

SUBSTRATE ROLLERS

CROSS-REFERENCE

[0001] This application claims priority to U.S. Provisional Patent Application Serial No. 61/527,087, filed August 24, 2011, which application is entirely incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] Thin metal foils are often used to make a variety of useful products ranging from stamped items for automobiles to substrates for high tech coatings for electronic applications. Regardless of the specific product, thin metal foil substrates or webs in roll form are transported through some type of machine that performs one or more operations to make a final product. The handling of the webs during the processing can become difficult when extreme physical conditions are required, such as high temperatures, for example. In electronic applications where thin layers of material are coated onto the webs, the coatings may be sensitive to contact with various components of the coating equipment, which may lead to loss of yield in the manufacturing process. One such example is a thin film solar cell that is deposited on a stainless steel foil substrate where contact of the coating with transport rollers may create small electronic defects in the solar cell.

SUMMARY

[0003] This disclosure provides rollers for thin magnetic foil substrates with improved contact resistance for small wrap angles.

[0004] In an aspect of the invention, a roller for handling a substrate web comprises a rotatably fixed shaft and a sleeve circumscribing the rotatably (or rotationally) fixed shaft. The sleeve can be configured to rotate about the shaft. The roller further comprises an array of magnets adjacent to the shaft. Individual magnets of the array of magnets are oriented so as to provide magnetic field lines propagating along a direction orthogonal to the rotatably fixed shaft. The magnetic field lines are configured to couple to the substrate directed adjacent to the sleeve. In some examples, the rotatably fixed shaft does not rotate during rotation of the sleeve.

[0005] In another aspect of the invention, a roller for moving a substrate comprises a sleeve circumscribing a rotatably fixed shaft, wherein the sleeve is configured to rotate about the rotatably fixed shaft. The roller further comprises an array of magnets disposed between the sleeve and the rotatably fixed shaft. The array comprise two or more magnets that have poles that are oriented in an anti-parallel configuration so as to provide magnetic field lines propagating along a direction orthogonal to the rotatably fixed shaft, which magnetic field lines are configured to couple to the substrate disposed adjacent to the sleeve.

[0006] In another aspect of the invention, a roller system comprises a roller as described above or elsewhere herein, alone or in combination, a pay-out roll and uptake roll, and a substrate web that is directed about or along the roller from the pay-out roll to the uptake roll.

[0007] In another aspect of the invention, a method for moving a substrate web comprises providing a roller, as described above or elsewhere herein, and providing a substrate web adjacent to a sleeve of the roller. The substrate web is moved upon the coupling of the substrate web to magnetic field lines provided by the roller.

[0008] Additional aspects and advantages of the present disclosure will become readily apparent to those skilled in this art from the following detailed description, wherein only illustrative embodiments of the present disclosure are shown and described. As will be realized, the present disclosure is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects, all without departing from the disclosure. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

INCORPORATION BY REFERENCE

[0009] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings of which:

[0011] FIG. 1 is a schematic isometric sketch of a roller.

[0012] FIG. 2 is a schematic isometric sketch of an alternative design for a roller.

[0013] FIG. 3 is a schematic cross sectional side view of two roller arrangements for driving a web.

[0014] FIG. 4 is a schematic cross sectional layout of a web handling (or roller) system for a manufacturing operation.

[0015] FIG. 5a is schematic cross sectional representation of a vacuum drum type coating machine.

[0016] FIG. 5b is schematic cross sectional representation of a vacuum drum type coating machine which avoids roller contact with the coated side of the substrate.

[0017] FIG. 6 is a schematic cross sectional view of a roller showing the basic concept of magnetically enhancing the roller for use with thin magnetic foil substrates.

[0018] FIG. 7 is a schematic cross sectional view of a magnetically enhanced roller utilizing a semi-circular pole piece.

DETAILED DESCRIPTION

[0019] While various embodiments of the invention have been shown and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only.

Numerous variations, changes, and substitutions may occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein may be employed in practicing the invention.

[0020] The term “rotatably fixed,” as used herein, can refer to a structure that does not rotate. In some examples, a rotatably fixed structure does not rotate when another structure circumscribing or circumscribed by the rotatably fixed structure rotates in relation to the rotatably fixed structure.

[0021] An aspect of the invention provides a roller for handling a substrate web. The roller comprises a rotatably fixed shaft and a sleeve circumscribing the rotatably fixed shaft. The sleeve can be configured to rotate about the shaft. The rotatably fixed shaft can be configured such that the shaft does not rotate while the sleeve rotates. The roller further comprises an array of magnets adjacent to the shaft. Individual magnets of the array of magnets are oriented so as to provide magnetic field lines propagating along a direction orthogonal to the rotatably fixed shaft. The magnetic field lines are configured to couple to the substrate directed adjacent to the sleeve.

[0022] The magnetic field lines may propagate away from said shaft (and towards said sleeve) along an angle of at least about 0°, 5°, 10°, 20°, 30°, 40°, 50°, 60°, 70°, 80°, or 90° from a vector that is normal to a surface of said rotatably fixed shaft. In an example, when said angle is 0°, said magnetic field lines propagate along a direction that is orthogonal to said rotatably fixed shaft.

[0023] In some embodiments, the shaft does not rotate. However, in some cases, the shaft may rotate, such as, e.g., along a direction that is opposite to the direction of rotation of the sleeve.

[0024] In some cases, the shaft is rotatably fixed by attachment to a support member, and the sleeve is permitted to rotate by decoupling the sleeve from the shaft. The roller can include one or more separation members to separate the sleeve from the shaft. The separation members can be ball bearings. The sleeve can be configured to rotate around (or about) the shaft with the aid of one or more bearings. For instance, the roller can include at least 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100 bearings, which may be situated at an opposing end of the sleeve. The bearings can be ball bearings. In some cases, a separation member can be a spacer that enables the sleeve to be rotatably decoupled from the shaft.

[0025] The roller can be cylindrical in shape. In some cases, the shaft and/or the sleeve can be cylindrical. The sleeve can be removable from the roller, such as by sliding the sleeve off of the roller.

[0026] The roller can include a pole piece adjacent to the rotatably fixed shaft. An individual magnet of the array of magnets can be attached to the pole piece.

[0027] The array of magnets can include at least 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, or 100 magnets. The array of magnets can comprise a magnet formed of a ferromagnetic material. In some cases, the array of magnets can comprise a magnet formed of iron, nickel, cobalt or combinations

thereof. In some examples, the array of magnets comprises a magnet formed of one or more rare earth metals. Alternatively, the array of magnets can include one or more electromagnets, which may be adapted to provide a magnetic field upon the application of power (or electricity) to the electromagnets.

[0028] In some cases, the roller can be configured to direct the substrate web adjacent to the sleeve upon the application of the magnetic field lines, or upon bringing the substrate web in proximity to the sleeve such that the substrate web is attracted by the magnetic field lines. The substrate web can be directed at a wrap angle (as may be measured in relation to a tangent to the sleeve). In some situations, the array has a radial size that is larger than the wrap angle. The array may have a radial size that is less than or equal to about 99%, 90%, 80%, 70%, 60%, 50%, 40%, 30%, 20%, 10%, or 5% of the circumference ($2\pi \times$ sleeve radius) of the sleeve. In some examples, the array has a radial size that is less than or equal to about $1/2$, $1/3$, $1/4$, $1/5$, $1/6$, $1/7$, or $1/8$ of the circumference of the sleeve.

[0029] The array of magnets can include a first magnet having a north pole adjacent to the rotatably fixed shaft and a south pole adjacent to the sleeve, and a second magnet having a north pole adjacent to the sleeve and a south pole adjacent to the rotatably fixed shaft. The array of magnets can further comprise a third magnet having a north pole adjacent to the rotatably fixed shaft and a south pole adjacent to the sleeve. The second magnet can be radially disposed between the first and third magnets. Alternatively, the third magnet can be radially disposed between the first and second magnets.

[0030] In some cases, an individual magnet of the array of magnets is separated from the sleeve by a gap. The gap can permit the sleeve to rotate without coming in contact with an individual magnet of the array of magnets.

[0031] Rollers provided herein may enable movement or translation of a substrate web without substantial bending or other deformation that may adversely impact the substrate web. In some cases, the substrate web can be translated with reduced friction, thereby aiding in improving processing efficiency and providing energy savings.

[0032] The substrate web can be formed of any material that magnetically attractable—e.g., a material that moves or deforms in the presence of an applied magnetic field. In some examples, the substrate web is provided for use in manufacturing photovoltaic (PV) solar cells. However, other use cases are possible. For example, the roller may be used to move or direct a substrate web that includes data, such as, e.g., video, still pictures, or other information. For example, the substrate web can be a magnetic recording medium.

[0033] The roller can be used to move or otherwise translate a substrate web or other support structure. In another aspect of the invention, a method for moving a substrate web comprises providing a roller, as described elsewhere herein. For instance, the roller can comprise a rotatably fixed shaft, a sleeve circumscribing the rotatably fixed shaft, and an array of magnets adjacent to the shaft. Individual magnets of the array of magnets are oriented so as to provide magnetic field lines propagating along a direction orthogonal to the rotatably fixed shaft. Next, a substrate is provided adjacent to the sleeve. The substrate web is then moved upon the coupling of the substrate web to the magnetic field lines.

[0034] The substrate web in some cases is coupled to the magnetic field lines by bringing the substrate web in proximity to the magnetic field lines, such as, for example, in proximity to the sleeve. In some cases, the substrate web is brought in contact with the sleeve. The substrate may be attracted to the substrate web with the aid of the magnetic field lines.

[0035] In some examples, the substrate web comprises a magnetically attractable material, as described elsewhere herein. In an example, the substrate web is formed of stainless steel.

[0036] In some cases, the substrate web is moved with the aid of the roller by providing translational motion to the substrate web. Translational motion can be provided along a tangential direction of the sleeve. For example, the substrate web can be moved or directed by providing motion to the substrate web along a direction that is parallel to (and in some cases orthogonal to a longitudinal axis of) a surface of the sleeve.

[0037] The substrate web can be moved about the sleeve by bringing the substrate web adjacent to the sleeve and providing translational motion to the substrate web or the sleeve. In some cases, the substrate web wraps around the sleeve at a wrap angle during movement.

[0038] Translational motion can be provided to the substrate web with the aid of a rolling member, such as a motor (e.g., tension motor) attached to another roller around which the substrate web can be wound. In some situations, translational motion can be provided by rotating the sleeve, such as with the aid of a motor coupled to the sleeve. For example, the motor can be configured to rotate the sleeve at a fixed angular velocity, and attraction of the substrate web to the sleeve (with the aid of the magnetic field lines) provides frictional force that is sufficient to move the substrate web along the sleeve.

[0039] Reference will now be made to the figures, wherein like numerals refer to like parts throughout. It will be appreciated that the figures are not necessarily drawn to scale. It shall be understood that the figures are for illustrative purposes only and are not intended to be limiting.

[0040] The disclosure provides various systems for directing a substrate support web (also “web” herein). A web may be controlled and directed through processing equipment using a system of rollers. Some of the rollers may be driven, while others may act as idlers.

[0041] Roller systems of the disclosure can include one or more rollers that are configured to direct a substrate web along one or more directions. For example, a roller system can direct a substrate web from a payout roll to a pickup roll. Roller systems of the disclosure may be suited for thin film deposition processes, such as deposition processes suited for forming photovoltaic devices.

[0042] A design for a roller is shown in the isometric sketch of **FIG. 1**. A web 1 is shown directed over a roller comprising a polished sleeve 2, a flange 3, and a bearing shaft 4 running in bearings 5. The shaft need not be solid (it may be tubular, for example) and it need not extend all the way through the sleeve, but it should be rigidly attached to the flanges that are in turn attached to the sleeve. The bearings can be supported as indicated schematically by blocks 6. The web 1 may make contact with the sleeve 2 over at least a portion of its circumference. That angle of contact between the sleeve 2 and the web 1 may be referred to as the wrap angle, and is indicated by θ . The web 1 may be transported

under some amount of tension 'T' which can be supplied by a driven element (or member) or elements (or members) somewhere else in the system, such as, for example, a motor or a plurality of motors that are adapted to provide tension to the web 1. For any roller that is used to drive the web, the wrap angle and the coefficient of friction between the web 1 and the roller may determine the amount of force that can be applied to pull the web 1. The coefficient of friction may be a function of the tension in the web 1.

[0043] FIG. 2 schematically illustrates another roller system. Bearing shaft 4 extends through the sleeve as shown by the dashed lines, and is fixed so that it does not rotate as illustrated schematically by blocks 7. Bearing 5 is seated in flange 3 or is directly pressed into polished sleeve 2, depending on sizes as may be appropriate. This type of roller may allow for a simplified method of roller alignment at the fixed ends, since the bearings and their housings do not have to be dealt with at the same time.

[0044] FIG. 3 is a cross sectional sketch showing two roller arrangements for driving a web. For simplicity the bearings are not shown. In arrangement A, web 1 forms a wrap angle θ of 180 degrees on the roller. Therefore the web leaves the roller in a direction parallel to the direction it enters.

Practically, it is difficult to increase the wrap angle on a single roller very much more than this.

Arrangement B illustrates a way to double the net wrap angle to a net 360 degrees by using a pair of rollers. This is known as the classic "S" wrap for driving a web system using rollers. The total wrap angle on the two rollers can be increased significantly beyond 360 degrees by rotating the rollers about the center point of dashed line 8 by some angle Φ . A maximum wrap angle of nearly 270 degrees on each roller occurs just before the rotated rollers touch the entering or exiting web, and the rollers themselves are brought together so that they nearly touch.

[0045] As an example of a situation where an improved roller could be useful, FIG. 4 shows a cross sectional schematic layout of a simple web handling system for some manufacturing operation. Web 1 from a payout roll of material 9 is transported over roller 10 and through region 11 where some type of manufacturing operations takes place. Then the web goes over roller 12 and is rewound on takeup roll 13. Payout and take-up rolls 9 and 13 are driven, and rollers 10 and 12 are idlers. In this type of layout the wrap angle θ on the rollers is rather small, and it may be at least inconvenient and certainly more expensive to arrange the system in a way that makes the angle significantly larger. However, it is often desirable to maintain the tension in the manufacturing region between the rollers (by driving them) which could be different from the unwind and rewind tensions on the supply and takeup rolls, but with such a small wrap angle this cannot readily be done.

[0046] Another example of a system in which an improved roller may be used to advantage is illustrated in the cross sectional schematic representations of two vacuum drum type coating machines shown in FIG. 5a and FIG. 5b. A drum coating architecture is shown in FIG. 5a. Basically a driven drum 14 is used to support and transport web substrate 1 while it is coated at various types of coating stations 15 arrayed around the circumference of the drum. The drum is often heated or cooled to provide desired web process conditions. Rollers 16 are known in the trade as "lay-on rollers" which are

not driven, but have a large wrap angle with the web. Normally they are fitted with load cells which measure the tension forces in the web. Rollers 17 are simple idle rollers. Driven payout and takeup rolls of web material 9 and 13 receive feedback tension information from the load cells and adjust their response to maintain a selected tension in the web. A major problem with this classic setup can occur when the substrate and/or the coating is sensitive to defects that can be produced by the contact between the lay-on rollers and the coated side of the web.

[0047] One way to avoid the contact with the coated side of the web is shown in **FIG. 5b**. The lay-on rollers are removed, and repositioned fixed rollers 17 redefine the geometry of the web with respect to drum 14. The two unavoidable consequences of this arrangement is first the loss of some coating area around the drum, so not as many coating stations 15 can be used. And second, the wrap angle on rollers 17 is small, which can lead to slippage and false reading from load cells fitted to them. The wrap angle on rollers 17 can be increased by moving them to positions fairly distant and above the respective payout and takeup rolls, but the geometry becomes complicated by the changing sizes of the substrate rolls during coating, and the machine dimensions become larger making it more expensive.

[0048] An aspect of the invention provides a magnetically enhanced roller for improved handling of thin foil magnetic substrates. The roller comprises a rotatably fixed shaft and a sleeve circumscribing the rotatably fixed shaft. The sleeve can be configured to rotate about (e.g., around) the shaft with the aid of bearings. The roller can include an array of magnets adjacent to the shaft. The array of magnets can be oriented so as to provide magnetic field lines along a direction orthogonal to the rotatably fixed bearing shaft. In some cases, the roller includes a pole piece that can include an individual magnet of the array of magnets attached thereto. Such a roller can provide greater contact friction with a substrate (e.g., substrate web) at small wrap angles than that which may occur for conventional rollers.

[0049] **FIG. 6** is a cross sectional view of a roller that has been magnetically enhanced it for use with thin magnetic foil substrates, such as steel or other ferromagnetic materials (e.g., iron, nickel, cobalt, rare earth metals). In the illustrated example, the roller comprises a shaft or tube (dashed circle) 4 and sleeve 2. The roller can be similar to that shown in **FIG. 2**, where the shaft 4 is held fixed while the sleeve 2 is allowed to rotate around the shaft on bearings (not shown in this figure).

[0050] In some examples, the sleeve 2 can rotate about the shaft 4 at a rate of at least about 1 revolution per minute (rpm), 2 rpm, 3 rpm, 4 rpm, 5 rpm, 6 rpm, 7 rpm, 8 rpm, 9 rpm, 10 rpm, 20 rpm, 30 rpm, 40 rpm, 50 rpm, 60 rpm, 70 rpm, 80 rpm, 90 rpm, 100 rpm, 500 rpm, or 1000 rpm.

[0051] In some examples, the sleeve 2 can be heated with the aid of resistive heating elements (not shown). In some cases, the sleeve can be cooled with the aid of a cooling system (not shown).

[0052] With continued reference to **FIG. 6**, the shaft 4 can include three rows of magnets 18 attached along the length (orthogonal to the plane of drawing) of the roller, or at least of sufficient length to cover the width of the web 1. The poles of the magnets are inverted from one row to the next as indicated by the north (N) and south (S) nomenclature. In some cases, the poles may be inverted from the way they are shown in **FIG. 6**. Sleeve 2 can be made from a non-magnetic material so that the

magnetic lines of force 19 can penetrate the sleeve with little attenuation and couple into magnetic web 1.

[0053] Suitable materials that may be used to form the sleeve 2 include, without limitation, copper, molybdenum, chromium, gold, silver, platinum, aluminum, steel, stainless steel, and combinations thereof. In an example, the sleeve is formed of 300 series stainless steel.

[0054] During use, the magnetic field generated by the magnets attracts the web 1 towards the sleeve 2. Any extra frictional force between the web 1 and sleeve 2 created by the magnetic attraction may be sufficient to allow a small wrap angle roller to be used as a driver or load cell roller in various web handling situations, where it may not function as such otherwise. In some low wrap angle web handling situations, it may be desirable to have the foil slide over the roller without having the roller turn. This may aid in adding more tension in the web 4 at some locations. The magnetic roller may also be used in a static mode if desired, with additional frictional drag being supplied by the magnetic fields.

[0055] The magnets 18 can extend radially outward from the shaft 4 of the roller. The magnets 18 are disposed with their poles in an alternating fashion. A first magnet is disposed with its south pole adjacent to the shaft 4 and its north pole adjacent to the sleeve 2, and a second magnet adjacent to the first magnet is disposed with its north pole adjacent to the shaft 4 and its south pole adjacent to the sleeve 2. A third magnet adjacent to the second magnet is disposed with its north pole adjacent to the sleeve 2 and its south pole adjacent to the shaft 4. As an alternative, the poles of some of the magnets can be aligned. For example, the first and second magnets can have their north poles adjacent to the shaft 4 and their south poles adjacent to the sleeve 2, or their south poles adjacent to the shaft 4 and their north poles adjacent the sleeve 2. The third magnet can have its north and south poles disposed in an opposite configuration in relation to the first and second magnets. For example, if the first and second magnets have their north poles disposed adjacent to the sleeve 2, the third magnet can have its north pole disposed adjacent to the shaft 4 and its south pole disposed adjacent to the sleeve 2.

[0056] In some embodiments, the roller can have n magnets, wherein ' n ' is greater than or equal to 2. For example, n can be greater than or equal to 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 600, 700, 800, 900, or 1000. If n is equal to 2, then adjacent magnets may have their poles disposed in an anti-parallel configuration (i.e., north adjacent to south). If n is greater than 2, then at most $n-1$ magnets may have their poles in a parallel configuration (i.e., north adjacent to north, south adjacent to south), while at least 1 of the n magnets may have its pole oriented in an anti-parallel configuration with respect to the $n-1$ magnets.

[0057] In some embodiments, the magnets 18 do not contact the sleeve 2. The roller may include a gap between an individual magnet 18 and the sleeve 2. In some examples, the gap has a width less than or equal to about 6 inches, 5 inches, 4 inches, 3 inches, 2 inches, 1 inch, 0.5 inches, 0.1 inches, 0.01 inches, 0.001 inches, 0.0001 inches, or 0.00001 inches.

[0058] In some examples, the roller has 2, or 3, or 4, or 5, or 6, or 7, or 8, or 9, or 10, or more magnets. The magnets may be distributed as desired to effect a predetermined distribution of magnetic field lines 19. While the roller includes three rows of magnets 18, the roller can include at least 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 20, 25, 30, 35, 40, 45, 50, 100, 200, 300, 400, 500, or 1000 magnets. Adjacent magnets may be oriented so as to have poles aligned oppositely in relation to one another.

[0059] Modern magnets made from high energy density magnetic materials, such as Neodymium Iron Boron and Samarium Cobalt, may have form factors such that the thickness in the magnetized direction is substantially equal to the width. In some cases, it may be practical to make an array of magnets that are attached to a semi-circular pole piece, rather than have them directly attached to the central shaft 4. This may permit the array of magnets to be removed from the roller without removing the shaft. This can advantageously permit the array of magnets to be tailored to provide various warp angles, as may be desired in a given application. The pole piece can be formed of a magnetic material (e.g., steel, such as low carbon steel). The pole piece can also permit a smoothing of an otherwise non-uniform magnetic field. **FIG. 7** shows a cross sectional view of a magnetically enhanced roller where semi-circular pole piece 20 is arrayed with several rows of high energy density magnets 21. The pole piece 20 may be cylindrical along a direction orthogonal to the plane of the page of the figure. In the illustrated example, the magnetic sense alternates with each row, as described elsewhere herein, and inversion of all the magnets may yield the same functionality. The array can be rigidly (or fixedly) attached to shaft 4, and roller sleeve 2 rotates around the fixed array as web 1 is transported. This semi-circular array of magnets may be combined with or modified by the flat array of magnets described in U.S. Patent Publication No. 2010/0266810 ("Magnetic Hold-Down for Foil Substrate Processing"), which is entirely incorporated herein by reference.

[0060] With continued reference to **FIG. 7**, in an embodiment, the magnetic array is shown to extend over about half of the circumference of the roller, while the wrap angle of the web is substantially less. Magnetic flux 19 can couple to the magnetic web substrate over some of the region where the web does not touch the roller. However, since the strength of the magnetic flux from the array of magnets can decrease rapidly with increasing distance from the array, the coupling with the web can also decrease rapidly. Therefore, various array sizes in relation to the wrap angle may be used. The array in some cases is larger than the wrap angle. In some situations, the array size is less than or equal to about half the circumference of the roller.

[0061] In some cases, individual magnets of the array of magnets are in contact with the sleeve and the roller (shaft, array and sleeve) rotate as a single unit. In such a case, the array of magnets can be radially disposed around a substantial portion (e.g., 360°) of the roller.

[0062] A roller system can include multiple rollers. In an example, a roller system, such as that illustrated in any of **FIG. 1**, **FIG. 2**, **FIG. 3**, **FIG. 4**, **FIG. 5a** or **FIG. 5b**, comprises rollers as described in the context of **FIG. 6** or **FIG. 7**. A roller system can include a single roller (e.g., the roller of **FIG. 6**

or FIG. 7), or multiple rollers, each of which plurality of rollers may be as described in the context of FIG. 6 or FIG. 7.

[0063] Rollers and roller systems of the disclosure may be combined with or modified by other devices or systems, such as, for example, those described in U.S. Patent Nos. 4,047,609, 4,982,691, 7,106,011, 7,352,983, and 7,459,820, which patents are entirely incorporated herein by reference.

[0064] It should be understood from the foregoing that, while particular implementations have been illustrated and described, various modifications can be made thereto and are contemplated herein. It is also not intended that the invention be limited by the specific examples provided within the specification. While the invention has been described with reference to the aforementioned specification, the descriptions and illustrations of the preferable embodiments herein are not meant to be construed in a limiting sense. Furthermore, it shall be understood that all aspects of the invention are not limited to the specific depictions, configurations or relative proportions set forth herein which depend upon a variety of conditions and variables. Various modifications in form and detail of the embodiments of the invention will be apparent to a person skilled in the art. It is therefore contemplated that the invention shall also cover any such modifications, variations and equivalents. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.

CLAIMS

WHAT IS CLAIMED IS:

1. A roller for handling a substrate web, comprising:
 - (a) a rotatably fixed shaft;
 - (b) a sleeve circumscribing said rotatably fixed shaft, wherein said sleeve is configured to rotate about the shaft; and
 - (c) an array of magnets adjacent to the shaft, wherein individual magnets of said array of magnets are oriented so as to provide magnetic field lines propagating along a direction orthogonal to said rotatably fixed shaft, which magnetic field lines are configured to couple to said substrate directed adjacent to said sleeve.
2. The roller of claim 1, wherein said sleeve is configured to rotate around said shaft with the aid of one or more bearings.
3. The roller of claim 1, further comprising a pole piece adjacent to said rotatably fixed shaft, wherein an individual magnet of said array of magnets is attached to said pole piece.
4. The roller of claim 1, wherein said array of magnets comprises at least two magnets.
5. The roller of claim 1, wherein said array of magnets comprises a magnet formed of a ferromagnetic material.
6. The roller of claim 1, wherein said array of magnets comprises a magnet formed of iron, nickel, cobalt or combinations thereof.
7. The roller of claim 1, wherein said array of magnets comprises a magnet formed of one or more rare earth metals.
8. The roller of claim 1, wherein said array of magnets comprises an electromagnet.
9. The roller of claim 1, wherein said roller is configured to direct said substrate web adjacent to said sleeve upon the application of said magnetic field lines, wherein said substrate web is directed at a wrap angle.
10. The roller of claim 9, wherein said array has a radial size that is larger than said wrap angle.
11. The roller of claim 1, wherein said array has a radial size that is less than or equal to about 1/2 of a circumference of said sleeve.
12. The roller of claim 11, wherein said array has a radial size that is less than or equal to about 1/3 of the circumference of said sleeve.
13. The roller of claim 1, wherein said array of magnets comprises a first magnet having a north pole adjacent to said rotatably fixed shaft and a south pole adjacent to said sleeve, and a second magnet having a north pole adjacent to said sleeve and a south pole adjacent to said rotatably fixed shaft.

14. The roller of claim 13, wherein said array of magnets further comprises a third magnet having a north pole adjacent to said rotatably fixed shaft and a south pole adjacent to said sleeve.
15. The roller of claim 14, wherein said second magnet is radially disposed between said first and third magnets.
16. The roller of claim 14, wherein said third magnet is radially disposed between said first and second magnets.
17. The roller of claim 1, wherein said sleeve and/or said rotatably fixed shaft are cylindrical.
18. The roller of claim 1, wherein an individual magnet of said array of magnets is separated from said sleeve by a gap.
19. A method for moving a substrate web, comprising:
 - (a) providing a roller, said roller comprising:
 - (i) a rotatably fixed shaft;
 - (ii) a sleeve circumscribing said rotatably fixed shaft, wherein said sleeve is configured to rotate about the shaft; and
 - (iii) an array of magnets adjacent to the shaft, wherein individual magnets of said array of magnets are oriented so as to provide magnetic field lines propagating along a direction orthogonal to said rotatably fixed shaft; and
 - (b) providing said substrate web adjacent to said sleeve; and
 - (c) moving said substrate web upon the coupling of said substrate web to said magnetic field lines.
20. The method of claim 19, wherein said substrate web comprises a magnetically attractable material.
21. The method of claim 19, wherein said substrate web is formed of stainless steel.
22. The method of claim 19, wherein (b) comprises attracting said substrate web to said roller with the aid of said magnetic field lines.
23. The method of claim 19, further comprising providing translational motion to said substrate web.
24. The method of claim 23, wherein said translational motion is provided along a tangential direction of said sleeve.
25. The method of claim 19, wherein (c) comprises moving said substrate web adjacent to said sleeve at a warp angle.
26. The method of claim 19, wherein said array of magnets comprises a first magnet having a north pole adjacent to said rotatably fixed shaft and a south pole adjacent to said sleeve, and a second magnet having a north pole adjacent to said sleeve and a south pole adjacent to said rotatably fixed shaft.

27. The method of claim 19, wherein said array of magnets further comprises a third magnet having a north pole adjacent to said rotatably fixed shaft and a south pole adjacent to said sleeve.
28. The method of claim 27, wherein said second magnet is radially disposed between said first and third magnets.
29. The method of claim 27, wherein said third magnet is radially disposed between said first and second magnets.
30. A roller for moving a substrate, comprising:
- (a) a sleeve circumscribing a rotatably fixed shaft, wherein said sleeve is configured to rotate about said rotatably fixed shaft; and
 - (b) an array of magnets disposed between said sleeve and said rotatably fixed shaft, wherein said array of magnets comprises two or more magnets that have poles that are oriented in an anti-parallel configuration so as to provide magnetic field lines propagating along a direction orthogonal to said rotatably fixed shaft, which magnetic field lines are configured to couple to said substrate disposed adjacent to said sleeve.
31. A roller system, comprising:
- (a) a roller as in claim 1 or 30;
 - (b) a pay-out roll and uptake roll; and
 - (c) a substrate web that is directed about or along the roller from said pay-out roll to said uptake roll.