in the filament surface.

One of the objects of our invention is to provide an improved and satisfactory method or process of evaporating metals which normally do not wet heater filament coils of tungsten, tantalum, molybdenum, or columbium, by alloying the metal so as to cause the metals to wet the coils of such filaments and to coat the coils by capillary attraction so that thermal evaporation can then be carried out.

Another object of our invention is to apply to a tungsten, tantalum, molybdenum or columbium filament a metal to be evaporated which does not wet such filament coils, alloyed with a suitable proportion of chromium which alloys with the filament and brings about a proper wetting or coating of the filament wires by capillary attraction under the influence of heat applied to the filament.

As another object of our invention there is provided an improved method or process whereby a metal which is to be evaporated and which does not normally wet heater filaments of tungsten, tantalum, molybdenum and columbium is alloyed with chromium and applied to such a filament, and by securing a wetting and coating of the filament by capillary attraction of the metal desired to be evaporated may be deposited upon the face or surface of an article, by thermal evaporation, to provide such article with a reflective or metallized surface coating.

As a further object there are provided filaments which have been pre-alloyed with small amounts of chromium which may be used directly to evaporate the normally non-wetting metals since such alloyed filaments are found to be wetted readily by the molten pure metals desired to be evaporated.

A further object of our invention is to apply to a tungsten, tantalum, molybdenum or columbium filament, a metal such as copper, silver, gold, zinc, tin, antimony, cadminum, bismuth, lead, indium or thallium, alloyed with a suitable proportion of another metal which brings about a desirable wetting or coating of the filament metal by capillary attraction under the influence of heat applied to the filament and thus permits thermal evaporation of the metals.

Generally speaking, and in accordance with our present invention, the metal to be evaporated which normally does not wet the heater filament is applied alloyed with small amounts of chromium to the extent of 0.1% to 5% or more, providing wetting characteristics to the coils of a filament which may be formed from tungsten, tantalum, molybdenum or columbium. Thus in order to thermally evaporate copper, zinc, gallium or arsenic, which are metals of the chemical periodic table arrangement found in series 5 or the metals silver, cadminum, indium, tin and antimony, which include metals of series 7, or the metals gold, thallium, lead and bismuth which in the periodic arrangement include series 11, all of which metals do not wet filaments made of tungsten, tantalum, molybdenum or columbium, we first bring about a satisfactory wetting and adhesion of these metals to the filaments by applying the metals to the filaments as an alloy with small amounts of chromium and then by energizing the filament and thus heating it we cause a melting of the metals. When the applied metal alloys are thus melted they react with any oxide coatings upon the filaments and reduce such to the metals, tungsten, tantalum, molybdenum, or columbium and then they apparently alloy to some degree with the metal comprising the heater filament wire and by reason of such the molten metals wet the filament wires and by capillary attraction are drawn out over the surface of the coils. The molten metal which has thus covered considerable surface of the heated coil and is held thereto by capillary adhesion is thereafter evaporated uniformly from the heater coils to apply a surface coating of a metallic or reflective nature to an article such as a piece of glass, porcelain, silica, mica, plastic, metal, Cellophane, resin, or other support material, by deposition resulting from the thermal evaporation of the metal from the filament. The operations of thermal evaporation may with some of the metals, be carried out at normal pressure but generally are preferably carried out in vacuum chambers known to the art and within a high vacuum, which may be of the order of one millimeter down to 10 to the minus 5 millimeters or better. It is very necessary that the metal to be evaporated wet and coat the coil surfaces in order that the metal will evaporate uniformly in all directions. By securing such wetting action the thermal deposition of these metals, in addition to being made possible, has been found by our process to give uniform coatings.

We may also proceed to secure the objects within the scope of this invention by supplying chromium in the filament either as an alloy with the tungsten, tantalum, molybdenum or columbium, or as a surface coating; or as a surface alloy on such filaments. When the pure metals such as

silver, copper or gold which will not normally wet the pure tungsten, tantalum, molybdenum or columbium filaments are applied to these filaments containing some chromium they will on melting readily wet the chromium-containing filaments. Thus, in general, the invention comprises melting the metal desired to be evaporated upon a tungsten, tantalum, molybdenum or columbium filament in the presence of chronium which brings about the desired wetting and adherence of the molten metal to the heated filaments.

As will be shown fully later, pieces of the metal to be evaporated and which have been previously alloyed with the metal which brings about the alloying with and wetting of the filament, may be hung onto the loops or coils of the filament.

The foregoing and other objects and advantages of the present invention will appear from the following description and appended claims when considered in connection with the accompanying drawings formed a part of this specification wherein similar characters of reference designate corresponding parts in the several views.

In said drawings:

Figure 1 is a perspective view, partly broken away, illustrating one suitable apparatus for carrying out our improved method or process.

Figure 2 is a perspective view of a fragment of an electric filament showing the application of a suitable metal alloy to several of the coils or convolutions thereof, and illustrating one phase of the method or process of wetting or coating the filament by said alloy; and

Figure 3 is a view similar to Figure 2 showing the filament after the completion of the wetting process by the alloy of Figure 2.

Figure 4 is an enlarged, cross-sectional view of a tungsten, tantalum, molybdenum or columbium electric resistance filament precoated with a thin layer of chromium.

Figure 5 is another enlarged, cross-sectional view showing a filament of tungsten, tantalum, molybdenum or columbium which is alloyed only in the surface of the filament with chromium.

Figure 6 is also an enlarged, cross-sectional view of a filament formed from tungsten, tantalum, molybdenum or columbium, which is alloyed throughout with a small amount of chromium and upon which the pure metals, on melting, will directly show a good wetting action.

Figure 7 is a perspective view of a filament containing chromium such as shown in Figures 4, 5, and 6 and upon which pieces of the pure metal to be evaporated have been hung.

Figure 8 is a perspective view after the filament and pieces of metal of Figure 7 have been heated to effect a wetting of the filament.

Before explaining in detail the present invention it is to be understood that the invention is not limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of other embodiments and of being practiced or carried out in various ways. It is to be understood also that the phraseology or terminology employed herein is for the purpose of description and not of limitation.

Referring now to the drawings, we have shown a suitable apparatus for carrying out our improved method or process, as well as one suitable metal alloy and the steps of applying the alloy or a filament by a wetting action resulting from capillary attraction. We have also shown suitable alloyed filaments and the steps of applying

the pure metal to be evaporated to such filaments and the wetting action upon the filament resulting from capillary attraction after the pure metal is melted.

Suitable apparatus employed by us, and illustrated in Figure 1, comprises, as shown, a supporting base 10 upon which is mounted a housing, shown as a whole at 11. The housing 11 may be in the form of a bell-jar or the like having a dome-like or semi-spherical top portion or enclosed end and a bottom open end having a surrounding flange or projection 12 which is adapted to rest upon the top face or surface of the supporting base 10.

Within the chamber provided by the housing 11, we have shown a suitable work-piece support 13 for supporting a work piece, such as a plate or piece of glass, plastic, plaster, paper, porcelain, metal, or the like 14, in upright position.

Located within the chamber and mounted upon the supporting base 10 is a pair of upright supporting posts 15 between which is carried or supported, in substantially horizontal position, an electric filament 16. The filament, as shown, is in the form of a coiled wire made of tungsten, tantalum, molybdenum or columbium, or an alloy of these with chromium or precoated with a layer of chromium whose opposite ends are attached to brackets 17 mounted upon the supporting posts 15 and adjustable thereon so as to vary the position or location of the filament 16 with relation to the supporting base 10.

The chamber provided by the housing 11 may, if desired, be completely evacuated of air through outlet pipe or conduit 10a and have a high vacuum created therein by means of suitable air evacuating and vacuum creating means, such as a pump (not shown).

In accordance with one method embodying our invention which is to be performed or carried out within the chambered housing 11, we preferably provide a metal alloy which may consist of silver, copper or gold or other normally non-wetting metal and approximately 0.1% to 5% or more of chromium. Pieces of this preformed silver and chromium alloy, for example, or copper and chromium alloy, for example, or gold and chromium alloy, for example, several of which are shown at 18, in Figures 1 and 2, are bent and hung on the loops or convolutions 16a of the filament 16 composed of pure tungsten, tantalum, molybdenum or columbium in the manner shown.

It is known that silver, copper and gold lend themselves admirably to thermal evaporation but they have no wetting affinity for tungsten, tantalum, molybdenum or columbium surfaces and therefore silver, copper or gold alone is unsatisfactory for coating the filament 16 formed from either of these metals by a wetting action effected by capillary attraction. Wetting of the filament wire is essential to secure a maximum of evaporating surfaces to provide evaporation uniformly in all directions, to the securing of uniform deposits, and also to avoid the dropping of the molten metal off the heater wires. We have found that chromium readily alloys with silver, gold and copper and the alloys have a wetting affinity for the four above-mentioned metals, any one of which may be used for making the filament 16, and thus chromium is particularly useful in securing the wetting of the filament by capillary attraction. Therefore, by including a certain percentage of chromium, preferably 0.1% to 5% or more, with the silver, copper or gold to form the alloy 18, the chromium will serve to

bring about wetting or coating of said filament by the molten metal by capillary attraction when the filament is energized and thus heated and will act to cause the silver, copper or gold to also cling to or wet the filament. An early stage or phase of the wetting action of the filament 16 by the alloy 18 is shown generally at 19, Figure 2. As the wetting action by capillary attraction continues, the two metals of the alloy will proceed to wet the coils of the filament 16 and in fact, will substantially wet or coat and cover the surfaces of the filament. In Figure 3, we have illustrated several of the coils or loops 16a of the filament as being coated at 20 by the alloy from which the pieces 18 are formed.

Thus, by including chromium with the silver, copper or gold, as an alloy, it is possible to quickly and effectively coat or wet the filament 16 by capillary attraction. Since therefore, the alloy builds up onto the surfaces of the filament in substantially the manner illustrated in Figure 3, there will be a relatively uniform coating or wetting of the filament and a uniform dependable evaporation of the silver, copper or gold. Heretofore, when attempts were made to wet the filament by the use of the silver, the copper or the gold alone, only small portions of the molten metal would cling to the filament as droplets hanging from the lower ends of the coils of the filament, with the major portion of the molten metal dropping or falling off the coils. This was particularly undesirable since it was practically impossible to produce, by thermal evaporation, an even surface coating by deposition, or to control the deposition to desired coating deposit thicknesses on the surface of an article, such as the article 14, to which it was desired to apply a reflective surface coating. By virtue of the fact that the silver, copper or gold did not properly wet the tungsten or other metal filament but had a tendency to drop off said filament, the process of coating with these metals by deposition was unsatisfactory, slow and painstaking because only a small portion or percentage of the filament received the metal coating. Considerable shutting down and starting over again was required when most of the gold, silver, or copper on first melting dropped off the coils and no evaporation was secured. Thus great waste occurred, the process was considerably slowed down, and the coating produced by deposition, if any, was uneven or spotty and unsatisfactory because of such uneven character thereof on the surface of the article coated. Commercial production under such uncertain conditions was impossible.

It is to be understood that in carrying out our method or process as described above, in the chamber of the housing 11, the chamber depending upon the metal being evaporated, may be at atmospheric pressure, or it may be evacuated of air and a vacuum created therein. Thus, after the pieces 18 of the silver and chromium alloy or copper and chromium alloy or gold and chromium alloy, as the case may be, have been applied to the coils of the filament 16 and the workpiece 14 mounted upon its support 13 within the chamber, a vacuum of 10 to the minus 3 millimeters or better is created and the filament 16 is then energized and therefore heated so as to melt the alloys and to cause the hot chromium to reduce any oxide coatings on the filaments and to start in motion the wetting action of the filament by capillary attraction, as explained above. After the wetting action has been completed as illustrated generally at 20 in Figure 3, the filament

16 is heated further whereby silver, copper, or gold in the coating 20 of the alloy will be thermally evaporated and transferred by deposition to the face or surface of the workpiece 14 which, as shown, is disposed in a position opposite the filament 16.

We have found that the desired wetting may also be brought about by applying pure metals as pieces, as shown at 23 in Figure 7, to a filament of tungsten, tantalum, molybdenum or columbium, indicated at 16 which has been precoated at 24, Figure 4, pre-alloyed at 25, Figure 6, or surface-alloyed at 26, Figure 5, with the chromium. In carrying out the operation, the filament 16 is mounted as in Figure 1 and the pure metal pieces 23 of Figure 7 are applied thereto. After the object 14 to be coated has been placed in position, the bell jar 11 is lowered, the vacuum is created, and electric current is applied to the filament through the electrodes 15 to cause melting of the applied pieces and a wetting of the coil as illustrated in Figure 8. By continued application of heat to the coil, the applied metal will be thermally evaporated and deposited upon the object 14.

During the evaporation of the higher boiling metals such as gold, silver and copper, some of the chromium is also distilled while in the case of the lower boiling metals such as lead and zinc, where the filaments are operated at relatively low temperatures, little of the chromium whether present originally as an alloy with the metal to be distilled or present in or on the filament is distilled. Thus, in the latter case practically pure lead or zinc coatings are deposited whereas in the case of gold, silver or copper an alloy of chromium and these metals is thermally deposited upon the object being coated.

A further advantage of very practical importance in the thermal exaporation of the various metals has been secured through our securing good wetting of the filaments in that the metals being evaporated show very little explosive boiling or spitting which by reason of small chunks of metal blown over onto the article being coated has caused spoilages. This appears to have been accomplished by the decrease of surface tension forces accompanying the wetting and also in the elimination of conditions leading to superheating by getting the metal to spread out in a thin coating over most of the filament surfaces.

The precoating of filaments with chromium in Figure 4 may be accomplished by thermally evaporating in a vacuum a coating of the chromium upon the cold filaments. If the filaments also carry the metal to be evaporated, such as silver, etc., the latter also would become coated with the chromium and upon heating the coated filaments, good wetting by silver, etc., is secured with subsequent evaporation. Such chromium-coated filaments may also be heated to cause the chromium to surface-alloy with the filament to produce structures as illustrated by Figure 5. Where it is desired to introduce the chromium into the filament as a uniform alloy, this may be accomplished by introducing chromium into a molten alloy and thereafter in the known manner producing wire by pulling such alloy through dies.

From the foregoing it will be seen that we have provided an improved method or process for applying certain metals to a filament of tungsten tantalum, molybdenum or columbium by causing a wetting resulting from capillary attraction through the presence of small quantities of chromium and applying heat from the filament,

and have thereby been able to carry out evaporation of such metals after the wetting action has been completed by thermally evaporating the metals and have caused their deposition upon the face or surface of a workpiece to provide metallized or reflective surface therefore. It will also be seen that while we secure the desirable requisite of wetting of the filaments of tungsten, tantalum, molybdenum or columbium by metals which normally do not wet these, by the presence of chromium this may be accomplished in several ways. Thus, we may apply separate pieces of a preformed alloy of such metals with chromium and these will wet the pure metallic filaments, or we may apply the pure metals to be evaporated to a filament containing some chromium either in its surface or throughout.

While we have referred to the use of tungsten, tantalum, molybdenum, or columbium as suitable metals from which the coiled filament or element 16 may be formed, other suitable metals may be used for this purpose. We have mentioned these metals particularly since their high melting points and low vapor pressures at the boiling temperatures of other metals make these the practically desirable metals for use as such filaments.

We have described our improved method or process as preferably being carried out in a vacuumized chamber in which the step of wetting the filament takes place, as does also the step of thermal evaporation of the metal to effect its deposition upon the workpiece to provide a reflective coating thereupon.

Obviously also in the case of the most readily volatile metals, such as cadmium and zinc, the melting of the metals and the wetting of the filaments, as well as the evaporation of the readily volatile metals, such as cadmium or zinc, may be carried out under atmospheric conditions of pressure if desired, while employing a suitable inert atmosphere.

Having thus described our invention, what we claim is:

1. The method of making mirrors by the deposition of a metal on a polished support material, comprising evaporating a metal from a filament made of a metal selected from the group consisting of tungsten, tantalum, molybdenum and columbium wherein the metal is heated on such filament as an alloy with chromium which causes the metal desired to be evaporated to wet, to adhere to, and to spread out over the filament surfaces and by the continued application of heat to evaporate, and depositing a coating thereof on said polished support material.

2. The method of coating surfaces which comprises evaporating metals from a filament made of a metal selected from the group consisting of tungsten, tantalum, molybdenum and columbium wherein the metal is heated on such filament as an alloy with chromium which causes the metal desired to be evaporated to wet, to adhere to, and to spread out over the filament surfaces and by the continued application of heat, to evaporate and to deposit upon said surfaces.

3. The method of coating articles by evaporating silver from a filament selected from the group consisting of tungsten, tantalum, molybdenum and columbium wherein the silver is alloyed with chromium and is heated on such filament and wherein said chromium causes the silver desired to be evaporated to wet, to adhere to, and to spread out over the filament surfaces and by the continued application of heat, to evaporate and to coat the articles by deposition of the silver thereon.

4. The method of coating a support material by evaporating silver within a vacuum from a filament selected from the group consisting of tungsten, tantalum, molybdenum and columbium wherein the silver is heated on such filament in the presence of chromium and wherein said chromium causes the silver desired to be evaporated to wet, to adhere to, and to spread out over the filament surfaces and by the continued application of heat, to evaporate within the vacuum and to coat by deposition said support material.

5. The method of coating a support by evaporating copper from a filament selected from the group consisting of tungsten, tantalum, molybdenum and columbium wherein the copper is heated on such filament in the presence of chromium and wherein said chromium causes the copper desired to be evaporated to wet, to adhere to, and to spread out over the filament surfaces and by the continued application of heat, to evaporate and to coat by deposition thereof on a surface of the support.

6. The method of coating a support by evaporating copper within a vacuum from a filament selected from the group consisting of tungsten, tantalum, molybdenum and columbium wherein the copper is alloyed with a relatively small amount of chromium and is heated on such filament and wherein said chromium causes the copper desired to be evaporated to wet, to adhere to, and to spread out over the filament surfaces and by the continued application of heat, to evaporate within the vacuum, and to coat the support by deposition.

7. A method according to claim 4 wherein gold is substituted for silver.

8. A method according to claim 1, wherein the chromium is present in a relatively small amount.

9. A method according to claim 2, wherein the chromium is present in an amount less than 5%.

10. A method according to claim 3, wherein the chromium is present in an amount under 5%.

11. A method according to claim 4, wherein the chromium is present in a relatively small amount.

12. A method according to claim 4, wherein gold is substituted for silver and wherein the chromium is present in an amount less than 5%.

13. The method of coating a support material by evaporating a metal within a vacuum from a filament selected from the group consisting of tungsten, tantalum, molybdenum and columbium wherein the metal is heated on said filament in the presence of chromium and wherein said chromium causes the metal desired to be evaporated to wet, to adhere to, and to spread out over the filament surfaces and by the continued application of heat, to evaporate within the vacuum and to coat by deposition said support material.

14. A method according to claim 13, wherein the support material is a polished support material.

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REFERENCES CITED

The following references are of record in the file of this patent:

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