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VACUUM COATING APPARATUS

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This invention relates to apparatus for the coating of metallic and nonmetallic substrates in a vacuum.

A principal object of the present invention is to provide an improved apparatus for the vacuum coating of metallic and nonmetallic substrates.

Another object of the present invention is to provide an improved apparatus for the continuous vacuum coating of substrates of the above type.

Another object of the invention is to provide a novel type of vacuum seal for apparatus of the above type.

Still another object of the invention is to provide a vacuum seal for a vacuum chamber which reduces the leakage of air into the chamber, keeps the pumping requirements at a low level, and yet is large enough to allow passage of a moving substrate without physically or chemically affecting the substrate.

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

The invention accordingly comprises 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 drawings wherein:

FIG. 1 is a diagrammatic, schematic view of one embodiment of the invention; and

FIG. 2 is a diagrammatic, schematic expanded view of one of the vacuum seals illustrated in FIG. 1.

The vacuum coating of a moving substrate such as sheet steel, paper, or cellophane with a metal such as for example, aluminum is generally carried out in a chamber or compartment maintained under a pressure of less than about .001 mm. Hg abs. The desired degree of vacuum is determined, in any particular case, by the particular metal being deposited, the nature of the substrate being coated, and various operating factors.

More recently attempts have been made at truly continuous operations where the strip to be coated is continuously introduced from the atmosphere into the vacuum system, is coated and then removed from the vacuum system into the atmosphere. One method of accomplishing this is the introduction and removal of the substrate through a series of chambers or compartments connected by narrow slots. By means of a suitable vacuum pumping system, a pressure gradient is maintained between each chamber. The requirements for such narrow slots are extremely critical. On the one hand they must not be so large as to cause pumping requirements to become excessive due to leakage of air through a large slot.

On the other hand they must not be so small as to seriously interfere with the passage of the substrate with consequent tearing, jamming or scratching of the substrate. In the instant invention, there is provided a vacuum sealing means which permits the substrate to be introduced into and conveyed through a vacuum system and withdrawn therefrom without substantial loss of vacuum in the system, and without damage to the substrate.

In the present invention the substrate is passed through a plurality of seals so as to pass into a plurality of chambers which are evacuated to progressively lower pres-

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ures. In the lowest pressure chamber the substrate is coated with a vacuum-deposited film of a metal such as aluminum. It is a primary consideration of the present invention that the amount of air that leaks into the system be kept to a minimum and that the maximum amount of the total mass of air be pumped out of the system at the highest possible pressure. Accordingly, it is preferred that the leak rate of each seal, particularly those used at the high pressures be kept to less than 5000 millimeter cubic feet per minute per inch of substrate width passing through the seal. In order to achieve this low leak rate each seal must have a high impedance to the flow of air therethrough. This is achieved in the present invention by providing a gap through which the substrate passes between stages, this gap being substantially completely filled with fibers extending generally normal to the substrate surface. The gap is preferably several times thicker than the substrate and preferably has a length along the substrate which is at least one quarter the width of the substrate.

Leak rate is defined in terms of the quantity of gas flowing into a system from an external source in terms of pressure-volume units per unit time. In the expression used in the claims the "millimeter" is the pressure in mm. Hg abs., the "cubic feet" is the volume, and "minute" is the unit of time. This is a standard method of expressing leak rate. In the instant specification the additional dimension of leak rate defined in terms of substrate width has been added. Thus, if the substrate is 36 inches wide and the total leak rate is 36,000 millimeter cubic feet per minute, the leak rate per inch of substrate is

$$\frac{36,000}{36} = 1,000 \text{ millimeter cubic feet per minute per inch}$$

In the "Committee on Vacuum Techniques," 1954 Vacuum Symposium Transactions, page 138, the following definition appears:

Leak-rate.—The quantity of gas flowing into the system or through the pump from an external source in terms of pressure-volume units per unit time (usually in micron-liters per second, or liter-microns per second, or cc.-atmos./sec. at 25° C.).

Referring now to FIG. 1 there is illustrated one embodiment of the invention wherein 10 represents a vacuum chamber comprising four compartments, 12, 14, 16 and 18 and a coating compartment 20. A substrate 11, which is to be coated, is arranged to pass between the various compartments through vacuum seals 21, compartment 12 having two seals 21 to permit passage of the substrate to and from the atmosphere. The compartments are defined by partitions or walls 22, 24, 26, 28, 30 and 32. Compartments 12, 14, 16, 18 and 20 are evacuated through conduits 34, 36, 38, 40 and 42 respectively by means of suitable pumping systems, not shown. The compartments are maintained at progressively lower pressures, the pressure decreasing from atmospheric pressure outside compartment 12 to below 0.1 millimeter of pressure inside coating compartment 20. This pressure drop is possible due to the low leak rate of each seal 21. Within coating compartment 20 is a source 44, schematically illustrated as a crucible, for holding the metal such as aluminum to be melted and evaporated. The source 44, is suitably heated by means 46, schematically shown as an induction heating coil. The substrate 11 is guided over the source of coating vapors 44 by means of rollers or idlers 48. If desired a second such source (not shown) may be provided to permit coating both sides of the substrate.

Referring now to FIG. 2 wherein like numbers refer to like parts of FIG. 1, the vacuum seal 21 is illustrated in more detail. The individual vacuum seal 21 includes a rotatably mounted cylinder 23 which cooperates with a

stationary semi-cylindrical wall 25 to define a long narrow slot which has a thickness several times greater than the substrate 11, a width slightly in excess of the substrate width and an arcuate length "L" which is at least one quarter, and preferably one half or more the width of the slot. This slot is substantially completely filled with fibers 31 which extend across the slot in a direction generally normal to the substrate surface. These fibers are packed closely together to provide a high impedance path which enormously reduces the amount of air that could otherwise flow through the slot. In general, the fibers are less than 1/4 inch long so that they remain sufficiently stiff to span the slot, this limitation of the fiber length being particularly important at the higher pressures where the air attempting to flow through the slot can exert considerable bending force on the individual fibers.

As illustrated schematically at 39, the fibers are preferably supported by a suitable carrier such as a web 29 which may be a felt base, for example, from which the fibers 31 extend. In one preferred embodiment the fibers are part of a flocked fabric wherein the individual fibers 31 are adhesively secured at one end to a cloth base 29.

Within the meaning of fibers, as used herein, there are included animal hair, human hair, synthetic fibers, bristles and naturally occurring fibrous material. For example, animal furs, synthetic fibers such as nylon, rayon, and the like; and naturally occurring fibrous materials such as cotton, silk, and products thereof such as felt and velvet etc., can be employed. The fibers are attached or imbedded in the support 29, or individually flocked in any manner which will give a dense soft pile of erect fibers. The fibers are of sufficient length to span the slot through which the substrate passes. It is preferable that the fibers be of sufficient length to slightly overlap onto the substrate. The bottom portion of the cylinder 23 is also engaged by a similar group of fibers 31 covering a portably cylindrical wall portion 27 to prevent leakage of the air around the bottom of the cylinder. Other types of seals can be used here where there is no danger of scratching or tearing the substrate. Typical of such seals are labyrinth seals or graphite blocks and the like.

In one preferred embodiment of the invention designed for passing a 36 inch wide strip of sheet steel into and through a coating chamber the cylinder 23 has a diameter of 16 inches, the spacing between the cylinder 23 and the housing 25 is about 0.075 inch when the sheet steel is 0.010 inch thick. This leaves a gap of 0.065 inch which is substantially completely filled by an artificial flock of cellulose acetate fibers, the flock being approximately 0.055 inch thick and having a fabric backing 0.010 inch thick. The length "L" of the slot is approximately 22 inches so that this length is about equal to 60% of the width of the steel strip. Such a slot has a total leak rate of less than 16,500 millimeter cubic feet per minute when operating at atmospheric pressure at one side of the seal and the pressure of 100 mm. Hg abs. on the other side of the seal.

The spacing across the seal becomes less critical as the absolute pressure drops across the seal become less; thus as the pressure drop becomes only a few hundred microns or so the gap can be opened up considerably without unduly increasing the leakage. This is due to the fact that, as the leakage flow of air through the slot becomes more nearly molecular, the impedance of the individual fibers to molecular flow becomes greater.

While one preferred embodiment of the invention has been shown in FIGS. 1 and 2 above, a number of modifications can be made. For example, the slot can be made straight rather than curved, as shown, and the fibers constituting the sealing surface can, if desired, be mounted on movable supports such as rolls or belts so as to move either with or against the motion of the substrate.

Since certain changes may be made in the above apparatus without departing from the scope of the invention herein involved, it is intended that all matter contained in the above description, and shown in the accompanying

drawings, shall be interpreted as illustrative and not in a limiting sense.

What is claimed is:

1. Apparatus for coating a substrate in a vacuum, said apparatus comprising a plurality of vacuum chambers, means to evacuate said chambers, a source of coating vapors within one of said chambers, means for guiding said substrate over said source of coating vapors, a plurality of vacuum seals to allow passage of said substrate into and between said vacuum chambers, at least one of said vacuum seals comprising an elongated passage extending through a wall defining one of said chambers, said passage having a length at least as long as one half its width, one surface of said passage being provided with closely packed fibers extending generally normal to the substrate, said fibers being sufficiently long to contact said substrate, said fibers contacting an extended area of said substrate when said substrate is within said passage, said passage being sufficiently long and said fibers being sufficiently closely packed to provide a leak rate less than 5000 millimeter cubic feet per minute per inch of substrate width when a pressure drop of at least 200 mm. Hg abs. exists across said seal.

2. The apparatus of claim 1 wherein said fibers are at least twice as long as the thickness of the substrate.

3. The apparatus of claim 1 wherein said fibers are sufficiently long to extend completely across said passage with no substrate in the passage.

4. Apparatus for coating a substrate in a vacuum, said apparatus comprising a plurality of vacuum chambers, means to evacuate said chambers, a source of coating vapors within one of said chambers, means for guiding said substrate over said source of coating vapors, a plurality of vacuum seals to allow passage of said substrate into and between said vacuum chambers, at least one of said vacuum seals comprising an elongated passage extending through a wall defining one of said chambers, said passage having a length at least as long as one half the width of said substrate, one surface of said passage being provided with closely packed fibers extending generally normal to the substrate, said fibers being sufficiently long to contact said substrate, said fibers contacting an extended area of the substrate when said substrate is within said passage and serving to provide a seal having high impedance to the passage of air therethrough, and means for moving said substrate through said chambers, said passage defining an arc of between 90° and 180° in the direction of substrate travel.

5. Apparatus for coating a substrate in a vacuum, said apparatus comprising a plurality of vacuum chambers, means to evacuate said chambers, a source of coating vapors within one of said chambers, means for guiding said substrate over said source of coating vapors, a plurality of vacuum seals to allow passage of said substrate into and between said vacuum chambers, at least one of said vacuum seals comprising an elongated passage extending through a wall defining one of said chambers, said passage having a length at least as long as one half the width of said substrate, one surface of said passage being provided with closely packed fibers extending generally normal to the substrate, said fibers being sufficiently long to contact said substrate, said fibers contacting an extended area of the substrate when said substrate is within said passage and serving to provide a seal having high impedance to the passage of air therethrough, and means for moving said substrate through said chambers, a plurality of said seals being provided with said fibers, the fibers in a seal cooperating with a roller to form a sealed passage which curves around the surface of the roller in the direction of the substrate travel.

6. Apparatus for coating a substrate in a vacuum, said apparatus comprising a plurality of vacuum chambers, means to evacuate said chambers, a source of coating vapors within one of said chambers, means for guiding said substrate over said source of coating vapors, a plurality of vacuum seals to allow passage of said substrate

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into and between said vacuum chambers, at least one of said vacuum seals comprising an elongated passage extending through a wall defining one of said chambers, one surface of said passage being provided with closely packed fibers extending generally normal to the substrate, said fibers being sufficiently long to contact said substrate, said fibers contacting an extended area of the substrate when said substrate is within said passage and serving to provide a seal having high impedance to the passage

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of air therethrough, and means for moving said substrate through said chambers, said passage defining an arc of between 90° and 180° in the direction of substrate travel.

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