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(71) Applicant: **Strip Tinning Limited**
West Midlands B45 0JA (GB)

(72) Inventors:
- **O'Connor, Stephen**
Solihull, B91 1LR (GB)
- **Holmes, Christopher**
Birmingham, B45 0JA (GB)
- **Barton, Richard**
Rugeley, WS15 1QQ (GB)

(74) Representative: **HGF Limited**
Belgrave Hall
Belgrave Street
Leeds LS2 8DD (GB)

(54) COATINGS

(57) Apparatus 1' for forming a busbar having a width of less than 25mm and a thickness of less than 120microns, the apparatus 1' comprising means to continuously supply a length of substrate having a pair of major surfaces, a width of less than 25mm and a thickness of less than 120microns, means 3' to clean the substrate, a hot dip overlayer application means 5' comprising a bath 50' for overlayer material OL to apply, in use, an overlayer material OL to all of the surfaces of the substrate S, overlayer control means (51', 60') to control the amount of overlayer material OL adhered to the substrate S, the overlayer control means (51', 60') comprising wiping means 51' to physically contact both major surfaces of the substrate S, wherein the wiping means 51' are located, in use, beneath the surface level of overlayer material OL retained in the bath 50'.

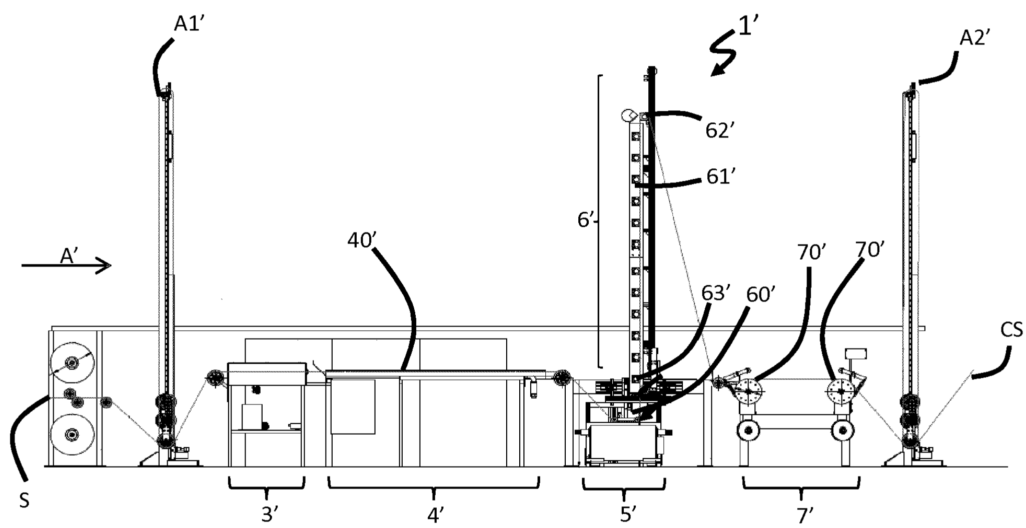

Figure 2

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Description

[0001] This invention relates to coatings and specifically, although not exclusively, to coatings provided on electrical conductors and to apparatus to coat a substrate.

[0002] A busbar is typically used to provide electrical contact between a source of electrical energy and plural circuits in an electrical apparatus or system. Hence, they are formed of electrically conductive material and are typically provided as strips or tubes. It is usual to use a strip or tube shape because of those shape's inherent heat dissipation efficiency. Busbars may be electrically isolated by use of covering insulators or by use of earthed enclosures. In many cases a busbar is used for electrical conduction and not for performing a structural function.

[0003] It is known to provide as a busbar a copper strip which has been coated with tin. Such busbars are thin so that they can be provided between panes of glass to facilitate electrical connection to one or more resistively heatable wires or filaments (the heating element) in a heated windscreen. Because the busbar is thin it does not cause or generate air gaps between the facing panes of glass, which could lead to failure of the heating element. The tin coating protects the underlying copper from oxidising or otherwise reacting, for example with or in the presence of ingressing water. An example of a busbar comprising a copper conductive element coated, in part, with tin is described in GB2402554. In this document, a copper substrate is coated with tin by electroplating and the coated substrate is split lengthwise to form plural busbar lengths. As will be appreciated, although the method set out in the document enables plural lengths of busbar to be produced in parallel, because the copper substrate is split lengthwise after coating the tin does not cover the edges of the copper, *i.e.* the longitudinal edges of the copper are exposed to the atmosphere.

[0004] Whilst such busbars are capable of providing the necessary electrical connectivity there is a desire to provide a busbar which is more robust, has less defects and/or which can be manufactured at at least the same rate and preferably at a higher rate than in the prior art.

[0005] It is an object of the current invention to satisfy at least one of the issues aforementioned.

[0006] Accordingly, in a first aspect of the invention there is provided apparatus for forming a busbar having a width of less than 25mm and a thickness of less than 120microns, the apparatus comprising means to continuously supply a length of substrate having a pair of major surfaces, a width of less than 25mm and a thickness of less than 120microns, means to clean the substrate, a hot dip overlayer application means comprising a bath for overlayer material to apply, in use, an overlayer material to all of the surfaces of the substrate, overlayer control means to control the amount of overlayer material adhered to the subsrate, the overlayer control means comprising wiping means to physically contact both major surfaces of the substrate, wherein the wiping means are located, in use, beneath the surface level of overlayer material retained in the bath.

[0007] A second aspect of the invention comprises a method of forming a busbar having a width of less than 25mm and a thickness of less than 120microns, the method comprising continuously supplying a length of substrate having a pair of major surfaces, a width of less than 25mm and a thickness of less than 120microns to a cleaning station, cleaning the substrate, drying the substrate, applying an overlayer material to all surfaces of the substrate in a hot dip bath of molten overlayer material, controlling the amount of overlayer material adhered to the substrate by physically contacting the overlayer material applied to both major surfaces of the substrate, where said physical contact occurs beneath the surface level of overlayer material retained in the hot dip bath.

[0008] Preferably the length of substrate may be continuously supplied at a rate of over 2 m/s, for example over 2.5 m/s, e.g. over 3, 3.5, 4, 4.5, 5 m/s.

[0009] The overlayer material will usually protect the substrate, for example an electrically conductive material, from environmental degradation (e.g. oxidation and/or other chemical or physical damage). Typically the overlayer material will be dimensionally invariant. The overlayer material may be applied to a thickness of from 0.5 to 20 microns, say 0.6 to 15 microns, e.g. 0.8 to 15 microns, for example 0.5 to 5 microns and, in some embodiments, 1 to 4 microns.

[0010] The means to clean the substrate may comprise an acid bath. The means to clean the substrate may comprise one or more wash baths. There may be provided drying means between the cleaning means and the overlayer application means.

[0011] The bath containing overlayer material preferably comprises liquid (e.g. molten) overlayer material.

[0012] The apparatus may further comprise an electroplating application means.

[0013] The means to control the amount of overlayer material applied to the substrate preferably comprises at least one air knife, preferably a pair of air knives, preferably operable to impinge a stream of gas upon a facing major surface of the substrate. Preferably, each of the pair of air knives is operable to impinge or bear on one of the major surfaces of the substrate. The or each air knife may have an outlet width which may be larger than the width of the substrate on which the overlayer material is to be controlled. The outlet width of the or each air knife may be at least twice, for example from two to five times, the width of the substrate on which the overlayer material is to be controlled.

[0014] The wiping means may be located from 1 to 40 cm below the surface level of overlayer material in the bath, say from 1 to 30 cm, preferably from 1 to 20 cm.

[0015] Additionally or alternatively, the wiping means may comprise one or more wiping surfaces over which the coated substrate runs. Advantageously, the wiping means comprises one or more static wiping surfaces, e.g. one or more non-rotatable bodies or pins over which the coated substrate runs in contact therewith. We believe that such contact ensures an intimate engagement of the overlayer material with the cleaned substrate, thereby leading to a robust coating with a low incidence of microscopic holes and/or other defects. Preferably the wiping means is heated. If so, the wiping means may be heated to or sometimes above the temperature of the overlayer material retained in the bath, for example above the melting temperature of the overlayer material. We prefer to use a smooth, preferably metal, surface to contact the substrate and as part of the wiping means.

[0016] There is further provided, in another aspect of the invention, a busbar for installation on or in a structure, the busbar comprising a substrate having a width of less than 25mm and a thickness of less than 120microns, and an overlayer material secured over all of the surfaces of the substrate. The overlayer material may be equal to or less than 20 microns *(i.e.* $\leq 2 \times 10^{-5}$m) thick, for example 15, 14, 13, 12, 11, 10, 9, 8, 7, 6, 5, 4, 3, 2, 1 microns thick. Preferably the protective coating is from 0.25 to 7, say 0.5 to 5 microns thick, for example from 1 to 4 microns thick.

[0017] The substrate may be dimensionally invariant.

[0018] In this specification, the term dimensionally invariant means a material which has a constant cross section in a longitudinal direction, and constant in this context means that the cross sectional area varies by less than 15%, preferably equal to or less than 10%, preferably equal or less than 9, 8, 7, 6 or 5% along a 1 mm longitudinal portion, for example along a 2, 3, 4, 5, 6, 7, 8, 9, 10mm longitudinal portion. In one embodiment, the bus bar is 5, 10 or 15cm long and the cross sectional area of both the substrate and/or the overlayer material varies by 5% or less along the entire length.

[0019] The substrate is preferably elongate. The substrate is preferably in strip form, i.e. it has a length and width dimension significantly larger than its thickness dimension. For example, the substrate's width dimension can be over 50, say over 60, 70, 80, 90, 100 times its thickness dimension.

[0020] The substrate may be in strip form having a width of from 3 to 15 mm, say from 4 to 14 mm, for example from 5 to 10 mm. In one embodiment the strip may be about 6 mm wide, in another embodiment the strip may be 8 mm wide. The variation of width is preferably tightly controlled, for example less than 10%, say less 9, 8, 7, 6, 5, 4, 3, 2% in a longitudinal direction. The substrate may have a thickness of from 10 to 120 or 100 microns, say from 15 or 30 to 100 or 90 microns. In one embodiment the substrate is from 20 to 80 microns thick, say from 30 to 70 microns thick, for example 50 microns thick. The variation of thickness is preferably tightly controlled, say less than 15%, preferably less than 14, 13, 12, 11, 10, 9, 8, 7 or 6%, e.g. from 1-5%.

[0021] The substrate preferably comprises an electrically conductive material which is preferably formed from copper. The electrically conductive material may comprise, for example be formed of, for example, a substrate, say a metal substrate (e.g. copper) coated with a protective coating, for example tin or tin alloy, or a polymeric coating. The protective coating is dimensionally invariant and coats all of the major surfaces and the longitudinal edges of the strip. The protective coating is preferably from 1 to 4 microns thick across the entirety of the strip.

[0022] In a further aspect of the invention there is provided a busbar formed by any previously mentioned apparatus or method.

[0023] In order that the invention may be more fully understood it will now be described, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 is a schematic diagram of apparatus according to the invention;

Figure 2 is a schematic diagram of further apparatus according to the invention;

Figure 3 is a schematic diagram of a component of the apparatus of Figure 2;

Figure 4 is a schematic diagram of a component of the apparatus of Figure 2; and

Figure 5 is a schematic diagram of a further component of a second embodiment of apparatus of the invention; and

Figure 5A is an exploded view of a component of Figure 5.

[0024] Referring first to Figure 1, there is shown a schematic representation of apparatus 1 according to the invention for the continuous manufacture of coated busbar.

[0025] Substrate material S is supplied from a reel 2 through the following zones, in sequence a cleaning zone 3, drying zone 4, overlayer application zone 5, overlayer control zone 6, an optional tensioning zone 7 from where coated substrate CS is located on a reel 8. In order to ensure that subsequent or further reels of substrate S can be supplied without slowing or stopping production there may be provided an optional first accumulator A1. To ensure that reels of coated substrate CS can be removed continuously from the apparatus 1 without slowing or stopping production there may be provided an optional second accumulator A2.

[0026] The cleaning zone 3 comprises means to ensure that the substrate S is clean, that is that the surface is free from surface contaminants and/or other detritus to enable to the surface of the substrate S to accept the overlayer. Typically the cleaning is carried out in an inorganic fluid, preferably liquid, system. Although an organic fluid system may be used we prefer an inorganic system.

[0027] The drying zone 4 ensures that any fluids or liquids on the surface of the substrate S are evaporated before the substrate reaches the overlayer application zone. To complete this we prefer a heat tunnel, for example a tunnel through which the substrate S is conveyed and which has hot air forced therethrough and/or therealong (preferably in a direction opposite to the substrate conveying direction A).

[0028] The substrate S is then conveyed to the overlayer application zone 5 which, we prefer, comprises a bath of overlayer material through which the substrate S is conveyed. As the coated substrate CS emerges from the overlayer application zone 5 all of the exposed surfaces of the substrate S (including the two major faces and the longitudinal edges) have overlayer material adhered thereto. The coated substrate CS is then conveyed through the overlayer control zone 6 which enables the overlayer to be cured or otherwise secured permanently to the surface of the coated substrates CS.

[0029] The coated substrate CS may then be conveyed through the optional tensioning zone 7 which exerts some tension on the coated substrate CS to ensure that the coated substrates CS is flat and to reduce its (or any) tendency to curl or otherwise bend transversely and to reduce or remove any tendency to curl or otherwise bend longitudinally.

[0030] The coated substrate CS may then be deposited on a reel 8 for subsequent use. Typically, lengths of the coated substrate CS will be cut to length. Additionally or alternatively, the reel 8 of coated substrate CS may be taken for downstream treatment, for example for the application of a low melting point solder material along the length thereof. As will be appreciated, the application of another substance may occur in-line, *i.e.* between overlayer control zone 6 and the reel 8. For example, before or after the optional tensioning zone 7 or before or after the optional accumulator A2.

[0031] Reference is now made to Figure 2 which shows a first detailed embodiment of the general apparatus 1 set out above. As such, each of the zones will be indicated, where appropriate, using the same numeral but with a prime (') suffix.

[0032] Thus, in Figure 2 there is shown apparatus 1' for the manufacture of overlayer coated busbar.

[0033] The apparatus 1' comprises a cleaning zone 3', drying zone 4', overlayer application zone 5', overlayer control zone 6', an optional tensioning zone 7' from where coated substrate CS' is locatable on a reel (not shown). In order to ensure that reels of substrate S can be supplied continuously without slowing or stopping production there may be provided an optional first accumulator A1'. To ensure that reels of coated substrate CS can be removed continuously from the line without slowing or stopping production there may be provided an optional second accumulator A2'.

[0034] The cleaning zone 3' comprises a bath containing hydrochloric acid through which the substrate S' is passed. Typically the hydrochloric acid will have a concentration of 30% (wt/wt%). The bath is typically from 900 to 1500 mm long to give the substrate S sufficient residence time within the bath to effect the cleaning operation.

[0035] The drying zone 4' comprises a tunnel 40' through which the substrate S passes. The tunnel 40' may be from 1 to 3 m long (typically from 2 to 3m long) and is preferably supplied with hot air heated to a temperature of from 90 to 250°C, preferably from 95 to 200°C, to evaporate any liquid on the substrate S.

[0036] The dried substrate S is passed over an intervening roller 41' and into the overlayer application zone 5', which is best seen in Figure 3. The application zone 5' comprises a bath or tank 50' holding a volume of liquid overlayer material OL. Preferably the overlayer material OL is tin and so the tank 50' (or at least the tin held therein) needs to be heated to beyond 232°C. If different overlayer materials OL are required they may be provided within the tank 50' in fluid form, for example by melting or dissolving in a suitable solvent.

[0037] The tank 50', contains rollers (R1, R2...Rn) which are typically free to rotate and over and under which the substrate S runs beneath the surface level of the overlayer material OL, thereby ensuring that all of the surfaces (minor and major) of the substrate S are coated in overlayer material OL. As the substrate S with a coating is drawn in a substantially vertical direction towards the surface of the overlayer material OL it passes over and/or between a pair of pins 51', which pair of pins 51' respectively bear against the opposed two major faces of the substrate S, to remove at least some of the overlayer material OL from the substrate S. Because the pins 51' are below the surface of the overlayer material OL the pins 51' are at or about the same temperature as the overlayer material OL. The pins 1' typically are not mounted for rotation and are rigidly supported. In this way, the pins 51' wipe the surface of the substrate S to control the amount of overlayer material OL which is retained thereon. We have surprisingly found that by causing both major surfaces of the substrate S to come into intimate contact with respective one of the pins 51' the surface of the coated substrate CS is improved. In fact, by a respective one of the pins 51' exerting a positive pressure on the substrate S as the major surface of the substrate S passes thereover and moves relative to the facing surface of the respective pin 51' we have found that the incidence of holes and/or other surface irregularities can be greatly reduced. Holes can be a significant issue when seeking micron-thickness overlayer coatings and we have surprisingly found that the pins 51', and preferably heated pins 51', eradicate (or at least substantially eradicate) the incidence of holes. The pins 51' may be formed of, or may comprise, metal to facilitate heating thereof.

[0038] After emerging from the bath 5' of overlayer material OL, the coated substrate CS then passes to the overlayer control zone 6' which comprises a pair of air knives 60' and a control tower 61'. The air knives 60' are upstream of the control tower 61' and preferably face each other so as to cause fluid (gas) to impinge on either side *(i.e.* against either major surface) of the coated substrate CS.

[0039] The control tower 61' preferably comprises one or more upper rolls 62' and optionally one or more lower rolls 63' over which the coated substrate CS runs. The coated substrate CS may make a pass over the upper roll 62', or a pass or repeated passes over the upper roll(s) 62' and/or lower roll(s) 3', before exiting to the optional tensioning zone 7'.

[0040] Referring to Figure 4, there is shown one of the air knives 60' in exploded form. The knife 60' comprises a first side portion 601, a body portion 602, a second side portion 602 and an adjuster 604. The body portion 602 has a first side 602a facing the first side portion 601 and a second side 602b facing the second side portion 603 and a flow bore 605 running transversely across the body portion 602 from the first side 602a to the second side 602b and having a principal axis P extending therealong. Outboard of, and parallel to, the flow bore 605 are a series of through holes 606.

[0041] The front 602f of the body portion 602 slopes downwardly and away from the top 602t and terminates in a flat face 602ff which is orthogonal to the top 602t.

[0042] Extending through the body portion 602 from, and along the length of, the flow bore 605 is a curved and tapered outlet 607 which emerges at a distal edge of the flat face 602ff. The outlet 607 tapers from the bore 605 toward the flat face 602ff. The outlet 607 separates the body portion 602 into a minor portion 6021 and a major portion 6022, with the minor portion 6021 above the outlet 607 and a major portion 6022 below the outlet 607 (as shown).

[0043] The front 602f carries a locating spigot 608.

[0044] Each of the first and second side portions 601, 603 has, in elevation, a periphery which is identical to the body portion 602 and the side portions 601, 603 are secured to the body portion 602 by securing means SM which extend from one of the side portions (e.g. 603) through the through holes 606 to the other side portion (e.g. 601). The second side portion 603 closes the flow bore 605 and provides a second terminal face for the outlet 607. The first side portion 601 has an aperture 601a which is aligned with, and provides fluid communication to, the flow bore 605 but otherwise the first side portion 601 provides a first terminal face for the outlet 607.

[0045] Each of the first and second side portions 601, 603 has a threaded aperture TA on its front face for the receipt of a threaded screw TS extending through the adjuster 604 to secure the adjuster 604 to the first and second side portions 601, 603 and hence to the body portion 602. The adjuster 604 also comprises a mating portion 604m to engage the locating spigot 608 on the front face 602f of the body portion 602 to maintain and ensure accurate registration. The adjuster 604 also has a pair of adjustment screws 604a which extend through the adjuster 604 to bear on the front face 602f of the body portion 602.

[0046] In use, with the side portions 601, 603 secured to the body portion 602 via securing means SM and the adjuster 604 located on the front 602f of the body portion 602 via registration of the mating portion 604m with the locating spigot 608, and secured to the side portions 601, 603 by the threaded screws TS engaging the threaded apertures TA, the surface area of the outlet 607 at its terminus can be adjusted by screwing in or out the adjustment screws 604a of the adjuster 604. Screwing the adjustment screws 604a inwardly will cause the minor portion 6021 of the body 602 toward the front 602f to pivot inwardly to reduce the size of the outlet 607 and *vice versa.* In this way the size (surface area) of the terminus of the outlet 607 can be controlled to high tolerances.

[0047] Thus, with a fluid source in communication with the aperture 601a of the first side portion 601, fluid can flow into the flow bore 605 and out through the outlet 607, which may be adjusted via the adjuster 604 to control the flow of fluid therefrom.

[0048] The overlayer control zone 6' comprises a pair of air knives 60' in facing relations, fluid exiting each from respective outlets 607 bearing on coated substrate CS to remove unwanted or excess overlayer material OL' from the surface of the substrate S and to reduce the temperature of the remaining overlayer material OL. In this way the thickness of the overlayer material coating on the coated substrate CS can be finely and accurately controlled. We prefer to use air or nitrogen as the fluid used in the air knives 60'. The fluid may be heated, cooled or at ambient temperature. Other fluids may also be used. The stream of fluid impinging from the air knives may engage the substrate orthogonally or at an angle thereto. For example, the stream of fluid may engage the substrate at an angle of 45° or from 45 to 90°, or from 0 to 45°, to the direction of flow of the coated substrate CS.

[0049] Our analysis suggests that the pins 51' help to provide a homogenous layer of overlayer material OL on the substrate S and reduce the incidence of surface irregularities. Our further analysis suggests that the air knives 60' help to ensure a thin and accurate thickness of overlayer material OL remains on the coated substrate CS.

[0050] Our analysis indicates that a 10 to 100 micron layer (e.g. 50micron) of overlayer material OL can be provided on the substrate upstream of the air knives 60' and that the action of the pins 51' causes an intimate and homogeneous metallic layer (usually without imperfections or irregularities) to be formed on the substrate S. The air knives 60' can further control the amount of overlayer material OL which remains on the coated substrate CS (in the manner described above) by action of the impinging fluid issuing from the outlet 607, and can accurately and repeatedly (even at the highest throughput rates required) provide a homogeneous coating in the range of 1 to 20 microns thick, and preferably in the range of 1 to 4 microns thick

[0051] Upon exiting the overlayer control zone 6' the coated substrate CS may pass to a tensioning zone 7' which at least partially removes curl (e.g. transverse and/or longitudinal curl or tendency to curl) in the coated substrate CS. The tensioning zone 7' briefly comprises a pair of rollers 70' which rotate slightly slower than the linear flow rate of the coated substrate CS to impart some tension to the length of coated substrate CS and thereby to reduce curl (or at least the tendency to curl).

[0052] The coated substrate CS then passes to a reel for storage or to a subsequent processing line, e.g. for further processing or cutting to length.

[0053] There may be further provided a second accumulator A2' which allows a significant length of coated substrate CS to accumulate thereon prior to it being conveyed further in the apparatus 1'.

[0054] In each case the accumulator (A1, A2, A1', A2') may comprise an upper and lower roller set between which the substance accumulated thereon may make repeated passes to provide an accumulated length. The upper roller set is movable with respect to the lower roller set to alter the accumulated length. For example if the upper roller set is a distance D from the lower set and x passes between the upper and lower roller set is made than the accumulated length will be in excess of *x.D* (taking into account the diameter of each roller set). If the upper roller set is moved further from the lower roller set (or *vice versa)* to, say, 2D, the accumulated length will be in excess of *2.x.D.* So, if it is required to change a reel for supply of substrate S or removal of coated substrate CS, the respective accumulator can be extended to allow sufficient time to change the appropriate reel without altering production speed or indeed stopping production altogether.

[0055] With the above apparatus 1' we are able to produce significant quantities of busbar material to extremely tight tolerances. Indeed, using the above-described apparatus 1' we have been able to produce coated substrate CS at rates of 2 to 4 m/s (57.6 to 115.2km per 8 hour shift). We prefer to use copper as a substrate material S with a width of from 2 to 17mm and a thickness of less than 100μm, preferably less than 50μm. It has heretofore been difficult to process substrate material S, for example copper strip, at such thicknesses *(i.e.* less than 120, say less than 100 microns and preferably at 10 to 50 micron thicknesses) at the rate we are able to achieve (e.g. 2 to 4 linear m/s) and to coat the substrate S with a homogenous, and very thin, layer of overlayer material OL (and with a very a very low incidence of overlayer holes). Using the apparatus 1' set out above, we are able to consistently coat a substrate material (and indeed all exposed surfaces of a substrate material S) with a layer of overlayer material OL of a thickness from 1 to 4 micron. Using the apparatus 1' described above, we do not see the 'dog-bone' effect mentioned in the prior art and, as a consequence, there is no need for the wasteful shearing operation. Moreover, because all of the surfaces of the coated substrate CS are coated in overlayer material OL (and to a tight tolerance) the so-formed busbar is more environmentally robust and performance characteristics are more homogenous.

[0056] We have found that where the terminus of each outlet 607 of the facing knives 60' is larger than the width of the substrate S, rather than reducing the amount of overlayer material OL adhered to and along the longitudinal edges of the substrate, the amount is controlled to within the tolerance across the major surface of the substrate S and along the edges of the substrate S. We have particularly found that for a substrate width of up to 12 mm, an outlet 607 width of up to 26 mm for each knife is ideal. In our analysis of various substrate widths, we have found it is preferable that the width dimension of the outlet 607 of the air knife 60' is at least twice the width dimension of the substrate S, but preferably no more than 5 times the width of the substrate.

[0057] We have further discovered that the rate of production can be increased and/or the homogeneity of the coated substrate CS can be even further improved by using a second embodiment of cleaning 3" and drying 4" zone, as shown in Figure 5 and Figure 5A.

[0058] The cleaning zone 3" is a modular system which can be altered to specific need, starting material, cleanliness of substrate S and so on. As shown, the cleaning zone 3" comprises a first acid bath 30", a first wash bath 31" and a second wash bath 32". In sequence, substrate (not shown) is conveyed through the first acid bath 30" and then into the first 31" and second 32" wash baths. Using a mineral acid (we prefer hydrochloric acid within the acid bath 30" of a strength 30 wt/wt%) it is possible to remove contaminants from the surface of the substrate S and to suitably prepare the substrate for the application of an overlayer material OL. Using a first and second wash bath 31", 32" it is possible to remove most, if not all, residues of the acid from the surface of the substrate S. We prefer to circulate the acid in the acid bath 30" and the fluid (usually water) in the respective first and/or second wash baths 31 ", 32".

[0059] The drying zone 4" comprises, in flow sequence, a pair of air knives 41" and a drying tunnel 40". The air knives 41" may be provided in accordance with the above description (*c.f.* Figure 4). The drying tunnel 40" may be from 0.5 to 1.5 m long and is preferably supplied with hot air heated to a temperature of from 90 to 250°C, preferably from 95 to 200°C, to evaporate any liquid on the substrate S. Thus the drying tunnel 40" need not be as long as the tunnel 40' described in relation to Figure 2. Indeed the drying tunnel 40" will typically be 1/3 the length. This has cost implications because it is much cheaper and easier to heat a shorter tunnel (40") than a longer tunnel (40'). The provision of the air knives 41" causes excess moisture to be removed from the substrate S before it enters the tunnel 40" which enables a shorter tunnel to be deployed. We have found that supplying ambient air to the air knives 41" is sufficient to allow a *ca*. 1m tunnel 40" to be used and still provide a completely dry substrate S at the downstream end of the drying zone 4" at the busbar production rates required.

[0060] Figure 5A provides an exploded view of the acid bath 30" (which may be identical to one or more of the wash baths 31, 32). The bath 30" comprises a lidded housing 300 with apertures 300a. The housing 300 holds a frame 301 which comprises a shelf 301s to support an elongate outer bath 302 which has a pair of aligned apertures 302a at each of its ends 302e. Located within the outer bath 302 are plural supports 303 which support an inner bath 304. We prefer that the outer bath 302, supports 303 and inner bath 304 are formed from a corrosion resistant material such as a plastics material (for example polypropylene). The inner bath 304 is elongate and has a pair of slots 304s in each of its ends 304e, the slots 304s aligning with the apertures 302a in the outer bath 302.

[0061] An acid supply vessel 305 and a pump 306 are provided.

[0062] In use the acid will be circulated from the vessel 305, under the action of the pump 306, to the inner bath 304 from where it will overflow into the outer bath 302 and flow, preferably under the influence of gravity, into the vessel 305.

[0063] In use, substrate S is threaded through the aligned apertures 300a, 302a and slots 304s in each end of the respective housing 300, outer bath 302 and inner bath 304 and the lid of the housing 300 closed. As the substrate is drawn through the acid bath 30" it will be cleaned and/or the surface prepared. As the substrate runs through the first water bath 31" and second water bath 32" the acid thereon will be removed. As the substrate S exits the cleaning zone 3" it will be dried by the air knives 41" and the drying tunnel 40".

[0064] We have found that the second embodiment of cleaning and drying apparatus allows us to run the substrate S through the apparatus at at least the rate of the first apparatus (and preferably faster) and it provides a better surface for adhesion of overlayer material OL, which, as a consequence is applied to a tighter tolerance and the apparatus may be run more economically. We also believe the apparatus of the further embodiment even further reduces the incidence of holes.

Claims

1. Apparatus for forming a busbar having a width of less than 25mm and a thickness of less than 120microns, the apparatus comprising means to continuously supply a length of substrate having a pair of major surfaces, a width of less than 25mm and a thickness of less than 120microns, means to clean the substrate, a hot dip overlayer application means comprising a bath for overlayer material to apply, in use, an overlayer material to all of the surfaces of the substrate, overlayer control means to control the amount of overlayer material adhered to the substrate, the overlayer control means comprising wiping means to physically contact both major surfaces of the substrate, wherein the wiping means are located, in use, beneath the surface level of overlayer material retained in the bath.

2. Apparatus according to Claim 1, wherein said means to clean the substrate comprises an acid bath.

3. Apparatus according to Claim 1 or 2, wherein means to clean the substrate comprises one or more wash baths.

4. Apparatus according to any of Claims 1 to 3, wherein there is provided drying means between the cleaning means and the overlayer application means.

5. Apparatus according to Claim 4, wherein the drying means comprises one or more of a drying tunnel and one or more air knives.

6. Apparatus according to any preceding Claim, wherein the apparatus further comprises an electroplating application means.

7. Apparatus according to any preceding Claim, wherein said overlayer control means comprises one or more air knives, preferably a pair of air knives operable to impinge a stream of gas upon a facing major surface of the substrate.

8. Apparatus according to Claim 7, wherein said overlayer control means comprises a pair of air knives each of which is operable to impinge or bear on one of the major surfaces of the substrate.

9. Apparatus according to Claim 7 or 8, wherein the or each air knife has an outlet width which is larger than the width of the substrate on which the overlayer material is to be controlled.

10. Apparatus according to Claim 9, wherein the outlet width of the or each air knife is at least twice or is from two to five times the width of the substrate on which the overlayer material is to be controlled.

11. A method of forming a busbar having a width of less than 25mm and a thickness of less than 120microns, the method comprising continuously supplying a length of substrate having a pair of major surfaces, a width of less than 25mm and a thickness of less than 120microns to a cleaning station, cleaning the substrate, drying the substrate, applying an overlayer material to all surfaces of the substrate in a hot dip bath of molten overlayer material, controlling the amount of overlayer material adhered to the substrate by physically contacting the overlayer material applied to both major surfaces of the substrate, whereby said physical contact occurs beneath the surface level of overlayer material retained in the bath.

12. A method according to Claim 11, wherein controlling the amount of overlayer material comprises impinging a thin stream of gas onto each major surface of the substrate.

13. A method according to Claim 12, wherein controlling the amount of overlayer material comprises impinging the major surface of the substrate with a stream of gas, the stream of gas having a width of at least twice the width of the substrate, preferably from 2 to 5 times the width of the substrate.

14. A method according to any of Claims 11, 12, 13, comprising continuously supplying a length of substrate at a rate of over 2 m/s.

15. A busbar formed using the apparatus of any of Claims 1 to 10 or the method of any of Claims 11 to 14.

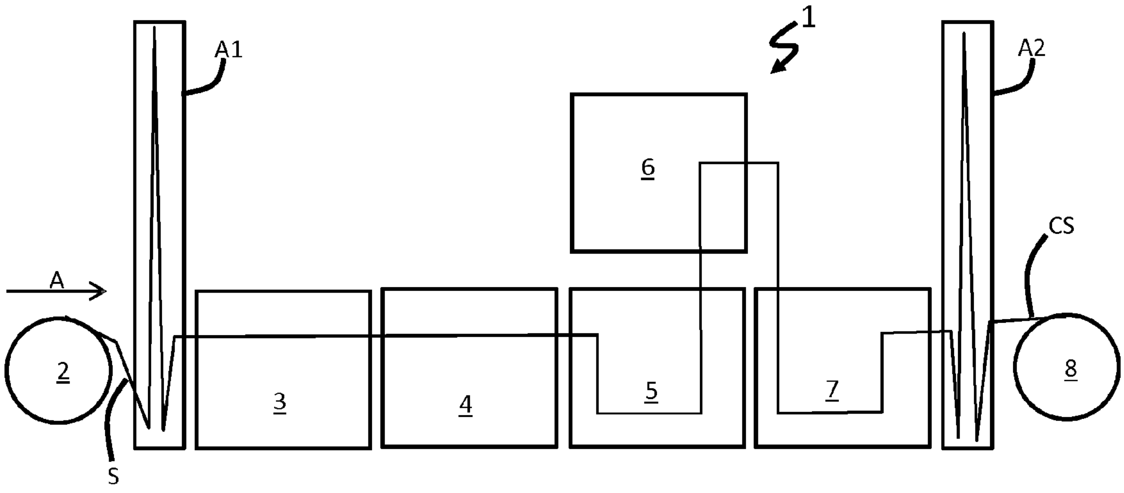

Figure 1

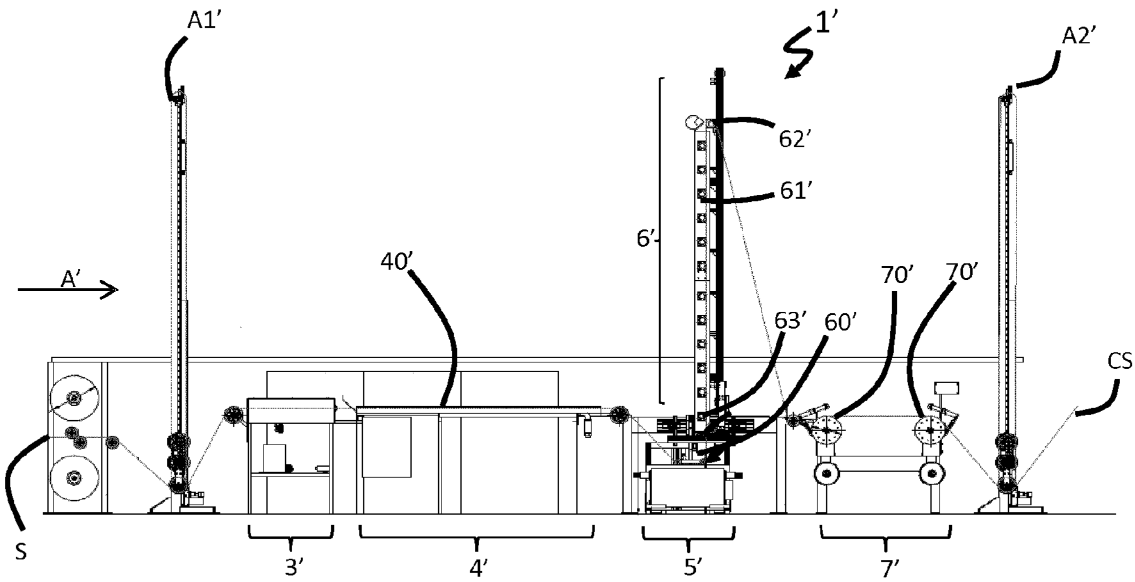

Figure 2

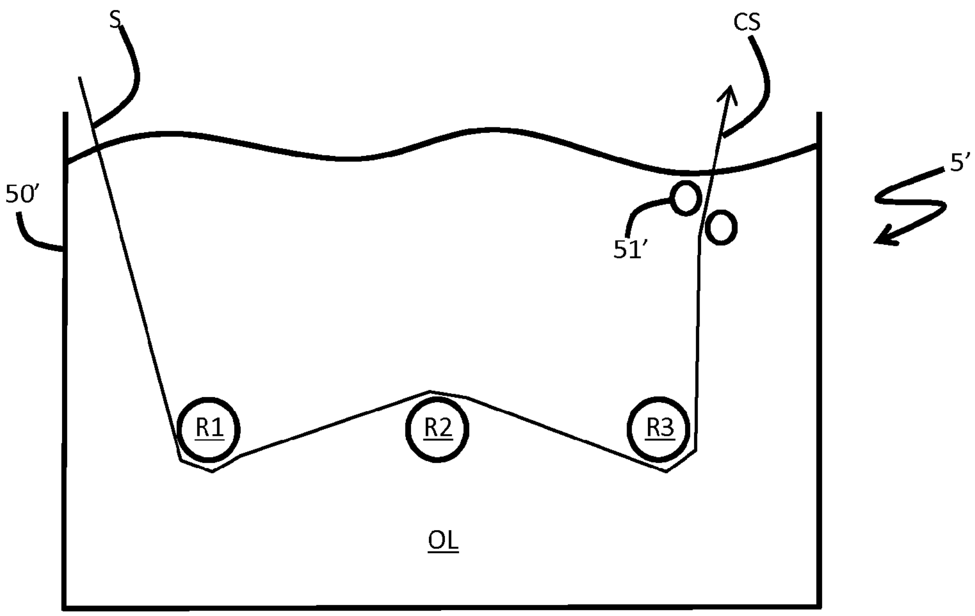

Figure 3

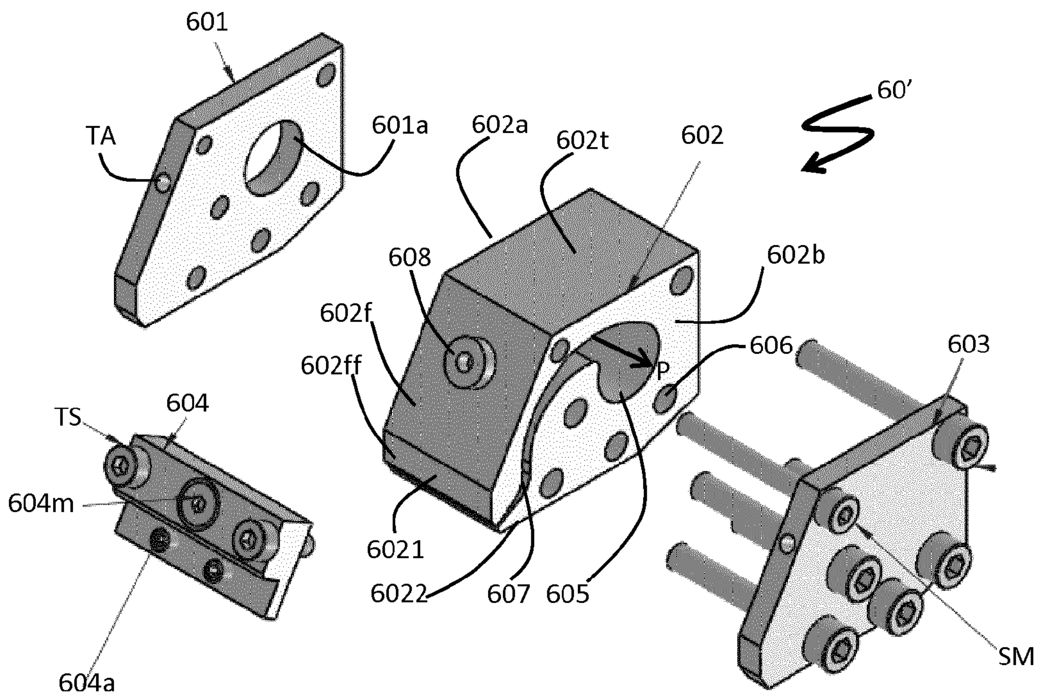

Figure 4

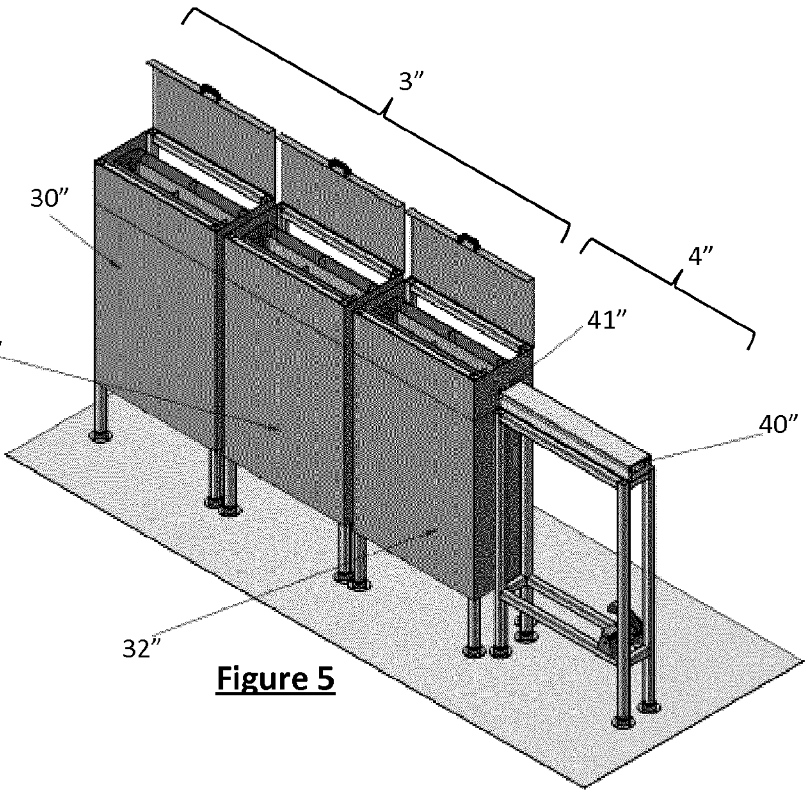

Figure 5

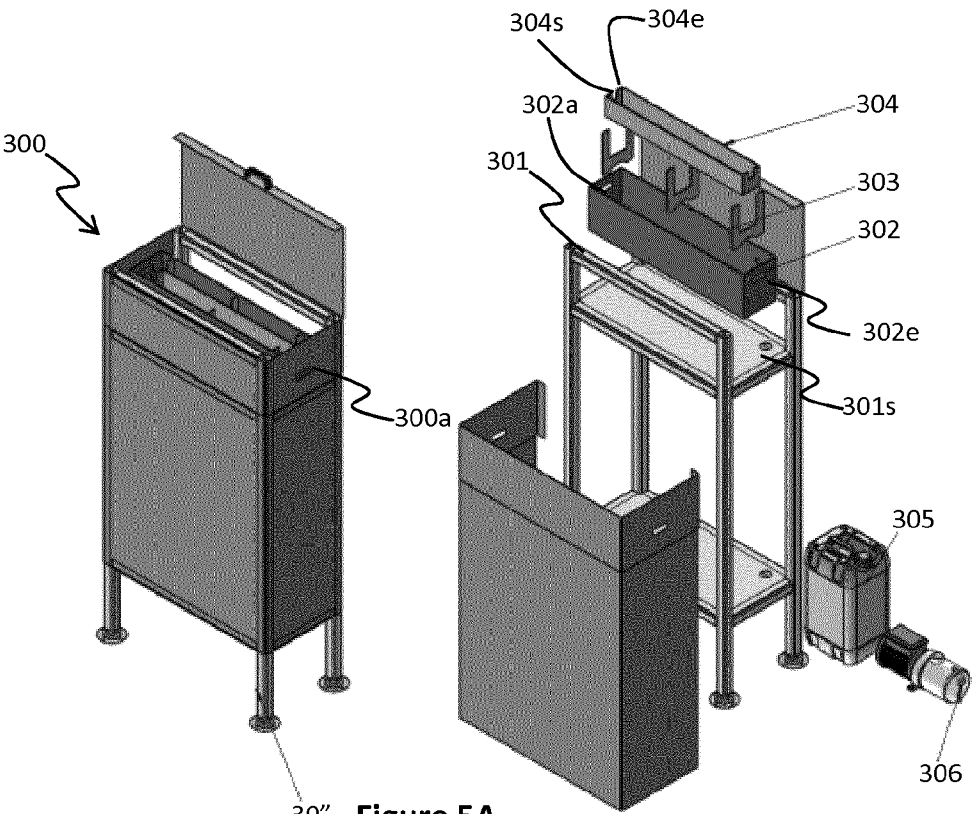

Figure 5A

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EUROPEAN SEARCH REPORT

Application Number
EP 15 17 2629

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1

Place of search	Date of completion of the search	Examiner
Munich	2 February 2016	Teppo, Kirsi-Marja

CATEGORY OF CITED DOCUMENTS

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