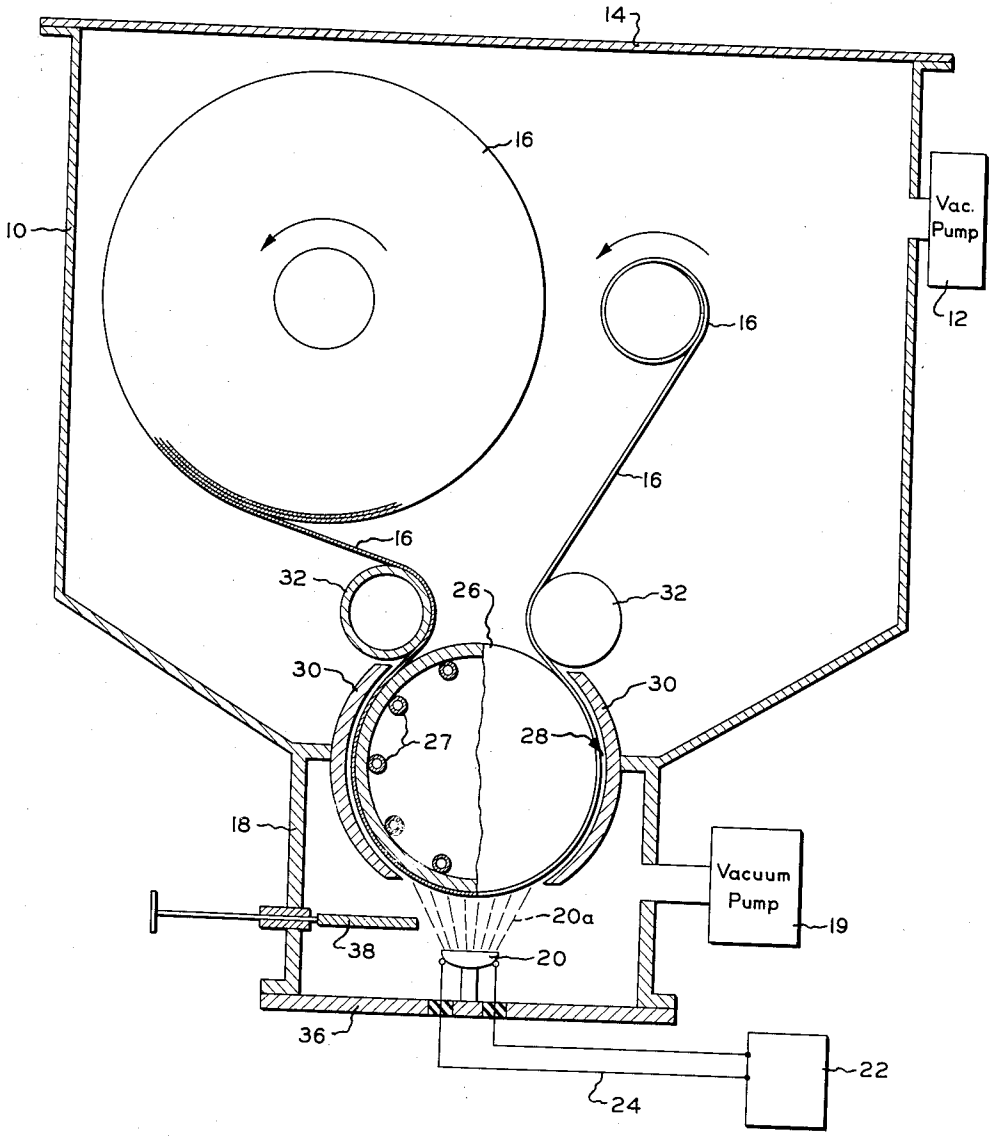
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VAPOR DEPOSITION METHOD AND APPARATUS

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VAPOR DEPOSITION METHOD AND APPARATUS

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This invention relates to coating and more particularly to the coating of heat-sensitive substrates, such as paper with aluminum, to provide a shiny surface having both functional and decorative utility.

Prior workers in the art of vacuum coating have been striving for many years to coat paper and similar materials with aluminum under conditions which are economically competitive with aluminum foil-paper laminates. To date none of these workers have been successful.

Accordingly, it is a principal object of the present invention to provide an improved process and apparatus for metallizing heat-sensitive substrates such as paper to produce a shiny aluminum coating on the substrate.

Another object of the invention is to provide an improved process and apparatus which produces such a coating under conditions which make it economically competitive with aluminum foil-paper laminates.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the process involving the several steps and the relation and the order of one or more of such steps with respect to each of the others and the apparatus possessing the construction, combination of elements and arrangement of parts which are exemplified in the following detailed disclosure, and the scope of the application of which will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawing which is a schematic, diagrammatic, sectional view of one preferred embodiment of the invention.

The present invention will be principally described in connection with its utility in the vacuum aluminizing of paper to produce a material which is economically competitive with aluminum foil-paper laminates. However, it will be apparent that the utility of the present invention extends far beyond the specific application described.

In the aluminizing of paper it is essential that the paper have a smooth, continuous surface to receive the aluminum so that a highly reflective surface film will result. This is due to the fact that the vacuum-deposited aluminum film is extremely thin (on the order of only a few millionths of an inch) and accordingly it will follow exactly the surface of the paper.

An additional important fact is that paper always contains a substantial percentage of water. Dehydrated paper is extremely brittle and essentially useless in most commercial applications. Accordingly, water vapor will come out of the paper when the paper is exposed to a vacuum on the order of a millionth of an atmosphere, which is the degree of vacuum preferred for vacuum aluminizing. Large amounts of water vapor are extremely detrimental to the vacuum coating operation. Attempts to partially dry the paper before aluminizing have not been uniformly successful and in most cases

have necessitated subsequent treatment of the paper to put additional water back into it.

We have discovered that the difficulties enumerated above can be largely avoided without resorting to any significant drying of the paper or to other complex pretreatment. This is partly achieved in the present invention by coating the surface to be aluminized with a substantially continuous film which can serve as at least a temporary mechanical barrier to water vapor and gases attempting to diffuse outwardly from the paper through the coating. This coating is preferably formed of a film-forming material such as polyvinyl acetate, latex or the like which can be applied as a water suspension and dried to form a smooth, continuous film. The process additionally includes the step of passing the thus-prepared paper through an intermediate vacuum chamber wherein both surfaces thereof are exposed for only a brief period of time to a vacuum on the order of 10 to 200 microns Hg abs. or at least in excess of 10 microns Hg abs. This exposure to the intermediate vacuum is primarily for the purpose of removing large quantities of physically entrapped air held between the layers of paper in a paper roll and within the voids necessarily present in any paper. Thereafter the paper, which has been freed of entrapped gas, is passed through a coating chamber which is maintained under a high vacuum (e.g. less than about 20 microns Hg abs.) and contains a source of aluminum vapor. In a preferred embodiment of the invention the substrate passes through the high vacuum chamber in less than about 1 second and preferably in less than $\frac{1}{10}$ of a second or $\frac{1}{20}$ of a second. During this extremely brief interval of time, it is subjected to a high intensity stream of aluminum vapors which provides on the exposed surface of the paper an aluminum film having a total reflectance of 70 percent or more.

The time during which the substrate is in the coating chamber is so short that practically none of the sorbed water is liberated from the paper. Any small portion of water which does manage to become desorbed is believed to be reacted almost immediately with the high concentration of aluminum vapors adjacent the paper surface. Accordingly, the paper loses substantially none of its water content and receives a shiny, adherent film of aluminum on one surface.

In order to permit the short coating time, the substrate is preferably passed through the coating chamber at a high rate of speed, on the order of one to two thousand feet per minute, and the distance through which the substrate passes while in the coating chamber is preferably kept short (e.g. on the order of a foot or less). The source of aluminum vapors is preferably maintained at an elevated temperature (above 1200° C., for example) and the area of molten aluminum in position to coat the substrate is preferably on the order of at least 10 percent of the area of paper being coated.

In a preferred form of apparatus embodying the invention, the substrate is fed into and through the coating chamber while being supported by and held in contact with a continuous, impermeable, moving surface, the surface preferably comprising a large cooled drum which can serve as one portion of the wall defining the coating chamber. Accordingly, the drum surface serves to seal the back surface of the paper during at least most of the time the paper is in the coating chamber and only the surface to be coated is exposed to the high vacuum in the coating chamber. As mentioned previously, this surface to be coated is preferably exposed to the high vacuum for a very small fraction of a second.

After coating, the substantial dehydration of the paper is prevented by rerolling the paper in the intermediate chamber within a second or two of the time that it is

coated. Equally, the paper can be passed out of the intermediate chamber to the atmosphere within a few seconds of coating. Throughout this invention, wherever the amount of volatiles liberated is minimized, as a necessary corollary, the pumping requirements for maintaining the desired vacuum are minimized.

Referring now to the drawings, there is illustrated a diagrammatic, schematic, sectional representation of one preferred embodiment of the invention. As illustrated, the apparatus includes an intermediate vacuum chamber **10** arranged to be evacuated by a high capacity vacuum pumping system **12**. This chamber **10** has a vacuum-tight cover **14** which can be lifted up to permit loading and unloading rolls of paper **16**. The apparatus also includes a vacuum coating chamber **18**, including a source of aluminum vapors **20**, this source preferably comprising an induction heated carbon crucible of the type described and claimed in the patent of Clough et al. 2,665,223. A suitable power supply is indicated at **22** with power leads **24**. Between the intermediate vacuum chamber **10** and the high vacuum coating chamber **18**, there is provided in a preferred embodiment a large drum **26**, cooled by cooling coil **27**, which almost completely fills an opening **28** between these two chambers. This opening is defined in part by curved surfaces **30** which cooperate with the drum surface to form high impedance paths substantially preventing transfer of large quantities of gas from the intermediate vacuum chamber **10** to the high vacuum coating chamber **18**. This drum is so positioned, with respect to a pair of guide rolls **32**, that the paper web **16** is pressed into contact with the drum **26** and held in contact with this drum while it is carried into the coating chamber **18**, through the stream of aluminum vapors (indicated at **20***a*) and back out of the coating chamber. The impedance paths created by the curved surfaces or "shrouds" and the drum thus constitute apertures through which the paper to be coated must pass. For highest impedance the aperture must be minimized; however, there must be sufficient clearance for the paper to pass, while in contact with the drum, without touching the shrouds. Moreover, when it is necessary to join one length of paper with another by means of a lap joint, the aperture must be large enough to allow two thicknesses of paper to pass without interference. Accordingly, it is preferred that the spacing between the shrouds and the drum be made adjustable to permit optimum spacing for different thicknesses of paper.

In a preferred use of the invention, the paper to be aluminized is first treated by having applied thereto a continuous film to give the paper a smooth, shiny surface to receive the aluminum coating. The paper, after receiving this continuous film, is preferably rolled up so that this film is always on the outside of the roll; thus, as roll **16** is being unwound in the intermediate vacuum chamber **10**, its outer surface is essentially continuously sealed by the continuous film. If desired, the ends of the roll can also be sealed by closely fitting metallic end plates, for example. Thus the paper, prior to aluminizing, is exposed to the vacuum only during the rather brief time when it is traveling from the roll onto the drum **26**. Similarly after metallizing, the paper is rewound again with the metallized surface facing away from the axis of the rewound roll.

In a preferred embodiment of the invention, vacuum pumps **12** and **19** are preferably high capacity mechanical vacuum pumps or steam ejectors. Pump **12** preferably can maintain the intermediate vacuum chamber at a pressure on the order of 10 to 200 microns, this vacuum being primarily for the purpose of removing air which is entrapped between the layers of paper **16** or within the voids necessarily present within the paper. The high vacuum coating chamber **18** is maintained by pumping at a pressure less than about 20 microns, preferably less than 10 microns. A pressure of much less than 10 microns is not necessary if the source of aluminum vapors is quite close to the paper being coated (e.g. about 6 inches) and the area of aluminum vapor source is relatively large with respect to the area being coated. For example, if the source is within about 6 inches of the paper and the area of the hot aluminum in the source is about 20 to 50 percent of the area of paper being coated at any instant of time, the pressure can be as high as **15** to **20** microns while still obtaining a shiny, adherent coating.

In a preferred embodiment of the invention, the high vacuum coating chamber **18** includes a removable bottom **36** which carries the electrical connections and supports the crucibles **20**. Thus the supply of crucibles can be rapidly changed by removing the whole assembly **36—20** and replacing this assembly with a spare, containing crucibles loaded with aluminum. A shield **38** is also preferably provided to permit the crucibles to be brought up to operating temperature without exposing the substrate to radiation from the crucible until the aluminum is at the desired evaporating high tempertaure on the order of 1200° C. to 1300° C.

In operating the device described above, the substrate is preferably moved through the high vacuum coating chamber at a relatively high speed on the order of 1000 to 2000 feet per minute. When the lineal dimension of the exposed area of the substrate (i.e. the area between th ends of the two shrouds **30**) is on the order of one linear foot, it is apparent that the time in which any unit area of the substrate remains in the high vacuum chamber is extremely short, on the order of $\frac{1}{16}$ to $\frac{1}{32}$ of a second depending upon the speed of the substrate. Where the distance between the shrouds is minimized, thus minimizing the exposed area of the substrate, it is apparent that more of the exposed area of the substrate is in the path of the aluminum vapors and is being coated than is not.

While one preferred embodiment of the invention has been described above, it is apparent that numerous changes can be made in the modifications described above without departing from the spirit of the invention. For example, numerous coatings can be applied to the substrate, the principal requirements being that this coating have a reasonably shiny surface and that it have sufficient resistance to the passage of water vapor and gases to prevent substantial release of water vapor and other sorbed volatiles in the small fraction of a second that the paper is exposed to the high vacuum of the coating chamber. Additionally the coating material should possess (*a*) good adhesive properties (i.e. be capable of bonding firmly to the substrate), (*b*) be capable of drying to a hard film within a reasonable length of time, and (*c*) not outgas appreciably when subjected to low pressures necessary for the vacuum deposition of aluminum. There are numerous coating materials which meet the above requirements. For instance, thermosetting resins such as the phenol-formaldehydes, urea or melamine formaldehydes, alkyd resins, silicone resins, and epoxy resins can be employed. These resins may be used along or they may be modified. Likewise certain organic lacquers and varnishes are suitable. Water glass can also be utilized.

Equally numerous other mechanical embodiments can be employed. For example, the drum can be replaced by a moving belt although the drum is much preferred from the standpoint of mechanical simplicity.

While the invention has been specifically described in connection with paper, it can also be utilized to advantage in the coating of heat-sensitive plastics such as cellophane, cellulose acetate and the like which contain appreciable quantities of sorbed water, plasticizer, or other volatiles. Since the high speed coating of the present invention permits the substrate to be moved through the high vacuum coating chamber in such a short period

of time, no substantial "outgassing" of the substrate can take place. Accordingly, the present invention can be utilized to coat materials which, in the past, have universally been considered as requiring extensive "outgassing" prior to coating.

The physical volume of the apparatus is preferably kept to an absolute minimum consistent with the space requirements for the bulk of the material to be placed within its vacuum chamber. Thus, when the apparatus is to be utilized for semi-continuous coating as illustrated, the chamber 10 is preferably made only slightly bigger than necessary to hold one completely full roll. Accordingly, as one roll is unwound and the other is rewound, the roll of increasing diameter will gradually take up the space previously occupied by the roll of decreasing diameter. Equally, the substrate may be passed from atmosphere into the coating chamber through a series of locks of the type shown in the copending Bugbee application, Serial No. 565,599, filed February 15, 1956. With this arrangement the coated substrate is also preferably continuously taken out of the vacuum chamber and rewound outside of any evacuated portion of the apparatus.

Since certain changes may be made in the above process and apparatus without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description, or shown in the accompanying drawing, shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. A process for coating aluminum onto a heat-sensitive substrate, such as paper, which contains adsorbed and absorbed volatiles, which comprises the steps of exposing the substrate to a vacuum of between about 20 and about 200 microns Hg abs. for a period sufficient to remove substantial quantities of entrapped gases, subsequently passing the substrate into and out of a coating chamber maintained at a pressure below about 20 microns Hg abs., exposing the front surface of the substrate to aluminum vapors while it is in the coating chamber, the concentration of aluminum vapors being sufficient to produce a coating having at least 70 percent reflectance, the substrate moving at such a rate that no unit area of the substrate is exposed to the high vacuum of the coating chamber for a period in excess of $\frac{1}{10}$ second, back surface of the substrate being held in contact with an impermeable surface moving at the same speed as the substrate for substantially all of the time that the substrate is in the high vacuum coating chamber, whereby the content of sorbed volatiles in the substrate remains substantially unchanged.

2. A process for coating aluminum onto paper which contains adsorbed and absorbed water and entrapped air, the process comprising the steps of exposing the paper to a vacuum of between about 20 and about 200 microns Hg abs. for a period sufficient to remove substantially all of the entrapped air without removing substantial quantities of sorbed water, subsequently passing the paper through a coating chamber maintained at a pressure below about 20 microns Hg abs., exposing the front surface of the paper to a source of aluminum vapors in the coating chamber, maintaining the source of aluminum vapors at a temperature above 1200° C., the source having sufficient area to evaporate at least 0.5 gram of aluminum per minute for each inch of paper width passing through the coating chamber, the paper being moved through the coating chamber at such a rate that no fiber of the paper is exposed to the vacuum of the coating chamber for a period in excess of $\frac{1}{10}$ second, the back surface of the paper being held in contact with an impermeable surface moving at the same speed as the paper for substantially all of the time that the paper is in the high vacuum coating chamber.

3. A process for coating aluminum onto a heat-sensitive substrate, such as paper which contains adsorbed and absorbed volatiles and entrapped air, the process comprising the steps of exposing the substrate to a vacuum of between about 20 and about 200 microns Hg abs. for a period sufficient to remove substantial quantities of entrapped air without removing substantial quantities of sorbed volatiles, subsequently passing the substrate through a coating chamber maintained at a pressure below about 20 microns Hg abs., exposing the front surface of the substrate to a source of aluminum vapors in the coating chamber, maintaining the source of aluminum vapors at a temperature above 1200° C., the source having sufficient area to evaporate at least 0.5 gram of aluminum per minute for each inch of substrate width passing through the coating chamber, back surface of the substrate being held in contact with an impermeable surface moving at the same speed as the substrate for substantially all of the time that the substrate is in the high vacuum coating chamber, the substrate being moved through the coating chamber at such a rate that no fiber of the substrate is exposed to the vacuum of the coating chamber for a period in excess of $\frac{1}{20}$ second.

4. A process for coating aluminum onto a heat-sensitive substrate, such as paper, which contains adsorbed and absorbed volatiles which comprises the steps of exposing the substrate to a vacuum above 20 and below about 200 microns Hg abs. for a period sufficient to remove substantial quantities of entrapped air, subsequently passing the substrate into and out of a coating chamber maintained at a pressure below about 20 microns, exposing the substrate to aluminum vapors while it is in the coating chamber, the concentration of aluminum vapors being sufficient to produce a coating having at least 70 percent reflectance, the substrate moving at such a rate that no fiber of the substrate is exposed to the high vacuum of the coating chamber for a period in excess of $\frac{1}{10}$ second, and maintaining the back surface of the substrate in contact with an impermeable surface moving at the same speed as the substrate for the whole time that the substrate is in the high vacuum coating chamber, whereby the content of absorbed volatiles in the substrate remains substantially unchanged.

5. A process for coating aluminum onto a heat-sensitive substrate, such as paper, which contains adsorbed and absorbed volatiles which comprises the steps of exposing the substrate to a vacuum of no lower than 20 microns Hg abs. for a period sufficient to remove substantial quantities of entrapped air, subsequently passing the substrate into and out of a coating chamber maintained at a pressure below about 20 microns, exposing the substrate to aluminum vapors while it is in the coating chamber, the concentration of aluminum vapors being sufficient to produce a coating having at least 70 percent reflectance, the substrate moving at such a rate that no fiber of the substrate is exposed to the high vacuum of the coating chamber for a period in excess of $\frac{1}{10}$ second, and maintaining the back surface of the substrate in contact with an impermeable surface moving at the same speed as the substrate for the whole time that the substrate is in the high vacuum coating chamber, and preventing prolonged exposure of the mass of substrate to any substantial dehydrating conditions by rerolling the substrate within one second of the time of application of the aluminum coating thereto, whereby the content of absorbed volatiles in the substrate remains substantially unchanged.

6. A process for coating aluminum onto a surface of a heat-sensitive substrate, such as paper, which contains adsorbed and absorbed volatiles, the surface having been first provided with a continuous film which creates a substantial barrier to the passage of vapor and gases, the process comprising the steps of exposing the substrate to a vacuum sufficient to remove substantial quantities of entrapped gases, subsequently passing the substrate into and out of an aluminizing chamber maintained

at a pressure below about 20 microns Hg abs., exposing the film-coated side of the substrate to aluminum vapors while it is in the aluminizing chamber, the concentration of aluminum vapors being sufficient to produce an aluminum coating having at least 70 percent reflectance, the substrate moving at such a rate that no unit area of the substrate is exposed to the high vacuum of the aluminizing chamber for a period in excess of 1/5 second, back surface of the substrate being held in contact with an impermeable surface moving at the same speed as the substrate for substantially all of the time that the substrate is in the high vacuum coating chamber, whereby the content of sorbed volatiles in the substrate remains substantially unchanged.

7. A process for coating aluminum onto a heat-sensitive substrate, such as paper, which contains adsorbed and absorbed volatiles, which comprises the steps of exposing the substrate to a vacuum of between about 20 and about 200 microns Hg abs. for a period sufficient to remove substantial quantities of entrapped gases, subsequently passing the substrate into and out of a coating chamber maintained at a pressure below about 20 microns Hg abs., exposing the substrate to aluminum vapors while it is in the coating chamber, while maintaining the side of the substrate which is not to be coated in intimate contact with an impermeable mechanized moving surface for substantially all of the period during which the substrate is within the coating chamber, the concentration of aluminum vapors being sufficient to produce a coating having at least 70 percent reflectance, the substrate moving at such a rate that no fiber of the substrate is exposed to the high vacuum of the coating chamber for a period in excess of 1 second, whereby the content of sorbed volatiles in the substrate remains substantially unchanged.

8. A process for coating aluminum onto a surface of a heat-sensitive substrate, such as paper, which contains adsorbed and absorbed volatiles, the surface having been first provided with a continuous film which creates a substantial barrier to the passage of vapor and gases, the process comprising the steps of exposing the substrate to a vacuum of above 20 microns Hg abs. for a period sufficient to remove substantial quantities of entrapped gases, subsequently passing the substrate into and out of an aluminizing chamber maintained at a pressure below about 20 microns Hg abs., exposing the film-coated side of the substrate to aluminum vapors while it is in the aluminizing chamber, the concentration of aluminum vapors being sufficient to produce an aluminum coating having at least 70 percent reflectance, the side of the substrate which does not have the film provided thereon being maintained in intimate contact with an impermeable moving surface for substantially all of the period during which the substrate is within the aluminizing chamber whereby the content of sorbed volatiles in the substrate remains substantially unchanged.

9. A process for coating aluminum onto a surface of a heat-sensitive front surface of the substrate, such as paper, which contains adsorbed and absorbed volatiles, the surface having been first provided with a continuous film which creates a substantial barrier to the passage of gases, the process comprising the steps of unrolling the substrate from a roll while exposed to a vacuum of between about 20 and about 200 microns Hg abs., the substrate having been rolled so that the surface of the substrate upon which the film has been provided faces away from the axis of the roll, passing the substrate immediately into a coating chamber maintained at a pressure below about 20 microns Hg abs., exposing the substrate to aluminum vapors while it is in the coating chamber, the concentration of aluminum vapors being sufficient to produce an aluminum coating having at least 70 percent reflectance, back surface of the substrate being held in contact with an impermeable surface moving at the same speed as the substrate for substantially all of the time that the substrate is in the high vacuum coating chamber, the substrate moving at such a rate that no unit area of the substrate is exposed to the high vacuum of the coating chamber for a period in excess of 1/5 second, removing the substrate from the coating chamber into a vacuum of between about 20 and about 200 microns Hg abs., and immediately winding the substrate upon a roll in the vacuum in such a manner that the coated surface of the substrate upon the roll faces away from the axis of the roll.

10. Apparatus for coating a substrate by vacuum vapor deposition techniques which comprises an intermediate vacuum chamber and a high vacuum coating chamber, said chambers being connected by means of at least one seal through which the substrate can be passed from one chamber to the other chamber, said seal being defined by a cylindrical gas impermeable rotatable support coaxially positioned within two arcuately curved walls, means for holding the substrate to be coated in contact with said cylinder as it passes from said intermediate vacuum chamber through said seal to said high vacuum coating chamber and subsequently back to said intermediate vacuum chamber, said holding means serving to maintain said substrate under tension so as to maintain one side of said substrate in contact with said rotatable support while it is in the high vacuum chamber, means for rotating said support at a surface velocity equal to linear velocity of said substrate, and means for providing a source of coating vapors within said high vacuum chamber.

11. Apparatus for coating a substrate by vacuum vapor deposition techniques, said apparatus comprising an intermediate vacuum chamber, a high vacuum coating chamber, a continuous surface extending from within said intermediate vacuum chamber into said high vacuum chamber, means for pressing said substrate into contact with said surface and means for moving said surface into and out of said high vacuum chamber while said substrate is held in contact with, and moves with said surface, said moving means being arranged to move said substrate at a speed in excess of 1000 feet per minute, said pressing means being arranged to hold said substrate in contact with said moving surface during substantially the whole time that the substrate is moved through the high vacuum chamber, vacuum pumping means for maintaining said intermediate vacuum chamber at a pressure between about 20 and about 200 microns Hg abs., vacuum pumping means for maintaining said coating chamber at pressure less than about 20 microns Hg abs., and means for vaporizing aluminum in said coating chamber.

12. An apparatus for coating one side of a paper substrate by metal vapor deposition, which paper is received from and returned to a low vacuum chamber, said apparatus comprising a high vacuum chamber adjoining the low vacuum chamber from which the paper is fed from and returned to, said high vacuum chamber containing a means for generating the metal vapors to be deposited on the paper, a large rotatable cylinder defining a portion of the side of the high vacuum chamber next adjoining the low vacuum chamber, the remaining portion of said side containing stationary shrouds which tightly enclose said cylinder such that only space is left between the curved sides of said cylinder and the stationary shrouds to permit the passage of two thicknesses of the paper being coated while in contact with the cylinder, without contact with the stationary shrouds, means in the low vacuum chamber for guiding the paper substrate on to the cylinder as the paper is fed to the high vacuum chamber and off the cylinder as the paper is returned from the high vacuum coating chamber, said guiding means comprising a pair of rolls that press the paper onto the surface of the roll and hold the paper in contact with the roll while the paper passes through the coating chamber the cylinder being so positioned as to be in the direct line of vapor coming from the source of the metal vapor

such that more paper surface exposed to the high vacuum in the chamber is being contacted by the direct flow of the metal vapor than is not being so contacted.

13. An apparatus for coating one side of a moving paper substrate, which paper is received from a chamber having a pressure no lower than 20 microns Hg abs. and returned subsequent to coating to a chamber having a pressure no less than 20 microns Hg abs., said apparatus comprising a high vacuum chamber maintained at a pressure no greater than 20 microns Hg abs., a source of coating vapors within the high vacuum chamber and a means provided for introducing the substrate, supporting and cooling the substrate while being coated and removing the substrate subsequent to coating, said means comprising a large rotatable supported water-cooled cylinder positioned in one of the walls of the high vacuum chamber next adjoining the chambers from which the paper is introduced and returned, the cylinder being surrounded by portions of the wall so as to leave only two small apertures between the cylinder and the walls, one on each side of the cylinder, through which the paper is fed to the high vacuum chamber and removed from the high vacuum chamber, the paper being in contact with the cylinder throughout its presence in the high vacuum chamber, the cylinder being rotated at a circumferential speed equal to that of the moving paper, the source of coating vapors being positioned so as to produce vapors which impinge directly upon the paper as it moves upon the cylinder, the water-cooled cylinder serving to cool the substrate as the vapors impinge thereupon, thus permitting the formation of a film of coating upon the paper substrate.

14. The apparatus of claim 10 wherein the source of aluminum vapors comprises a means for supporting a body of high temperature liquid aluminum having a surface exposed to the paper which is at least 10 percent of the area of the paper in position to receive aluminum vapors at a given instant of time.

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