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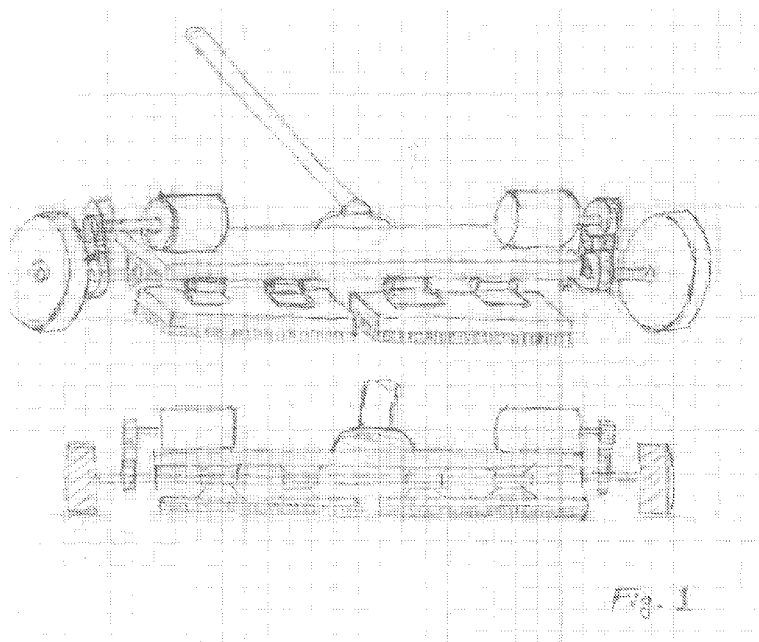
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(54) Title: THIN-FILM COATING APPARATUS FOR APPLYING ENHANCED PERFORMANCE COATINGS ON OUTDOOR SUBSTRATES

(57) Abstract: A thin-film coating applicator assembly is disclosed for coating substrates in outdoor applications.



THIN-FILM COATING APPARATUS FOR APPLYING ENHANCED PERFORMANCE COATINGS ON OUTDOOR SUBSTRATES

CROSS REFERENCE TO PRIORITY APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/949,842 filed on March 25, 2014.

FIELD OF THE TECHNOLOGY

[0002] The instant innovation relates to optical coating devices and apparatuses, in particular for providing high-quality performance enhancement coatings, including, but not limited to anti-reflective coatings on installed photovoltaic panels, glass windows and similar substrates directly in the field.

BACKGROUND

[0003] Silicon photovoltaic panels typically have a protective top layer of cover glass or plastic to protect the underlying photovoltaic cells. Enhanced performance optical coatings such as thin-film energy transmission improvement layers in the form of antireflective coatings on the top surface of the cover glass or plastic protective layer is desirable from the standpoint of increasing solar cell efficiency. Such films improve the transmission of infrared, visible and ultraviolet wavelengths of light through the cover glass or plastic protective layer, typically by providing a refractive index gradient to better capture incident light energy that otherwise would be reflected from the surface of the cover glass or plastic protective layer. Enhanced transmission of light energy to photovoltaic cells provides an advantage by increasing the number of photons available for electricity production. Energy transmission improvement

coatings, again in the form of antireflective coatings, may also provide an advantage for glass windows by reducing the light reflected off of the surface, reducing the glare normally emanating from glass surfaces. Increased energy transmission, in the form of increasing the number of photons transmitted through the glass from outside a building to the inside of the building, may also reduce the need for interior electric lighting. Both photovoltaic panel cover glass and window glass are typically large and require even coatings of uniform thickness to be effective.

[0004] Thin film coating technologies have been developed and perfected for industrial scale production in window and solar panel manufacturing. As it has become known that thin-film antireflective coatings improve solar cell efficiencies, it has become desirable to now manufacture solar photovoltaic panels with such coatings in recent years. However, retrofitting older panels not originally coated with antireflective coatings requires dismantling of the photovoltaic array and sending the individual panels to a factory or facility for coating, an expensive and disruptive endeavor. Similarly for glass window panes installed on commercial buildings and storefronts, many may benefit from an antiglare coating, but are already installed and would need to be replaced with new pre-coated window panes, or by installing anti-glare sheets on the pane. Currently, there are no viable, cost effective solutions for retrofitting photovoltaic panels and window panes with high quality thin-film optical coatings.

SUMMARY

[0005] The innovation described herein is a novel coating apparatus for applying performance enhancement coatings such as optical coatings to the surfaces of utilitarian substrates such as photovoltaic (solar) panels, glass windows, and the like, used outdoors or inside buildings.

Embodiments of the invention comprise manually controlled and autonomous mobile devices adapted to travel along a substrate surface while spreading an even and uniform layer of a liquid coating solution, which then cures to form a solid coating layer. The coating may be an optical coating, as, for example, an anti-reflective coating, advantageous for increasing efficiencies of photovoltaic panels and solar thermal panels, or reducing glare from glass window panes.

[0006] It is a primary object of the innovation described herein to provide a facile means of applying coatings of field installations of substrates post-manufacture, as, for example, an array of photovoltaic panels installed outdoors at a power generation facility, an array of solar thermal panels installed on a building roof or in another outdoor location, and the like. As optical coatings such as anti-reflective coatings are proven to increase efficiencies of photovoltaic panels in particular and have begun to gain wide acceptance in recent years, it may be advantageous to retrofit older panels already deployed in installations with such coatings; however, present coating systems are stationary apparatuses for use in a manufacturing facility, for example, and the current post-manufacture coating protocol requires the dismantling of a photovoltaic (or other) array and sending the panels to a facility to have the coating done. This is obviously expensive and disruptive, where the costs of going this route may outweigh the efficiencies gained by the optical coating, at least in the short term. The instant innovation provides a desirable solution to this dilemma, whereby a portable coating system is provided having the ability to traverse the surface of a panel substrate and deposit a high-quality optical coating across the entire surface of the substrate, at least equaling the quality of a factory coating. By high quality, it is understood that the films

deposited by the instant innovation are substantially uniform in thickness and composition across the substrate.

[0007] To achieve such uniformity in coating thickness, the instant innovation is adapted to be placed on a panel substrate, and then to traverse the panel at constant speed while spreading the coating solution at a constant flux, or flow rate. The instant innovation is a mobile coating assembly adapted for coating installed panel substrates of the type described above, which includes a mobile support structure with dimensions that are compatible with panel dimensions (i.e., the width of the support structure is compatible with the width of the panel), and having a traction mechanism that is adapted to move the mobile support structure at a constant rate along its trajectory on the surface of the panel substrate.

[0008] The inventive coating assembly further comprises one or more innovative coating applicator heads affixed to the mobile support structure (platform). The coating applicator heads comprise a means to deposit the coating solution on the surface of the substrate, said means including, but not limited to spray heads, rollers, slots, brushes, doctor blades, wipers, draw-bars, sponges, foam, porous textile layer or a combination of such.

[0009] In a preferred embodiment, the coating applicator heads comprise a deformable core body, preferably composed of a compliant and deformable sponge-like material, and a microporous “skin”, or interface layer having a certain micropore volume sufficient to hold a determined amount of liquid coating solution and contacting a portion of the surface of the deformable core body. The deformable core body may also be porous in nature and serve the function of an additional reservoir for a liquid coating solution, and the microporous layer

serves the function of an interface between the deformable core body and the substrate surface, whereby the micropores act as a capillary array to transfer coating solution to the substrate. In some embodiments, a textile such as a felt fabric may be used as the microporous interface layer. Felt fabrics have a large plurality of fibers oriented randomly within the fabric, where the interstitial spaces between the fibers present an extensive array of tortuous micropores. Moreover, felts can be fabricated from a large variety of fibers to virtually any thickness, and have very fine and soft textures ideal for uniform spreading of liquids on surfaces. The soft and compliant nature of felts make them ideal for use as a microporous interface layer. In addition to felts, other fabrics and materials may be used for the same purpose (e.g. woven sheet and high porosity foam). The micropores of the felt interface or an interface created by other materials effectively act as an array of capillaries that store and transfer liquid coating solution to the surface in a manner that is substantially uniform over the contact surface of the applicator head. As coating solution is depleted in the microporous interface layer, in one embodiment where the deformable core is also porous and contains coating solution, the microporous interface layer may draw coating solution from the deformable core and transfer it to the substrate surface. In another embodiment, coating solution may be pumped from a reservoir through a plurality of tubes to the microporous interface layer before or during the coating process.

[0010] The instant innovation includes manually guided and automated embodiments, and combinations thereof. Manually guided embodiments of the instant innovation comprise the mobile support structure and coating head assembly discussed above, further comprising a handle extension of the mobile support structure that may be rigid or bendable, where the

latter may comprise springs in the handle to compensate for variations in hand-applied pressure, which can lead to non-uniformities in coating thickness. Handles may also be pivotally attached to the inventive applicator head, providing ergonomic deployment of the invention. Automated embodiments may comprise mechanized or robotic deployment of the innovative coating assembly, whereby the mobile support structure and coating head assembly may further comprise a motorized drive mechanism coupled to the traction device. An example of this type of embodiment is an electric motor affixed to the mobile support structure, and coupled to a roller axel via a chain, belt or a gear train. Preferably, the electric motor is controlled by an electronic motor control circuit. More preferably, the electronic motor control circuit is programmable, and most preferably the electronic control circuit is capable of wireless control and programming. The motor serves the function of driving the innovative coating assembly at a constant speed, necessary for deposition of coatings having substantially uniform thicknesses. Moreover, if a thickness gradient is desired across the substrate, the motor can be programmed to ramp the speed of the assembly.

[0011] Preferably, the effective width of the mobile support structure is sufficient to span the width of a panel substrate, requiring only a single excursion of the innovative coating assembly in one direction along the length of the substrate to deposit the coating, simplifying the coating process. In other embodiments, the motorized drive mechanism may translate the applicator head both lengthwise and widthwise across the substrate in a grid fashion or other motion, for example, when coating areas wider than the width of the mobile support. Most preferably, the effective width of the mobile support structure is adjustable to span the width of substrates of non-standardized widths. Related to this aspect, further automated embodiments include an

elongated handle for manual placement and removal of the innovative coating assembly on a substrate. The elongated handle is advantageous for extended reach, and as such has ergonomic value. Moreover, the handle is preferably pivotally affixed to the mobile support structure, providing further ergonomic advantages. In other embodiments, the mobile support structure may be positioned on to or translated across the substrate by a robotic arm. In yet other embodiments, the mobile support structure may be translated across the substrate by the motor without the use of a handle or robotic arm to guide it. In yet other embodiments, a combination between manually guided and automated functions may include a handle whereby the operator may help control any motion in an axis orthogonal to the direction of coating while the automated motorized functions may guide the coating assembly in the direction of coating.

[0012] It is a further objective of the innovation to provide coatings of uniform thickness. For embodiments where the coating heads are compliant and deformable, the degree of deformation may be a function of the weight of the entire assembly supported by the coating heads when engaged, as well as other vertical forces imposed on the innovative assembly. The weight of the coating assembly may also be supported in part by the traction device. The deformation may furthermore pressurize any liquid contained within the microporous interface layer, and if a porous deformable core body is used, any liquid contained within the porous deformable core body as well, increasing the flux of the liquid when discharged to the substrate surface during the coating process. While the weight of the coating assembly may remain substantially constant during the coating process, fluctuations in vertical forces, for instance, those due to changes in hand or arm pressure fluctuations that may occur when the coating

assembly is manually guided during the excursion in manual embodiments, may cause fluctuations in deposition rate of the coating, therefore resulting in random variations in coating thickness, if measures are not taken to mitigate these fluctuations.

In some embodiments, coating heads may be attached to the mobile support structure by force-absorbing strut members responsive to changes in vertical force, mitigating them to various extents. In one type of embodiment, the struts are in the form of leaf springs. In other embodiments, struts comprise spring-loaded articulating joints interposed between elongated members, rigid or non-rigid. In yet further embodiments, struts may be in the form of a shock-absorbing dashpot mechanism, or simple compression springs. In all cases, the spring constants, or stiffness, of the various types of strut spring components may be chosen to cause the spring to deform sufficiently in response to the magnitude of changes in applied force. The struts then may absorb force fluctuations before these are transferred to the deformable porous core bodies of the coating heads, causing fluctuations in the geometry and therefore the pressure on the liquid contained within. As mentioned above, these changes translate to variations in the flux of coating solution being discharged from the porous core, ultimately resulting in variations in coating film thickness.

[0013] In the embodiments described in the preceding paragraph, the force-absorbing struts connect the coating heads to the mobile support structure. In alternative embodiments, struts may connect the traction device to the mobile support structure, whereas the coating heads may be either suspended by more rigid members, or again connected by force-absorbing members. In other embodiments, the coating heads may be connected to the mobile support

structure by means of hinged brackets or slides which minimize the transfer of vertical forces from the mobile support structure to the coating heads during the coating process.

[0014] In some embodiments, coating solution may be charged to the one or more coating heads in a continuous manner, for instance by an on-board pumping system, and in other embodiments, the coating heads are charged discontinuously by an offline means. Reducing complexity, weight and expense of the innovative coating assembly, offline transfer of coating solution to the coating head or heads is a preferable solution, whereby the pumping system and coating solution reservoir is eliminated from the assembly. To this end, a separate charging or re-filling station may be provided. In one embodiment, a charging station comprises a frame or superstructure, a dosing platform, a receiving structure to place the innovative coating assembly, whereby the receiving structure is adapted to position the coating heads of the innovative coating assembly on the dosing platform. Other method of charging the coating heads are embodied by continuous and intermittent on-board pumping systems.

[0015] In addition to anti-reflective coatings, this invention may be used to deposit other performance enhancement coatings, including wave-length shifting coatings and filter coatings such as "Low-E" coatings that minimize the transmission of either ultraviolet light or infrared light or both.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Fig. 1. View of the coating assembly preferred embodiment. Oblique view and frontal view shown.

[0017] Fig. 2. Detailed view of coating application head construction, showing the deformable core and capillary interface layer arrangement.

[0018] Fig. 3a. Bottom oblique view of deformable core of coating applicator head.

[0019] Fig. 3b. Top oblique view of coating applicator head assembly, showing lever spring struts disposed for attachment to mobile support structure.

[0020] Fig. 3c. Top oblique view of coating applicator head assembly, showing leaf-spring struts disposed for attachment to mobile support structure.

[0021] Fig. 3d. Top oblique view of coating applicator head assembly, showing dashpot mechanism struts disposed for attachment to mobile support structure.

[0022] Fig. 4. Top oblique view of manually controlled embodiment of the inventive coating assembly.

[0023] Fig. 5a. Side view of manually controlled embodiment of the inventive coating assembly, having a flexible handle structure, having a bendable leaf spring action to mitigate vertical forces.

[0024] Fig. 5b. Side view of manually controlled embodiment of the inventive coating assembly, having a flexible handle structure, having a bendable lever spring action to mitigate vertical forces.

[0025] Fig. 6. Details of motorized drive coupling to drive axel.

[0026] Fig. 7a. Top oblique view of coating assembly service station embodiment for transferring coating solution to coating applicator heads.

[0027] Fig. 7b. View of bottom side of dosing platform component of coating assembly services station.

[0028] Fig. 8. Sectional view of alternative embodiment of coating applicator head, adapted for delivery coating precursor solution by pumping means to a distribution manifold built into the coating applicator head.

DETAILED DESCRIPTION

[0029] The inventive coating assembly system 100 in its preferred embodiment is shown in Fig.

1. Assembly 100 comprises a mobile support structure, chassis or carriage unit 101. Support structure or carriage 101 incorporates a traction device, which may be rollers or wheels 102, as shown in Fig. 1, but may equally be caterpillar tracks. Coating assembly further comprises one or more coating applicator heads 103. Two such coating heads 103 are shown in Fig. 1 attached to the underside of carriage 101 so that the assembly may be deployed on the surface of a substrate, and to engage the coating heads on the surface with the object of delivering a flux of liquid precursor coating solution to produce a coating layer having a substantially uniform thickness on the substrate surface. Preferably, the innovative coating assembly includes a motorized drive, such as motor 104 coupled to the traction system 102 via drive train 105 to allow the coating assembly 100 to undergo powered excursions. The function of motor 104 is to drive coating assembly 100 at constant and uniform speed along the substrate surface while coating heads 103 are engaged with the surface. The coating heads 103 are furthermore adapted to deliver a substantially constant and uniform flow rate of coating solution to the

substrate surface so long as the coating heads contact the surface with a substantially constant force and sweep along at a substantially constant speed.

[0030] Still referring to Fig. 1, elongate handle 106 is attached to mobile support structure 101 via rotatable coupling 107. Coupling 107 may be a ball joint to allow rotation in any direction. Elongate handle 106 serves to allow manual manipulation of coating assembly 100, for instance, allowing an operator to pick and place assembly 100 on a substrate surface, maneuver or transport coating assembly by hand.

[0031] The innovative coating assembly may comprise one more coating heads. For the purposes of illustration, the following description will be focused on a single coating head. Referring to Fig. 2, applicator head 200 comprises a deformable supporting body and a microporous capillary superficial layer that covers the deformable supporting body. Coating solution may be delivered from a reservoir to the superficial capillary layer by means of a pump in fluidic communication with the capillary layer through a plurality of tubes. Alternatively, coating solution may be delivered from a reservoir to the superficial capillary layer by means of a service station which saturates the capillary layer prior to coating. Preferably, the deformable support body comprises a porous sponge like structure, which can function as a mechanical support of the capillary layer and as a reservoir of fluid coating solution as well. The capillary layer serves as a coating interface that is in contact with a substrate surface, where liquid deposited thereupon may continually draw liquid coating solution from the capillary layer as the coating head is swept along the substrate surface. As indicated above, it is an object of the innovation to provide a uniform coating.

[0032] By the method of coating solution delivery exploited in this innovation, uniformity of coating depends on pressure vertical forces applied to the deformable support body or bodies, resulting in static pressure of the liquid coating solution contained within, the porosity of the capillary layer, and on the sweep speed of the coating heads. Variations in pressure liquid coating solution retained in the deformable support body would lead to variations in flow rate, thereby delivering the coating fluid in a non-uniform manner. These variations in pressure would in practice primarily be due to variations or fluctuations in vertical forces applied to the innovative coating assembly. Such variations may be due to manual handling of the apparatus, for example by an operator manually sweeping the coating assembly, a method prone to fluctuations in vertical forces applied to the coating assembly as it is moved across a substrate by means of an extended handle. In a robotic mode, fluctuations in vertical forces may also occur due to, for example, steadily decreasing weight of the assembly from consumption of coating solution stored in the coating heads, or by inadvertent shocks to the coating assembly during deployment. Advantageously, the innovation circumvents this problem by providing means to compensate for any fluctuations in vertical forces.

Coating head construction

[0033] As mentioned above, the coating heads comprise at least a deformable core covered by a capillary interface layer. Exemplary details of such a structure are shown in Fig. 3a, shown in oblique view. Deformable core 301 is in the form of a spongy polymeric or rubber solid foam that preferably is mechanically compliant. In addition, the deformable core may be abundantly porous to perform the function of a reservoir for the liquid coating solution. The degree of compliance exhibited by the deformable core may be chosen to support at least a portion of

the weight of the coating assembly without excessive deformation. Thus the material may be chosen to withstand a predetermined weight for a given degree of deformation.

[0034] Alternatively, the weight of the coating assembly may be supported entirely or in part by auxiliary struts or by the traction device, such as rollers, directly, reducing the stiffness required of the deformable body. As shown in Fig. 3a, the capillary interface 302 may be in intimate contact with the bottom surface of deformable core 301, where, for example, the bottom surface of deformable core 301 may be laminated to the capillary interface 302. Capillary interface 302 may comprise a felt-like textile or a microporous fabric or porous polymer foam sheet that provides a large array of capillaries or micropores that extend through the thickness of the capillary layer, forming a substantial porosity in the fabric. The capillary interface can also be constructed from sheets of filter media made from fibrous or extruded polymer filter sheet. In the case where the deformable core 301 is a porous material acting as a fluid reservoir, capillary interface 302 may provide a means to draw out a liquid coating solution contained within deformable core 301 by capillary action in addition to static pressure within the body of the deformable core. Advantageously, capillary interface 302 also provides a means to evenly and smoothly spread the flux of coating solution to form a coating layer along the trajectory path of the inventive coating assembly. The thickness of the coating layer is substantially a product of the flow rate of the coating solution depositing from the capillary layer 302, and the velocity of the inventive mobile coating assembly. The more rapid motion of the coating assembly over the substrate results in more solution being deposited per unit area. Conversely, slower motion of the coating assembly over the substrate results in less solution being deposited per unit area.

[0035] An example of a more complete structure is shown in Fig. 3b, where a support structure or frame 303 is included, to which the deformable core 301 may be affixed by a variety of means. Frame 303 itself may exhibit a degree of compliance in order to conform to gentle contours that may be present in the substrate, and therefore may be constructed from various metal and plastics. As an example, a solar panel may not be entirely flat, but may exhibit some degree of curvature or bowing from one edge to the opposite edge. To obtain a complete coating, the coating head must be able to follow this contour. For this to be possible, frame 303 is preferably made to bend or bow to conform to surface non-planarities, so a flexible structure is preferable.

[0036] Frame 303 may further provide attachment points for struts (as described above) or other connecting means to affix or suspend the coating head to the mobile support structure. In Fig. 3b, struts 304 in the form of spring-loaded hinged lever mechanism 304. The structure 304 comprises at least two struts constructed by rigid elongated structures 305 and 306, connected together by spring-loaded joint 307. The spring constant of joint 307 may be adjusted in such a way that the spring deforms to an extent under the weight of the coating assembly structure, but will react to sudden fluctuations in vertical force, absorbing that force fluctuation, and restoring the deformation of the spring to its initial steady state.

[0037] In another exemplary embodiment, shown in Fig. 3c, , where leaf-spring struts 309 are bendable leaf springs that substantially absorb fluctuations in applied vertical forces by bending in proportion to the applied forces. The force fluctuations are thereby substantially not transmitted to the underlying coating heads, whereby the vertical force applied to the coating

heads resulting from the weight of the assembly remains substantially constant, ultimately allowing a substantially constant delivery of coating solution to the substrate.

[0038] In Fig. 3d, the force leveling mechanism is embodied as a shock-absorbing dashpot system. Here, the struts 310 comprise shock absorbing or dashpot structures 311. The structure may comprise simple compression springs, or may comprise more complex shock-absorbing devices, including viscoelastic materials. The shock absorbing struts 310 may be disposed as shown in Fig. 3d, either diagonally or vertically, connecting coating head 303 to the mobile support structure.

[0039] In alternative embodiments, force-absorbing struts may intervene to connect the traction device to the mobile support structure in lieu of or in addition to such struts used for the coating heads.

[0040] In certain embodiments, the coating assembly may be manually guided across the substrate. Fig. 4. depicts one such embodiment, shown in this case without a motor drive, mobile support structure 401 is rotatable about axle 402 by means of cables 403, which may be routed along handle 404 to an upper portion thereof (not shown) where a lever mechanism or equivalent may be used to raise and lower coating applicator head 405. To accomplish this, mobile support structure 401 may be affixed to applicator head frame 406, but passage holes 407 may be made to pass axle 402 therethrough, allowing free rotation about axle 402 without placing a torque thereupon. In this way, applicator head 405 may rest on a substrate surface under its own weight. In addition, Handle 404 may be pivotally affixed to axle 402 via bracket

408, which is attached to axel 402 via bushings 409. In this way, vertical motions of handle 404 are decoupled from coating applicator head 401.

[0041] In other manually guided embodiments, the applicator head assembly 500 may comprise an elongated handle 501 extending from the support structure 502 for use as a hand-held coating applicator. Application of optical energy transmission enhancement coatings require precision, particularly to obtain uniformity of thickness. Hand guiding the applicator may entail variations of stroke velocity and pressure applied, both of which may adversely affect the uniformity of the coating. For manual guidance of the applicator, the inventive applicator head assembly provides solutions for these deficiencies by the following aspects. Preferably, the handle 501 is pivotally affixed to support structure 502 as shown in Fig. 5a via pivot 503, in such a way that the angle between the support structure 502 and the handle 501 change gradually while the applicator head assembly 500 is manually guided across a surface. Handle 501 may be a flexible elongated structure as shown in Fig. 5, whereby the entire handle 501 acts as a bendable spring lever or leaf spring when pressed upon.

[0042] The bendable spring-like aspect of the handle 501 absorbs hand force that may otherwise be directed vertically on the applicator head that may result in increased pressure on the substrate. The increased pressure may induce more flow of coating solution that may result in non-uniform coating thickness along a swath, which may be random if hand pressure changes erratically, or may result in gradual changes in coating thickness if hand pressure gradually increases and decreases along a swath due to the ergonomic relationship of the substrate position and the disposition of the operator's range of motion. The instant embodiment of the invention provides an ergonomic applicator head assembly for manually

guided substrate coating by the force compensating handle for applying substantially constant pressure on the applicator head while applying a coating on a substrate. Increasing hand force on the leaf spring (or spring lever) handle 501 bows it according to the magnitude of the applied force. The bend of the spring handle increases with increasing force, while the non-absorbed portion of the force remains substantially constant, and is applied vertically to the applicator head assembly. Thus, the pressure applied to the substrate 805 is substantially constant.

[0043] In another embodiment shown in Fig. 5b, the handle 501 may comprise two or more rigid portions 504 and 505, and a coil or lever spring 506 forming a joint between any two rigid portions. The function of the structure is the same as the flexible handle embodiment described above. However, in the instant embodiment the spring joint 506 bends in accordance to the applied hand force, and take up increased applied force while the structure transmits a constant force to the substrate. The spring constant for the spring joint 506 may be low enough to allow for the handle to be readily bent with small hand forces. In this way, a minimum vertical force is applied to the inventive coating assembly 500, while small increases in hand force are readily absorbed. For the earlier embodiment, the spring constant of the spring lever or leaf spring handle may be low enough to bend easily with small increases in hand force to readily absorb the changes, mitigating fluctuations in vertical forces on the substrate.

Controlling the vertical forces on the applicator coating assembly as discussed is advantageous for embodiments both with and without motor drive and with and without handles for guiding the applicator coating assembly across the substrate.

[0044] As mentioned earlier, the innovative coating assembly provides a means of coating large area substrates such as solar panels with uniform optical coatings, for example, performance enhancement coatings. The innovation advantageously provides substantially uniform coatings by maintaining constant vertical forces on the assembly and by constant travel speed. The innovative coating assembly is equipped with a motorized drive coupled to the traction device (wheels) allowing a constant travel speed when deployed. In Fig. 6, such an arrangement is shown, where motor 601 affixed to mobile support structure 602 may be coupled to axel 603 through sprocket 604 and chain 605. Preferably, motor 601 is commandable via a programmable motor controller circuit. The programmable motor controller circuit may further be adapted to be programmed and commanded wirelessly.

[0045] The traction device may comprise rollers, as for example, wheel 606 depicted in Fig 6. Alternatively, the traction may be accomplished by use of tank tread (caterpillar track) 607. Other means, such as elongated roller extending the length of the mobile support structure (disposed in front and rear of the mobile support structure, for example) may be employed.

1. Non-continuous charging

[0046] Liquid coating solution may be transferred to the innovative assembly to fill the coating heads by simple dipping of the coating heads in a vat of solution. However, this method results in very random quantities of solution transferred to the coating head reservoirs. As one method of charging the innovative coating assembly may done in a non-continuous manner, the invention provides for the use of re-filling stations that is adapted to receive the coating assembly and charge the coating heads in a repeatable manner, dosing the heads with a

reproducible quantity of coating solution. An example of such a re-filling station is shown in Fig. 7a. Service, or re-filling station 700 comprises a support frame 701 dosing tray or platform 702. In addition, a rotatable receiving stage 703 may be also pivotally affixed to the support superstructure above the dosing tray 702 for initially receiving, holding and then pivoting the coating assembly onto the dosing tray 702. In one embodiment, dosing tray 702 may be a mesh, or perforated with a plurality of holes. Further, on the underside 704 of tray 702 (Fig. 7b) may be in contact with tubing 705, having perforations through its wall. Tubing 705, depicted as a tube or pipe disposed along underside 704 of dosing tray 702, where the perforations are oriented upwards, that is, toward the underside 704. Tubing 705 functions to deliver coating solution to dosing tray 702 by allowing coating solution to leak out of the upward-facing perforations of tubing 705, and to flow onto the upper surface of dosing tray 702 via the plurality of holes. This action may spread the coating solution substantially over the surface of dosing tray 702.

[0047] In the preferred embodiment, receiving structure 703 is adapted to receive the mobile support structure of the innovative coating assembly by means of brackets 706 that extend from a rotating shaft 707. In a ready position, receiving structure 703 may be rotated such that brackets 706 are rotated upwards, forming an angle with respect to the vertical, and then locked or blocked in this position. Brackets 706 are adapted to receive the mobile support structure of the innovative coating assembly by placement of the structure onto brackets 706, accomplished either manually or by a lifting mechanism. Receiving structure 703 may be then rendered free to rotate with its load, whereby it may be pivoted downward to rest the coating heads of the innovative coating assembly on top of dosing tray 702.

[0048] When placed thusly, the coating heads may be dosed by pumping coating solution to the dosing tray 702 via tubing 705. Dosing tray 702 is adapted to spread the coating solution over its upper surface, and to charge the coating head or heads by capillarity. By this arrangement, deformable porous cores of the coating heads are deformed to a predictable and repeatable geometry every time the coating assembly is placed on the dosing tray, due substantially to the weight of the assembly, as the coating heads may support the entire weight of the structure. In this way, a consistent volume of coating solution is taken up by the coating heads each time, allowing for the reproducible amount of liquid to be coated each time the coating assembly is charged.

[0049] An alternative means of charging the coating heads is by semi-continuous methods. . In alternative embodiments, coating solution may be automatically fed to the one or more applicator heads of the innovative coating assembly by a pumping means. As an example, a small syringe pump may be used to deliver a controlled quantity of coating solution to the one or more applicator heads on an on-demand basis, by manual command of the syringe pump by the operator. This may be done when the operator perceives that the porous layer in each of the one or more applicator heads is low on fluid. By way of example, this may be accomplished by visual or audible signals. Alternatively, a pump may be configured for automatic delivery if the application rate is constant, whereby the pump may be programmed to deliver a constant rate of coating solution to the one or more applicator heads during the coating excursion. In other embodiments, sensors, such as liquid conductivity sensors, measuring electrical conductance at one or more points in the one or more porous layers may be used to trigger the pump controller to provide a programmed amount of solution to the one or more applicator

heads. A meter may be used in conjunction with the sensors to measure the amount of fluid or trigger the pump.

[0050] An exemplary embodiment is shown in Fig. 8. A segment of tubing 801 may connect a pump to the base portion 802 of the support structure of the inventive applicator head assembly. Base portion 802 may comprise a plenum or a manifold 803 to distribute the coating solution to a porous deformable core 804 which may be in an overlying configuration relative to the base portion 802 of the support structure. Fig. 8 shows a porous compliant core 804 in intimate contact with the base portion 802 of the support structure, therefore coating solution may be transferred to the core 804 with no leaks. Fluid delivery of the pump may be determined by the rate of transfer of the coating solution to the substrate. As a further alternative, coating solution may be manually injected into the plenum or manifold of the base portion by the operator, whereby the operator replaces an electromechanical pump and manually controls a syringe containing coating solution, which is in fluid communication with the applicator head. In another instance, the pump may be replaced by a dosing pump for uninterrupted automated delivery of coating solution to the applicator head assembly.

Method of Use

[0051] For the purposes of illustration, a method of use of the innovation will be described. As noted above, the innovation solves the problem of field-retrofitting installed photovoltaic panels and glass window panels with high-quality performance enhancement coatings, for example, energy transmission enhancement coatings, and more specifically from this category, thin-film antireflective coatings. The example covers coating a photovoltaic panel that is part of

an outdoor array. The first step is to place the coating assembly on the surface of a photovoltaic panel. This step may comprise manually lifting the coating assembly onto the panel using an elongated handle, engaging the rollers on the top surface of the panel [or outer frame rails of the panel]. The operator may wish to use the motor drive to position the applicator head more precisely. In this case, the applicator heads may be retracted, so as not to contact the surface of the solar panel. .

[0052] To coat the panel, , the applicator heads may be lowered to contact the surface of the panel, and the motor drive may be engaged to set the coating assembly in motion and on a trajectory to travel from the starting end of the panel to the opposite end. The motor speed may be preset to deposit a coating of a given thickness, where the speed may be known by previously developed empirical correlations between excursion speed and coating thickness. The length of the trajectory may be known in advance as well, and may be pre-programmed into the motor control circuit, or programmed in the field by the operator before starting the coating process (wirelessly as well). The trajectory of the coating assembly may then be predetermined to travel the length of the panel in one direction with the traction devices engaged. Upon reaching the opposite end, the coating head may then be disengaged from the panel surface. Alternatively, the coating head may then reverse trajectory and travel back to the starting end and allowed to remain engaged with the panel surface and continue to deposit coating solution on the reverse trajectory.

[0053] While the forgoing embodiments disclosed above describe the invention in its various manifestations, the foregoing embodiments are to be understood by persons skilled in the art as exemplary in nature, and are in no way intended to be construed as the only embodiments

possible for the invention. Those skilled in the art will also understand that other embodiments and examples of deployment of the inventive AR coatings are conceivable and possible without departing from the scope and spirit of the invention.

CLAIMS

1. A coating assembly for applying a performance enhancement coating on a substrate substantially transparent or absorbent to visible, ultraviolet, or infrared light, comprising:
 - i) a mobile support structure having a top side and a bottom side, the mobile support structure having a traction means; and
 - ii) one or more performance enhancement coating applicator heads disposed on the mobile support structure, said one or more coating applicator heads comprising a mechanism to deposit said performance enhancement coating on said substrate.
2. The coating assembly of claim 1, wherein the mechanism to deposit said performance enhancement coating comprises a porous layer to transfer said performance enhancement coating onto said substrate.
3. The coating assembly of claim 2, wherein the porous layer is in intimate contact with a deformable core.
4. The coating assembly of claim 2, wherein the porous layer is a capillary interface layer.
5. The coating assembly of claim 1, wherein the mechanism to deposit said performance enhancement coating comprises one or more spray nozzles to transfer said performance enhancement coating onto said substrate.
6. The coating assembly of claim 1, wherein the mechanism to deposit said performance enhancement coating comprises one or more slots to transfer said performance enhancement coating onto said substrate.

7. The coating assembly of claim 1, wherein the mechanism to deposit said performance enhancement coating comprises one or more rollers to transfer said performance enhancement coating onto said substrate.
8. The coating assembly of claim 1, wherein the mechanism to deposit said performance enhancement coating comprises one or more brushes to transfer said performance enhancement coating onto said substrate.
9. The coating assembly of claim 1, wherein the mechanism to deposit said performance enhancement coating is selected from the group consisting of one or more doctor blades, one or more wipers and one or more draw bars.
10. The coating assembly of claim 1, wherein said substrate is the top surface of a solar panel.
11. The coating assembly of claim 9, wherein said solar panel is part of an existing outdoor solar panel array.
12. The coating assembly of claim 11, wherein the capillary interface layer is a porous foam.
13. The coating assembly of claim 11, wherein the capillary interface layer is a felt fabric.
14. The coating assembly of claim 11, wherein the capillary interface layer is a microporous textile.
15. The coating assembly of claim 1, wherein the coating applicator heads are movably affixed to the mobile support structure.
16. The coating assembly of claim 1, wherein the coating applicator heads are adapted to be raised and lowered relative to the mobile support structure.

17. The coating assembly of claim 1, further comprising a motor drive coupled to the traction means.

18. The coating assembly of claim 1, wherein said performance enhancement coating is substantially uniform across substrate.

19. The coating assembly of claim 1, wherein the traction means comprises one or more rollers.

20. The coating assembly of claim 1, wherein the traction means comprises caterpillar tracks.

21. The coating assembly of claim 1, further comprising a means to maintain a substantially constant vertical force on the one or more coating applicators.

22. The coating assembly of claim 21, wherein the means to maintain a substantially constant vertical force on the one or more coating applicators comprises a hinged mechanism affixed to one side of the mobile support structure and affixed to the one or more coating applicators.

23. The coating assembly of claim 21, wherein the means to maintain a substantially constant vertical force on the one or more coating applicators comprises a spring mechanism affixed to the mobile support structure and affixed to the one or more coating applicators.

24. The coating assembly of claim 1, wherein the coating applicators are affixed to the mobile support structure by struts.

25. The coating assembly of claim 24, wherein the struts are leaf springs.

26. The coating assembly of claim 24, wherein the struts comprise a spring-loaded hinge.

27. The coating assembly of claim 24, wherein the struts comprise a dashpot mechanism.

28. The coating assembly of claim 1, wherein the one or more applicator heads are adapted to pivot about an axis of the mobile support structure such that the one or more applicator heads are raised and lowered relative to the mobile support structure.

29. The coating assembly of claim 1, further comprising a means for flowing liquid coating solution to the applicator heads.

30. The coating assembly of claim 29, wherein the means for flowing liquid to the applicator heads is a pump in fluidic communication with the applicator heads through a plurality of tubes which supplies fluid from a fluid reservoir.

31. The coating assembly of claim 29, wherein the means for flowing liquid to the applicator heads is a service station.

32. The coating assembly of claim 31, wherein the service station comprises:

i) a superstructure;

ii) a dosing platform, having a top side and an underside, and a plurality of perforations disposed therethrough, the dosing platform adapted to disperse a liquid coating solution along the top side, the top side of said dosing platform adapted to receive a coating assembly;

iii) at least one liquid conduit disposed on the underside of the dosing platform, the at least one conduit having one or more apertures disposed along its wall whereby the interior of the conduit is in communication with the exterior, wherein the at least one conduit is adapted to deliver a liquid coating solution to the dosing platform; and

iv) a movable press structure adapted to apply a repeatable vertical force to the coating assembly wherein the coating assembly is pressed against the top side of the dosing platform.

33. The coating assembly of claim 1, further comprising an elongated handle pivotally affixed to said mobile support structure.

34. The coating assembly of claim 1, wherein said performance enhancement coating is an energy transmission improvement coating.

35. The coating assembly of claim 34, wherein said energy is light energy.

36. The coating assembly of claim 34, wherein said energy transmission improvement coating is an anti-reflective coating.

37. The coating assembly of claim 34, wherein said energy transmission improvement coating is a wave-length shifting coating.

38. The coating assembly of claim 34, wherein said energy transmission improvement coating is a filter coating.

39. The coating assembly of claim 38, wherein said filter coating is a Low-E coating that minimizes the transmission of light selected from the group consisting of infrared and ultraviolet light.

40. A method for coating a substrate with a performance enhancement coating, comprising:

i) providing a substrate in an ambient;

- ii) providing a coating apparatus comprising: a mobile support structure, the mobile support structure having a traction means, and one or more performance enhancement coating applicator heads affixed to the mobile support structure, said one or more coating applicator heads comprising a mechanism to deposit said performance enhancement coating on said substrate;
- iii) positioning said coating apparatus at a first location on the substrate;
- iv) supplying the one or more applicator heads with liquid coating solution;
- v) engaging the one or more coating applicator heads of said coating apparatus in close proximity or intimate contact with the substrate whereby the coating solution is transferred to the substrate from the applicator heads;
- v) translating the coating apparatus along the surface of the substrate in a trajectory leading from the first location to a second location on the substrate, and simultaneously depositing the performance enhancement coating onto the substrate surface wherein the applicator heads are adapted to cover at least a portion of the substrate surface.

41. The method of claim 40, wherein the step of translating the coating apparatus along the surface of the substrate comprises commanding a motorized drive to translate the coating apparatus between the first and second locations.

42. The method of claim 40, wherein the step of translating the coating apparatus along the surface of the substrate further comprises commanding the speed of translation of the coating apparatus along the surface of the substrate between the first and second locations.

43. The method of claim 40, wherein the step of engaging the one or more applicator heads with the substrate comprises lowering the one or more applicator heads from a raised position until one or more applicator heads are in close proximity or in intimate contact with the substrate.
44. The method of claim 40, wherein the step of supplying liquid performance enhancement coating solution to the applicator heads comprises a pumping means adapted to pump liquid coating solution from a reservoir to the applicator heads.
45. The method of claim 40, wherein the substrate is a photovoltaic panel.
46. The method of claim 40, where the substrate is a photovoltaic panel array.
47. The method of claim 40, wherein the substrate is a solar thermal panel.
48. The method of claim 40, wherein the substrate is a glass window pane.
49. The method of claim 40, wherein the ambient is out of doors.
50. The method of claim 40, wherein the ambient is indoors.
51. The method of claim 40, further comprising the step curing the coating by sunlight energy.
52. The method of claim 40, further comprising the step of curing the coating thermally at ambient temperatures.
53. The method of claim 40, wherein said performance enhancement coating is an anti-reflective coating.
54. The method of claim 40, wherein said performance enhancement coating is a wave-length shifting coating.
55. The method of claim 40, wherein said performance enhancement coating is a filter coating.

56. The method of claim 40, wherein said performance enhancement coating is a Low-E coating that minimizes the transmission of light selected from the group consisting of infrared and ultraviolet light.

