US 20060086321A1

(19) **United States**
(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0086321 A1**
**Brody et al.** (43) **Pub. Date: Apr. 27, 2006**

# (54) SUBSTRATE-TO-MASK ALIGNMENT AND SECURING SYSTEM WITH TEMPERATURE CONTROL FOR USE IN AN AUTOMATED SHADOW MASK VACUUM DEPOSITION PROCESS

(75) Inventors: **Thomas Peter Brody**, Pittsburgh, PA (US); **Paul R. Malmberg**, Pittsburgh, PA (US); **Jeffrey W. Conrad**, Verona, PA (US)

Correspondence Address:
**THE WEBB LAW FIRM, P.C.**
**700 KOPPERS BUILDING**
**436 SEVENTH AVENUE**
**PITTSBURGH, PA 15219 (US)**

(73) Assignee: **Advantech Global, LTD**, Tortola (VG)

(21) Appl. No.: **10/971,218**

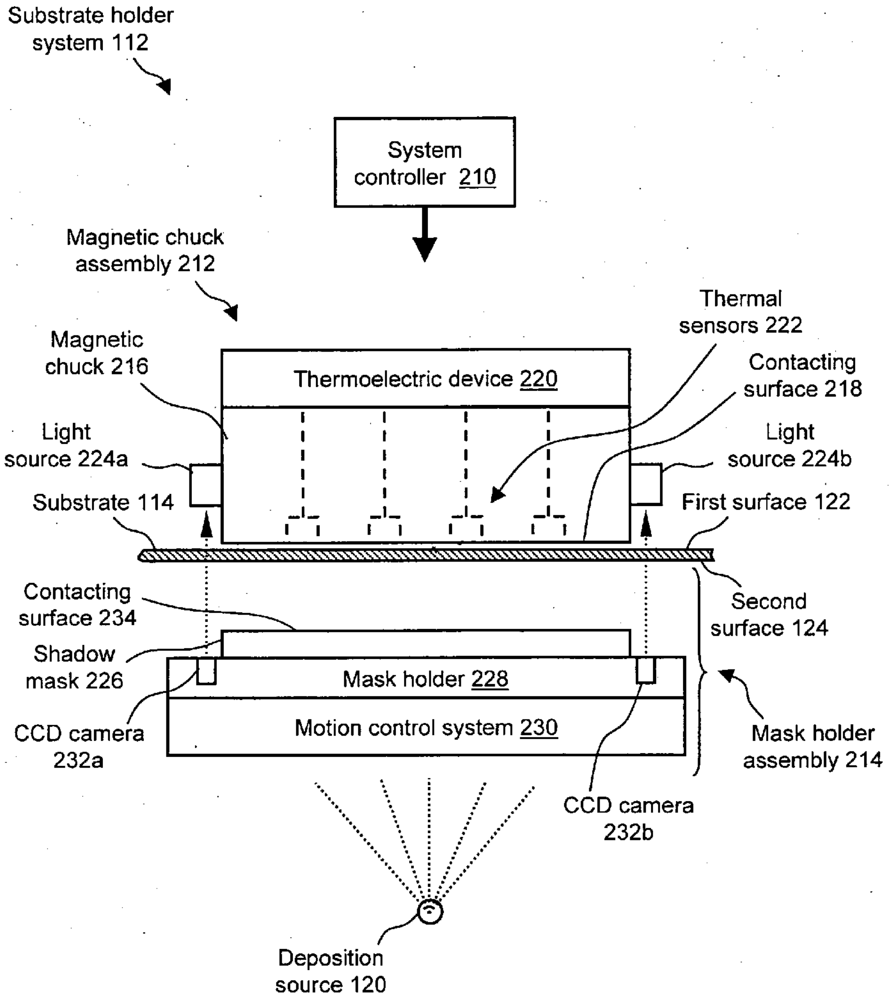
(22) Filed: **Oct. 22, 2004**

**Publication Classification**

(51) **Int. Cl.**
*C23C 16/00* (2006.01)
(52) **U.S. Cl.** ........................ **118/720**; 118/728; 427/248.1

## (57) ABSTRACT

The present invention is a substrate holder system for and method of providing a substrate-to-mask alignment mechanism, securing mechanism and temperature control mechanism. The substrate holder system is suitable for use in an automated shadow mask vacuum deposition process. The substrate holder system includes a system controller, and a substrate arranged between a magnetic chuck assembly and a mask holder assembly. The magnetic chuck assembly includes a magnetic chuck, a thermoelectric device, a plurality of thermal sensors and a plurality of light sources. The mask holder assembly includes a shadow mask, a mask holder, a motion control system and a plurality of cameras. The substrate holder system of the present invention provides close contact between the substrate and the shadow mask thereby avoiding the possibility of evaporant material entering into a gap therebetween.



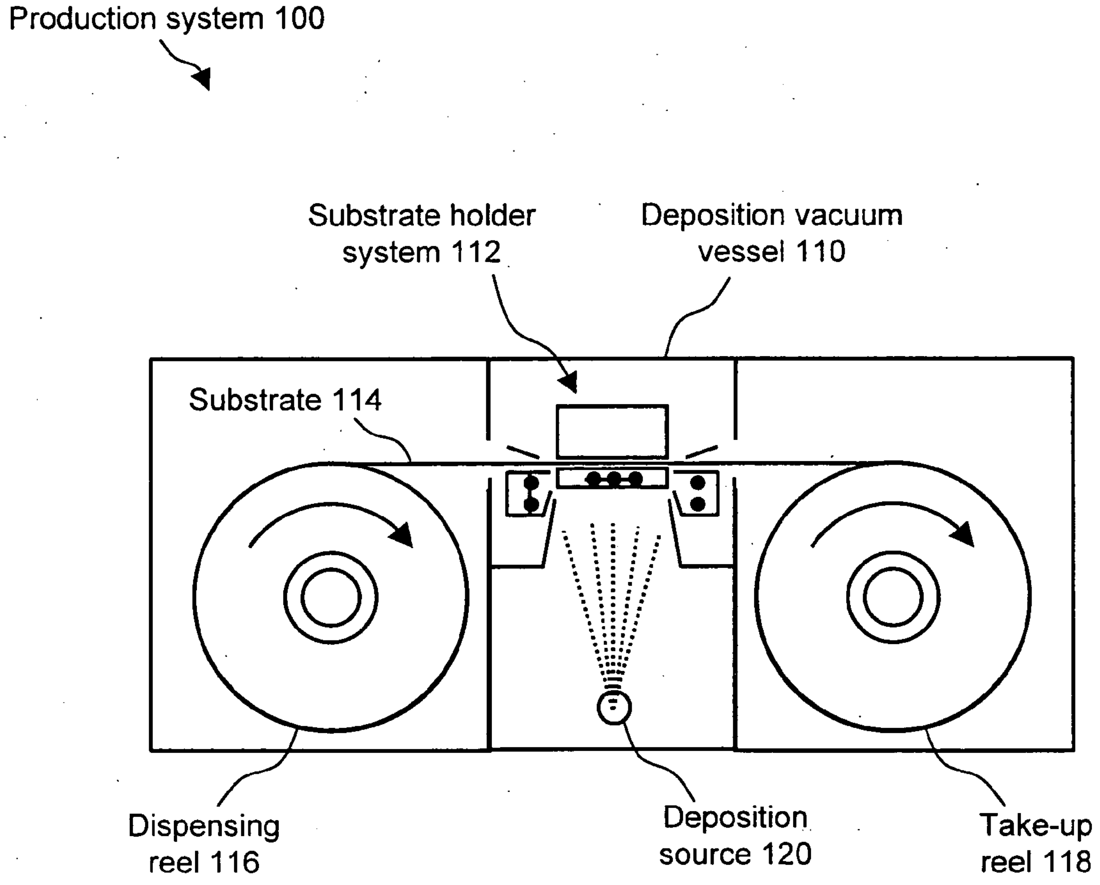

Production system 100
Substrate holder system 112
Deposition vacuum vessel 110
Substrate 114
Dispensing reel 116
Deposition source 120
Take-up reel 118

FIG. 1

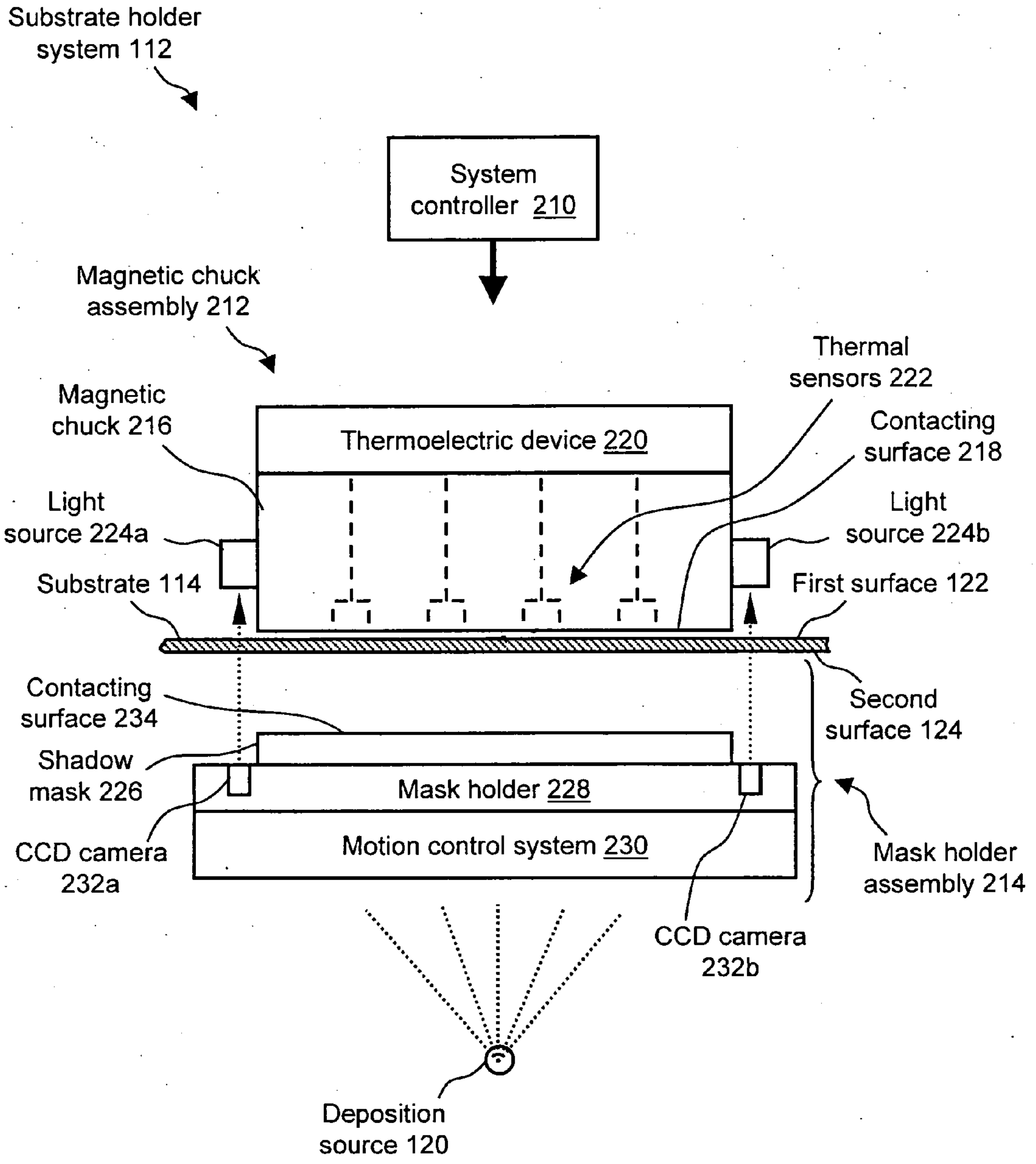

Substrate holder system 112
System controller 210
Magnetic chuck assembly 212
Thermal sensors 222
Magnetic chuck 216
Thermoelectric device 220
Contacting surface 218
Light source 224a
Light source 224b
Substrate 114
First surface 122
Contacting surface 234
Second surface 124
Shadow mask 226
Mask holder 228
CCD camera 232a
Motion control system 230
Mask holder assembly 214
CCD camera 232b
Deposition source 120

FIG. 2A

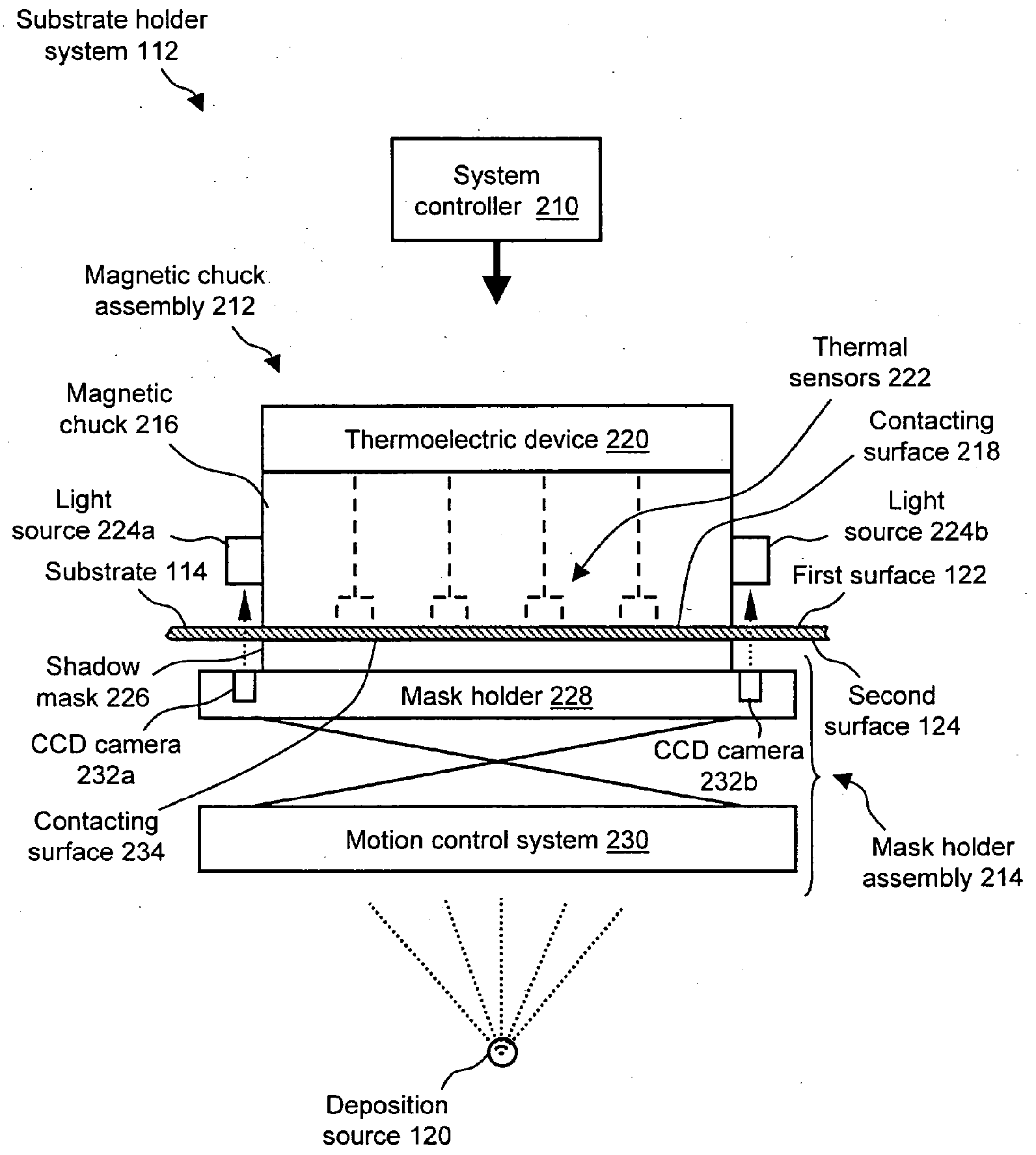

Substrate holder system 112
System controller 210
Magnetic chuck assembly 212
Thermal sensors 222
Magnetic chuck 216
Thermoelectric device 220
Contacting surface 218
Light source 224a
Light source 224b
Substrate 114
First surface 122
Shadow mask 226
Mask holder 228
Second surface 124
CCD camera 232a
CCD camera 232b
Contacting surface 234
Motion control system 230
Mask holder assembly 214
Deposition source 120

FIG. 2B

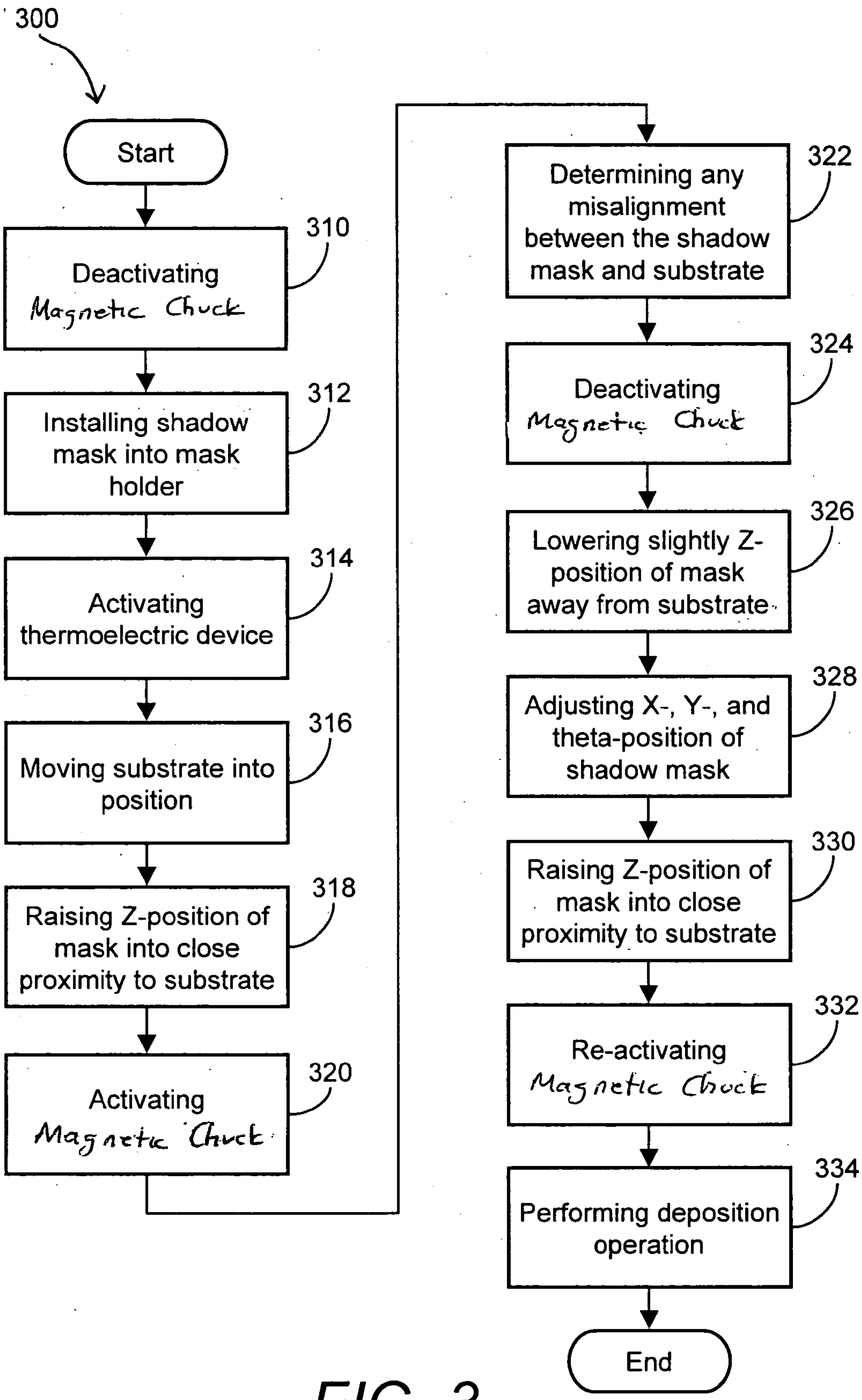

300
Start
Deactivating Magnetic Chuck
310
Installing shadow mask into mask holder
312
Activating thermoelectric device
314
Moving substrate into position
316
Raising Z-position of mask into close proximity to substrate
318
Activating Magnetic Chuck
320
Determining any misalignment between the shadow mask and substrate
322
Deactivating Magnetic Chuck
324
Lowering slightly Z-position of mask away from substrate
326
Adjusting X-, Y-, and theta-position of shadow mask
328
Raising Z-position of mask into close proximity to substrate
330
Re-activating Magnetic Chuck
332
Performing deposition operation
334
End

*FIG. 3*

# SUBSTRATE-TO-MASK ALIGNMENT AND SECURING SYSTEM WITH TEMPERATURE CONTROL FOR USE IN AN AUTOMATED SHADOW MASK VACUUM DEPOSITION PROCESS

## BACKGROUND OF THE INVENTION

**[0001]** 1. Field of the Invention

**[0002]** The present invention relates to shadow mask vacuum deposition and, more particularly, to a substrate holder system for use with a shadow mask vacuum deposition system.

**[0003]** 2. Description of Related Art

**[0004]** Thin-film display panels, such as liquid crystal displays or electroluminescent displays, are used for displaying information. Such displays include thin-film devices, such as electrodes and contact pads, deposited on a substrate in a manner to form a matrix display panel having individually energizable pixels. One of the challenges encountered in the manufacture of such display panels is the development of improved processes that pattern the thin-film electrode structures while they are in an in-line deposition system.

**[0005]** Thin-film devices of such displays are typically formed by photolithography or by shadow masking. Photolithography includes depositing a photosensitive material on a substrate, coating the photosensitive material with light-sensitive material, which is then exposed to a negative or positive pattern and developed and later stripped in various corrosive developing solutions. A disadvantage of this process includes its numerous labor intensive steps, each of which is subject to failure or possible contamination of the thin-film device.

**[0006]** Shadow masking is usually performed over small substrates with stiff masks that are manually clamped to ensure even contact with a particular substrate. Shadow masking is a relatively slow process and usually requires breaking vacuum in the deposition chamber which may result in some thin-film contamination. When using a large-area shadow mask in a deposition process, it is common that the substrate is not perfectly flat or not level with respect to its surrounding substrate holder. Additionally, most shadow masking processes required manually dropping each shadow mask over pins located on a substrate carrier.

**[0007]** In a shadow mask vacuum deposition process, each shadow mask is desirably in close contact with the corresponding substrate so that there is little or no gap between the shadow mask and the substrate whereupon the inadvertent deposition of material on undesirable area(s) of the substrate is avoided. Furthermore, in a shadow mask vacuum deposition process, it is desirable to have a uniform temperature across the area of the shadow mask in order to avoid misregistration caused by non-uniform expansion. For example, non-uniform expansion may cause the mask to be non-planar. Any such non-uniformity caused by expansion increases the possibility for inaccuracies in the deposition process.

**[0008]** Therefore, what is needed, and not disclosed in the prior art is a method and apparatus for use in a shadow mask vacuum deposition process that avoids material from being deposited in area(s) not defined by aperture(s) in the shadow mask and which also avoids temperature variations across the full area of the shadow mask in order to avoid misregistration between the substrate and the aperture(s) in the shadow mask.

## SUMMARY OF THE INVENTION

**[0009]** The invention is a material deposition system that includes a magnetic chuck that can be switched between a first state wherein magnetic flux generated by the magnetic chuck propagates from a contacting surface thereof and a second state wherein no magnetic flux propagates from the contacting surface thereof. The system includes a magnetically conductive shadow mask having a contacting surface. Lastly, the system includes means for movably supporting the contacting surface of the shadow mask in spaced parallel relation with the contacting surface of the magnetic chuck. In response to switching the magnetic chuck from its second state to its first state when a substrate is positioned between the contacting surface of the magnetic chuck and the contacting surface of the shadow mask, the magnetic flux generated by the magnetic chuck causes the shadow mask to be pulled toward the magnetic chuck thereby clamping the substrate between the contacting surface of the magnetic chuck and the contacting surface of the shadow mask.

**[0010]** In response to switching the magnetic chuck from the first state to the second state, the supporting means moves the shadow mask away from the magnetic chuck thereby forming a space between the substrate and the contacting surface of the shadow mask.

**[0011]** A material deposition source can be positioned on a side of the shadow mask opposite the magnetic chuck. The material deposition source can be operated to deposit a material on the substrate via the shadow mask when the substrate is clamped between the contacting surface of the magnetic chuck and the contacting surface of the shadow mask.

**[0012]** At least one thermal sensor can be provided for sensing a temperature of the magnetic chuck. A device can also be provided for heating or cooling the magnetic chuck to a desired temperature as a function of the temperature sensed by the thermal sensor.

**[0013]** A light source operative for outputting a beam of light can be coupled to the magnetic chuck or the supporting means. A camera can be coupled to the other of the magnetic chuck and the supporting means. A system controller can be provided for receiving an image output by the camera and for controlling the supporting means or a position of the substrate as a function of the image whereupon the camera is positioned to view the light beam output by the light source via a hole in the substrate.

**[0014]** The supporting means can include a mask holder coupled to a side of the shadow mask opposite the magnetic chuck and a motion control system coupled to a side of the mask holder opposite the shadow mask. The light source can be coupled to one of the magnetic chuck and the mask holder and the camera can be coupled to the other of the magnetic chuck and the mask holder. The system controller can receive the image output by the camera and can control at least one of the motion control system and the position of the substrate as a function of the received image.

**[0015]** The magnetic chuck, the shadow mask and the supporting means can be positioned in a vacuum vessel. A means for translating can be provided for translating at least a portion of the substrate into and out of the vacuum vessel.

**[0016]** The invention is also a vapor deposition method that includes: (a) positioning at least a portion of a substrate between a contacting surface of a magnetic chuck and a contacting surface of a shadow mask; (b) switching the magnetic chuck from a first state wherein no magnetic flux propagates from the contacting surface thereof to a second state wherein magnetic flux propagates from the contacting surface thereof whereupon the shadow mask is pulled toward the magnetic chuck thereby clamping the substrate between the contacting surface of the magnetic chuck and the contacting surface of the shadow mask; and (c) depositing a material on the substrate via at least one opening in the substrate.

**[0017]** The magnetic chuck can be switched from its second first state to its first state whereupon the shadow mask moves away from the magnetic chuck thereby forming a gap between the substrate and the contacting surface of the shadow mask. The portion of the substrate can then be translated from between the contacting surface of the magnetic chuck and the contacting surface of the shadow mask.

**[0018]** The magnetic chuck can be heated or cooled to a desired temperature. The heating or cooling of the magnetic chuck to the desired temperature can be controlled as a function of an actual temperature of the magnetic chuck.

**[0019]** Between step (b) and step (c) the method can include, in response to determining that the substrate and the shadow mask are misaligned, switching the magnetic chuck from its second state to its first state whereupon the shadow mask moves away from the magnetic chuck thereby forming a gap between the substrate and the contacting surface of the shadow mask. At least one of the substrate and the shadow mask can then be repositioned whereupon the substrate and the shadow mask are properly aligned. The magnetic chuck can then be switched from its first state to its second state whereupon the substrate is re-clamped between the contacting surface of the magnetic chuck and the contacting surface of the shadow mask.

**[0020]** The invention is also a material deposition system that includes a magnetic chuck operative between a first state where magnetic flux propagates from a contacting surface thereof and a second state wherein no magnetic flux propagates from the contacting surface thereof, and a magnetically conductive shadow mask having a contacting surface positioned in spaced relation to the contacting surface of the magnetic chuck. The system also includes means for supporting a substrate between the contacting surface of the magnetic chuck and the contacting surface of the shadow mask. In response to the magnetic chuck entering its first state, the shadow mask and the magnetic chuck clamp the substrate between the contacting surfaces thereof. In response to the magnetic chuck entering its second state the shadow mask and the magnetic chuck release the substrate.

**[0021]** The system can include a material deposition source operative for depositing a material on the substrate via one or more apertures in the shadow mask. The magnetic chuck, the shadow mask, the substrate and the material deposition source can be positioned in a vacuum vessel. The material deposition source can deposit the material on the substrate in the presence of a vacuum in the vacuum vessel.

**[0022]** A temperature sensor can sense a temperature of the magnetic chuck and/or the shadow mask and can output a temperature signal corresponding to the sensed temperature. A temperature control device can control the temperature of the magnetic chuck and/or the shadow mask as a function of the temperature signal output by the temperature sensor.

**[0023]** A mask holder can support the shadow mask and a motion control system can support the mask holder and the shadow mask. The motion control system can be operated to rotate the mask holder and the shadow mask around an axis normal to the contacting surface of the shadow mask, translate the mask holder and the shadow mask in a direction parallel to the axis, and/or translate the mask holder and the shadow mask in at least one direction perpendicular to the axis.

**[0024]** A light source operative for outputting a beam of light can be coupled to one of the magnetic chuck and the mask holder. A camera operative for outputting an image of an object positioned in a field of view of the camera can be coupled to the other of the magnetic chuck and the mask holder. A system controller can be operated for receiving the image output by the camera and for controlling at least one of the motion control system and a position of the substrate as a function of the image whereupon the camera is positioned to view the light beam output by the light source via a hole in the substrate.

**[0025]** Lastly, the invention is a vacuum deposition method that includes: (a) magnetically clamping a substrate between a chuck and a shadow mask; (b) depositing a material on the substrate via at least one opening in the substrate; and (c) releasing the magnetic clamp on the substrate whereupon at least one of the chuck and the shadow mask moves into spaced relation with the substrate whereupon the substrate can be translated from a position between the chuck and the shadow mask.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0026]** **FIG. 1** illustrates an exemplary production system for performing shadow mask vacuum deposition;

**[0027]** **FIG. 2A** illustrates a side view of a substrate holder system in accordance with the present invention in a non-activated state;

**[0028]** **FIG. 2B** illustrates a side view of the substrate holder system of **FIG. 2A** in an activated state; and

**[0029]** **FIG. 3** is a flow diagram of a method of using the substrate holder system of the present invention in an automated continuous production process.

## DETAILED DESCRIPTION OF THE INVENTION

**[0030]** With reference to **FIG. 1**, a production system **100** for performing shadow mask vacuum deposition includes a deposition vacuum vessel **110** having therein a substrate holder system **112** for securing a substrate **114** during a deposition operation. Substrate **114** is formed of, for example, anodized aluminum, flexible steel foil, glass or plastic. Physical reference features are formed on substrate

**114** in the form of, for example, punched holes or deposited patterns. These physical reference features are used to properly align substrate **114** to substrate holder system **112**. Substrate **114** translates through deposition vacuum vessel **110** by way of a reel-to-reel mechanism that includes a dispensing reel **116** and a take-up reel **118**.

[**0031**] Deposition vacuum vessel **110** further includes at least one deposition source **120** which can supply deposition source material, such as metal, semiconductor, insulator, or organic electroluminescent material, to be deposited via an evaporation process.

[**0032**] Production system **100** is not limited to one deposition vacuum vessel **110**, as shown in **FIG. 1**. Rather, production system **100** may include two or more deposition vacuum vessels **110** arranged serially, depending on the number of deposition events required for any given product to be formed therewith. Those skilled in the art will appreciate that production system **100** may include additional stages (not shown), such as an anneal stage, a test stage, one or more cleaning stages, a cut and mount stage, and the like, as is well-known. Furthermore, production system **100** is not limited to a reel-to-reel system for manipulating substrate **114**. Alternatively, production system **100** is a non-reel-to-reel system, i.e., a piece processing system. An example of a suitable production system **100** is disclosed in U.S. Patent Application Publication No. 2003/0228715, entitled "Active Matrix Backplane For Controlling Controlled Elements And Method Of Manufacture Thereof", which is incorporated herein by reference.

[**0033**] Deposition vacuum vessel **110** is utilized for depositing materials from one or more deposition sources **120** onto substrate **114** to form one or more electronic elements on substrate **114**. Each electronic element may be, for example, a thin film transistor (TFT), a diode, a memory element or a capacitor. A multi-layer circuit can be formed on substrate **114** solely by the successive deposition of materials via successive deposition events within a serial arrangement of multiple deposition vacuum vessels **110**.

[**0034**] With reference to **FIG. 2A** and with continuing reference to **FIG. 1**, substrate holder system **112** includes a system controller **210**, a magnetic chuck assembly **212** and a mask holder assembly **214**.

[**0035**] Magnetic chuck assembly **212** includes a magnetic chuck **216** that has a contacting surface **218** facing toward a first surface **122** of substrate **114**, a thermoelectric device **220** that is thermally coupled to magnetic chuck **216** and electrically coupled to a plurality of thermal sensors **222** installed at or adjacent contacting surface **218** of magnetic chuck **216**, and light sources **224***a* and **224***b* arranged at the outer perimeter of magnetic chuck **216**.

[**0036**] Mask holder assembly **214** includes a shadow mask **226** that is mounted upon a mask holder **228**, a motion control system **230** for providing X-, Y-, Z-, and theta-position adjustment to mask holder **228** and, thereby, to shadow mask **226**, and a plurality of charged coupled device (CCD) cameras **232***a* and **232***b*. Each CCD camera **232** of mask holder assembly **214** is associated with a respective light source **224** of magnetic chuck assembly **212**. A contacting surface **234** of shadow mask **226** faces a second surface **124** of substrate **114**. Operating under the control of a control program, system controller **210** manages the operation of magnetic chuck assembly **212**. More particularly, system controller **210** receives inputs from thermal sensors **222**, receives images from cameras **232** and outputs control signals that control the operation of magnetic chuck **216**, thermoelectric device **220**, light sources **224** and/or motion control system **230**.

[**0037**] Magnetic chuck **216** is commercially available and is formed of a magnetic material that has a large mass, as compared with the mass of substrate **114** and shadow mask **226**. Contacting surface **218** of magnetic chuck **216** is desirably smooth and planar. In one embodiment, magnetic chuck **216** generates a magnetic field in response to electrical stimulation. More specifically, in this one embodiment, magnetic chuck **216** is a pulsed electromagnet wherein a short pulse of current generates a first high intensity magnetic field. The magnetic material that forms magnetic chuck **216**, however, has a high residual flux density whereupon when the current pulse is ended, a second high intensity magnetic field remains. Desirably, the second high intensity magnetic field has the same flux density as the first high intensity magnetic field. However, this is not to be construed as limiting the invention since the second high intensity magnetic field can have a flux density less than the first high intensity magnetic field provided the second high intensity magnetic field has a flux density suitable for the present application. A reverse current pulse of suitable magnitude causes the intensity of the second high intensity magnetic field of magnetic chuck **216** to return to zero. In this way, the magnetic field of magnetic chuck **216** can be switched between the second high intensity magnetic field and zero. Because of the shortness of the current pulse, very little heat is generated when magnetic chuck **216** is energized and, thus, magnetic chuck **216** contributes very little heat to the overall system. Magnetic chuck **216** also has an associated power supply (not shown).

[**0038**] Magnetic chuck **216** and, thus, contacting surface **218** of magnetic chuck **216**, is sized according to the size of the product to be formed via the shadow mask vacuum deposition process. For example, to form a 16-inch diagonal display panel, contacting surface **218** of magnetic chuck **216** is approximately 10×13 inches. An exemplary manufacturer of magnetic chuck **216** in the form of a pulsed electromagnetic is Eclipse Magnetics of Sheffield, England.

[**0039**] In an alternate embodiment, magnetic chuck **216** is a mechanically switched magnet whose poles are engaged or disengaged pneumatically or manually via a lever. An exemplary manufacturer of a mechanically switched magnetic chuck is Eclipse Mechanics of Sheffield, England.

[**0040**] Thermoelectric device **220** is a commercially available Peltier junction-type device that can provide either heating or cooling to magnetic chuck **216**, depending on the direction of electrical current flowing through thermoelectric device **220**. Thermoelectric device **220** is electrically coupled to thermal sensors **222**, which provide feedback regarding the temperature of contacting surface **218** of magnetic chuck **216**. Thermal sensors **222** are, for example, standard temperature sensing devices installed within cavities at or adjacent contacting surface **218** of magnetic chuck **216**.

[**0041**] Thermoelectric device **220** is capable of providing heating and cooling in the range of 0.1 to 5 watts/second. Because substrate **114** and shadow mask **226** are stabilized to approximately room temperature during the shadow mask vacuum deposition process, thermoelectric device **220** need only be capable of heating or cooling substrate **114** no greater than ±40 degrees C. Example manufacturers of thermoelectric device **220** include Tellurex Corporation of Traverse City, Mich. and Thermo Electron Corporation of Waltham, Mass.

[**0042**] Light sources **224** of magnetic chuck assembly **212** are standard light source devices. Each light source **224** provides a suitably intense beam of light that is directed at an associated CCD camera **232**. Each CCD camera **232** is a light-sensitive device of the type that is used in most digital cameras to convert the light entering through a lens from a field of view of the camera into electronic signals that can be digitally processed and/or viewed on a video monitor unit. Each CCD camera **232** is mounted within the frame of mask holder **228** in a fixed and known position relative to shadow mask **226** which is also mounted upon mask holder **228**.

[**0043**] The combination of system controller **210**, light sources **224** and CCD cameras **232** form an exemplary machine vision system that can perform position measurements using well-known image processing and feature recognition techniques implemented in software. Therefore, the use of system controller **210**, light sources **224** and CCD cameras **232** provides the capability to accurately align shadow mask **226** to substrate **114**. However, those skilled in the art will appreciate that there are a number of well-known alignment techniques and instrumentation that may be used alternatively to the combination of system controller **210**, light sources **224** and CCD cameras **232**.

[**0044**] The combination of magnetic chuck **216** and thermoelectric device **220** is held stationary within, for example, deposition vacuum vessel **110** of production system **100**.

[**0045**] Shadow mask **226** is formed of a magnetic material, such as nickel, steel, Kovar or Invar, and has a thickness of, for example, 50-200 microns. Kovar and Invar can be obtained from, for example, ESPICorp Inc. of Ashland, Oreg. In the United States, Kovar® is a registered Trademark, United States Trademark Registration No. 337,962, currently owned by CRS Holdings, Inc. of Wilmington, Del. In the United States, Invar® is a registered Trademark, United States Trademark Registration No. 63,970, currently owned by Imphy S.A. Corporation of France. Shadow mask **226** includes a pattern of apertures (not shown), e.g., slots and holes, as is well-known. The pattern of apertures in shadow mask **226** corresponds to a desired pattern of material to be deposited on substrate **114** from deposition source **120** within deposition vacuum vessel **110** as substrate **114** is advanced therethrough.

[**0046**] Mask holder **228** is a frame structure that is desirably formed of a suitably rigid non-magnetic material, such as copper or aluminum, in order to avoid shorting the magnetic flux generated by magnetic chuck **216**. Alternatively, mask holder **228** is formed of a magnetic material, such as steel, Invar or Kovar. Mask holder **228** has, for example, a planar raised ridge (not shown) for bonding the perimeter of shadow mask **226** thereon. Bonding may be facilitated by an adhesive, resistance welding, or brazing. Additionally, shadow mask **226** is bonded to mask holder **228** with a desired tension using known techniques. A clearance area (not shown) is provided within the center region of mask holder **228** to allow evaporant from a deposition source, such as deposition source **120**, to pass therethrough and, subsequently, to allow the evaporant to pass through the aperture(s) of shadow mask **226**. Mask holder **228** is sized according to an expected size of shadow mask **226** or is alternatively designed to handle a range of shadow mask **226** sizes. Additionally, mask holder **228** is mechanically coupled to a standard motion control system **230** for providing X-, Y-, Z-, and theta-position adjustment to mask holder **228** and, thereby, to shadow mask **226**. An exemplary manufacturer of a standard motion control system that is suitable for use with mask holder assembly **214** is Aerotech Inc. of Pittsburgh, Pa.

[**0047**] When substrate holder system **112** of the present invention is in a non-activated state, first surface **122** of substrate **114** is not in intimate contact with contacting surface **218** of magnetic chuck **216** and substrate **114** is free to translate longitudinally in a plane parallel to contacting surface **218** and contacting surface **234** of magnetic chuck **216** and shadow mask **226**, respectively, via, for example, the rotation motion of dispensing reel **116** and take-up reel **118** of production system **100**.

[**0048**] With reference to **FIG. 2B** and with continuing reference to **FIGS. 1 and** 2A, when substrate holder system **112** is in an activated state, first surface **122** of substrate **114** is in intimate contact with contacting surface **218** of magnetic chuck **216**, and contacting surface **234** of shadow mask **226** is held in contact with second surface **124** of substrate **114**. As a result, substrate **114** is tightly secured between magnetic chuck **216** and shadow mask **226** whereupon substrate **114** is not free to move.

[**0049**] In operation of substrate holder system **112**, magnetic chuck **216** and thermoelectric device **220** are initially de-energized whereupon first surface **122** and second surface **124** of substrate **114** are spaced from contacting surface **218** and contacting surface **234** of magnetic chuck assembly **212** and mask holder assembly **214**, respectively, as shown in **FIG. 2A**. Substrate **114** and shadow mask **226** are aligned by use of CCD cameras **232**, light sources **224**, and motion control system **230**. More specifically, light from light sources **224** pass through alignment holes (not shown) in substrate **114** for receipt by CCD cameras **232**. Under the control of motion control system **230**, the position of mask holder **228** and, thereby, shadow mask **226** is adjusted to bring each CCD camera **232** into alignment with its corresponding light source **224** and the corresponding alignment aperture in substrate **114**. If desired, motion control system **230** can be operative for controlling the translation of substrate **114** to facilitate alignment between each CCD camera **232**, its corresponding light source **224** and the corresponding aperture in substrate **114**.

[**0050**] Shadow mask **226** is then moved in close proximity to substrate **114** via the Z-position adjustment of motion control system **230**. Magnetic chuck **216** is then activated to produce a magnetic field that propagates from contacting surface **218** thereof and pulls shadow mask **226** toward magnetic chuck **216** whereupon first surface **122** of substrate **114** is pulled into contact with contacting surface **218** of magnetic chuck **216** and contacting surface **234** of shadow mask **226** is pulled into contact with second surface **124** of substrate **114**. Thus, the activation of magnetic chuck **216** causes substrate **114** to be clamped between contacting surface **234** of shadow mask **226** and contacting surface **218** of magnetic chuck **216**.

[0051] Thermoelectric device **220** is then activated to heat or cool, as necessary, magnetic chuck **216**, substrate **114** and shadow mask **226** to a predetermined temperature. When first and second surfaces **122** and **124** of substrate **114** are in contact with contacting surfaces **218** and **234** of magnetic chuck **216** and shadow mask **226**, respectively, material evaporated from deposition source **120** passes through the aperture(s) of shadow mask **226** and condenses upon second surface **124** of substrate **114**.

[0052] Upon completing deposition of the material from deposition source **120**, magnetic chuck **216** and thermoelectric device **220** are deactivated. With magnetic chuck **216** deactivated, motion control system **230** adjusts the Z-position of mask holder **228** whereupon contacting surface **234** is caused to move away from second surface **124** of substrate **114**, e.g., to the position shown in **FIG. 2A**, whereupon the section of substrate **114** between magnetic chuck **216** and shadow mask **226** can be translated in a plane parallel to contacting surface **218**.

[0053] With reference to **FIG. 3** and with continuing reference to **FIGS. 1, 2A** and 2B, a method **300** of using substrate holder system **112** includes step **310** wherein under the control of system controller **210**, magnetic chuck **216** is held in a de-energized or deactivated state whereupon no magnetic field is generated for pulling shadow mask **226** toward magnetic chuck **216**. As a result, substrate **114** is free to translate between magnetic chuck **216** and shadow mask **226** in a plane parallel to contacting surface **218** of magnetic chuck **216**.

[0054] The method then advances to step **312**, wherein shadow mask **226** is secured on mask holder **228** in a fixed and known position relative to CCD cameras **232** by, for example, an adhesive, resistance welding or brazing.

[0055] The method then advances to step **314**, wherein, under the control of system controller **210**, thermoelectric device **220** is activated thereby generating heat or cold for holding magnetic chuck **216**, substrate **114**, and shadow mask **226** at a predetermined temperature, such as room temperature, when substrate **114** is in contact with magnetic chuck **216** and shadow mask **226**. Feedback from thermal sensors **222** located at or adjacent contacting surface **218** of magnetic chuck **216** are the mechanism for determining when the predetermined temperature is reached.

[0056] The method then advances to step **316**, wherein, substrate **114** is translated into the proper position relative to substrate holder system **112** via, for example, the rotation of dispensing reel **116** and take-up reel **118** of production system **100**.

[0057] The method then advances to step **318**, wherein, under the control of system controller **210**, the Z-position of mask holder **228** is adjusted by use of motion control system **230** to move contacting surface **234** of shadow mask **226** into close proximity with second surface **124** of substrate **114**.

[0058] The method then advances to step **320**, wherein, under the control of system controller **210**, magnetic chuck **216** is energized whereupon a magnetic field propagates from contacting surface **218** and pulls shadow mask **226**, which is formed of magnetic material, toward magnetic chuck **216**. As a result, first surface **122** of substrate **114** is held in contact with contacting surface **218** of magnetic chuck **216**, and contacting surface **234** of shadow mask **226** is held in contact with second surface **124** of substrate **114**. Consequently, substrate **114** is clamped or compressed between magnetic chuck **216** and shadow mask **226**.

[0059] The method then advances to step **322**, wherein, under the control of system controller **210**, it is determined whether there is misalignment between shadow mask **226** and substrate **114** using any well-known vision or optical measurement system. For example, the combination of system controller **210**, light sources **224** and CCD cameras **232** form an exemplary machine vision system that can perform position measurements using well-known image processing and feature recognition techniques implemented in software running on system controller **210**. In the case of substrate **114** having punched holes as the alignment reference features, light sources **224** are activated and CCD cameras **232** visually detect the position of the punched alignment features of substrate **114**. Because the position of CCD cameras **232** relative to shadow mask **226** is known, the position of substrate **114** relative to shadow mask **226** can be determined and transmitted to system controller **210**. System controller **210** then compares the actual position of substrate **114** relative to shadow mask **226** to an expected position, thereby defining the position error, if any. System controller **210** then transmits suitable position correction information to motion control system **230**.

[0060] The method then advances to step **324**, wherein, under the control of system controller **210**, magnetic chuck **216** is de-energized whereupon no magnetic field is generated for pulling shadow mask **226** toward magnetic chuck **216**. As a result, first surface **122** of substrate **114** is no longer pulled into contact with contacting surface **218** of magnetic chuck **216**, and contacting surface **234** of shadow mask **226** is no longer pulled into contact with second surface **124** of substrate **114**. Desirably, when magnetic chuck **216** is de-energized, a space or gap is formed between substrate **114** and at least one of magnetic chuck **216** and shadow mask **226**.

[0061] The method then advances to step **326**, wherein, under the control of system controller **210**, the Z-position of mask holder **228** is adjusted by use of motion control system **230** in order to ensure that shadow mask **226** does not touch substrate **114**.

[0062] The method then advances to step **328**, wherein, using the position correction information received from system controller **210** in step **322**, the motion control system **230** adjusts the X-, Y-, and theta-position of mask holder **228** by an amount determined in step **322** in order to achieve proper alignment of shadow mask **226** to substrate **114**.

[0063] The method then advances to step **330**, wherein, under the control of system controller **210**, the Z-position of mask holder **228** is adjusted by use of motion control system **230**, such that shadow mask **226** is in close proximity to substrate **114**.

[0064] The method then advances to step **332**, wherein, under the control of system controller **210**, magnetic chuck **216** is re-energized and, thus, a magnetic field is generated that pulls shadow mask **226** toward magnetic chuck **216**. As a result, first surface **122** of substrate **114** is pulled into contact with contacting surface **218** of magnetic chuck **216**, and contacting surface **234** of shadow mask **226** is pulled into contact with second surface **124** of substrate **114**. Consequently, substrate **114** is now clamped or compressed between magnetic chuck **216** and shadow mask **226**.

**[0065]** The method then advances to step **334**, wherein a deposition process is performed, such as the deposition process described in connection with production system **100** of **FIG. 1** or one of the deposition processes disclosed in U.S. Patent Application Publication No. 2003/0228715.

**[0066]** In summary, intimate contact between shadow mask **226** and substrate **114** within substrate holder system **112** is accomplished via switched magnetic chuck **216** which magnetically pulls shadow mask **226**, which is formed of magnetic material, into intimate contact with substrate **114**, which is sandwiched between magnetic chuck **216** and shadow mask **226**. Consequently, substrate **114** is also pulled into intimate contact with magnetic chuck **216**. Thermoelectric device **220** holds magnetic chuck **212** at a fixed, predetermined temperature. The intimate contact of magnetic chuck **216**, substrate **114** and shadow mask **226** assures that heat is transferred uniformly and that all three are held at or near the same temperature during the shadow mask vacuum deposition process, thereby ensuring accurate registration between shadow mask **226** and substrate **114** is maintained. Additionally, the intimate contact between substrate **114** and shadow mask **226** avoids evaporant material from entering any gaps therebetween. Furthermore, system controller **210** controls magnetic chuck **216**, thermoelectric device **220**, CCD cameras **232**, light sources **224**, and motion control system **230** thereby rendering substrate holder system **112** amenable to an automated continuous vacuum deposition process.

**[0067]** The use of substrate holder system **112** and method **300** of the present invention is not limited to a production system configuration wherein the substrate translates serially from one vacuum deposition vessel to the next and wherein each vacuum deposition vessel contains a unique shadow mask. Those skilled in the art will recognize that the use of substrate holder system **112** and method **300** is easily adapted for a production system configuration wherein only one vacuum deposition vessel exists and multiple shadow masks and deposition sources are moved into and out of the vessel with each successive deposition event.

**[0068]** Additionally, the use of substrate holder system **112** and method **300** of the present invention is not limited to a production system configuration wherein the substrate translates via a reel-to-reel system. Those skilled in the art will recognize that substrate holder system **112** and method **300** may be adapted for use with a non-reel-to-reel system, i.e., a piece processing system, which would include a substrate holder frame. For example, in a non-reel-to-reel system the X-, Y-, Z- and theta-position adjustments may be made to either mask holder **228** or the substrate holder frame. In the case of the non-reel-to-reel system, it is desirable to distribute the positioning axis to both mask holder **228** and the substrate holder frame, i.e., X- and Y-position adjustments are applied to mask holder **228** and Z- and theta-position adjustments are applied to the substrate holder.

**[0069]** The present invention has been described with reference to the preferred embodiments. Obvious modifications and alterations will occur to others upon reading and understanding the preceding detailed description. For example, the positioning of light sources **224** on magnetic chuck **216** and the positioning of CCD cameras **232** on mask holder **228** are not to be construed as limiting the invention since it is envisioned that one or more light sources **224** can be positioned on mask holder **228** and one or more CCD cameras can be positioned on magnetic chuck **216**. Moreover, the use of light sources **224** and CCD cameras **232** can be alternated on magnetic chuck **216** and mask holder **228**. For example, one CCD camera and its corresponding light source can be positioned on mask holder **228** and magnetic chuck **216**, respectively, while a second CCD camera and its corresponding light source can be positioned on magnetic chuck **216** and mask holder **228**, respectively. It is intended that the invention be construed as including all such modifications and alterations insofar as they come within the scope of the appended claims or the equivalents thereof.

The invention claimed is:

**1**. A material deposition system comprising:

a magnetic chuck, said magnetic chuck switchable between a first state wherein magnetic flux generated by said magnetic chuck propagates from a contacting surface thereof and a second state wherein no magnetic flux propagates from the contacting surface thereof;

a magnetically conductive shadow mask, said shadow mask defining a contacting surface; and

means for movably supporting the contacting surface of said shadow mask in spaced parallel relation with the contacting surface of said magnetic chuck, wherein, in response to switching said magnetic chuck from the second state to the first state when a substrate is positioned between the contacting surface of said magnetic chuck and the contacting surface of said shadow mask, the magnetic flux generated by said magnetic chuck causes said shadow mask to be pulled toward said magnetic chuck whereupon said substrate is clamped between the contacting surface of said magnetic chuck and the contacting surface of said shadow mask.

**2**. The system of claim 1, wherein in response to switching said magnetic chuck from the first state to the second state, said supporting means moves said shadow mask away from said magnetic chuck thereby forming a gap between said substrate and the contacting surface of said shadow mask.

**3**. The system of claim 1, further including a material deposition source positioned on a side of said shadow mask opposite said magnetic chuck, said material deposition source operative for depositing a material on said substrate via said shadow mask when said substrate is clamped between the contacting surface of said magnetic chuck and the contacting surface of said shadow mask.

**4**. The system of claim 1, further including:

at least one thermal sensor operative for sensing a temperature of said magnetic chuck; and

a device operative for heating or cooling said magnetic chuck to a desired temperature as a function of the temperature sensed by said thermal sensor.

**5**. The system of claim 1, further including:

a light source coupled to one of said magnetic chuck and said supporting means, said light source operative for outputting a beam of light;

a camera coupled to the other of said magnetic chuck and said supporting means; and

a system controller operative for receiving an image output by said camera and for controlling at least one of said supporting means and a position of said substrate as a function of said image whereupon said camera is positioned to view the light beam output by said light source via an alignment aperture in said substrate.

**6**. The system of claim 1, wherein said supporting means includes:

a mask holder coupled to a side of said shadow mask opposite said magnetic chuck; and

a motion control system coupled to a side of said mask holder opposite said shadow mask.

**7**. The system of claim 6, further including:

a light source coupled to one of said magnetic chuck and said mask holder, said light source operative for outputting a beam of light;

a camera coupled to the other of said magnetic chuck and said mask holder; and

a system controller operative for receiving an image output by said camera and for controlling at least one of said motion control system and a position of said substrate as a function of said image whereupon said camera is positioned to view the light beam output by said light source via an alignment aperture in said substrate when said substrate is clamped between the contacting surface of said magnetic chuck and the contacting surface of said shadow mask.

**8**. The system of claim 1, further including:

a vacuum vessel having the magnetic chuck, the shadow mask and the supporting means positioned therein; and

means for translating at least a portion of the substrate into and out of the vacuum vessel.

**9**. A vapor deposition method comprising:

(a) positioning at least a portion of a substrate between a contacting surface of a magnetic chuck and a contacting surface of a shadow mask;

(b) switching said magnetic chuck from a first state wherein no magnetic flux propagates from the contacting surface thereof to a second state wherein magnetic flux propagates from the contacting surface thereof whereupon said shadow mask is pulled toward said magnetic chuck thereby clamping said substrate between the contacting surface of said magnetic chuck and the contacting surface of said shadow mask; and

(c) depositing a material on said substrate via at least one opening in said substrate.

**10**. The method of claim 9, further including:

(d) switching said magnetic chuck from the second state to the first state whereupon said shadow mask moves away from said magnetic chuck thereby forming a gap between said substrate and the contacting surface of said shadow mask.

**11**. The method of claim 10, further including:

(e) moving the portion of said substrate from between the contacting surface of said magnetic chuck and the contacting surface of said shadow mask.

**12**. The method of claim 9, further including:

heating or cooling said magnetic chuck; and

controlling said heating or cooling as a function of a temperature of said magnetic chuck.

**13**. The method of claim 9, further including between step (b) and step (c) the steps of:

in response to determining that said substrate and said shadow mask are misaligned, switching said magnetic chuck from the second state to the first state whereupon said shadow mask moves away from said magnetic chuck thereby forming a gap between said substrate and the contacting surface of said shadow mask;

repositioning at least one of said substrate and said shadow mask whereupon said substrate and said shadow mask are properly aligned; and

switching said magnetic chuck from the first state to the second state whereupon said substrate is clamped between the contacting surface of said magnetic chuck and the contacting surface of said shadow mask.

**14**. A material deposition system comprising:

a magnetic chuck operative between a first state where magnetic flux propagates from a contacting surface thereof and a second state wherein no magnetic flux propagates from the contacting surface thereof;

a magnetically conductive shadow mask having a contacting surface positioned in spaced relation with the contacting surface of said magnetic chuck;

means for supporting a substrate between the contacting surface of said magnetic chuck and the contacting surface of said shadow mask, wherein:

in response to said magnetic chuck entering the first state, said shadow mask and said magnetic chuck clamp said substrate between the contacting surfaces thereof; and

in response to said magnetic chuck entering the second state, said shadow mask and said magnetic chuck release said substrate.

**15**. The system of claim 14, further including a material deposition source operative for depositing a material on said substrate via one or more apertures in the shadow mask.

**16**. The system of claim 15, further including a vacuum vessel having said magnetic chuck, said shadow mask, said substrate and said material deposition source received therein, wherein said material deposition source deposits said material on said substrate in the presence of a vacuum in said vacuum vessel.

**17**. The system of claim 14, further including:

a temperature sensor for sensing a temperature of at least one of said magnetic chuck and said shadow mask and for outputting a temperature signal corresponding to the sensed temperature; and a device for controlling the temperature of the at least one of said magnetic chuck and said shadow mask as a function of the temperature signal output by the temperature sensor.

**18**. The system of claim 14, further including:

a mask holder for supporting said shadow mask; and

a motion control system for supporting said mask holder and said shadow mask, said motion control system operative for at least one of:

rotating said mask holder and said shadow mask around an axis normal to the contacting surface of said shadow mask;

translating said mask holder and said shadow mask in a direction parallel to said axis; and

translating said mask holder and said shadow mask in at least one direction perpendicular to said axis.

**19**. The system of claim 18, further including:

a light source coupled to one of said magnetic chuck and said mask holder, said light source operative for outputting a beam of light;

a camera coupled to the other of said magnetic chuck and said mask holder, said camera operative for outputting an image of an object positioned in a field of view of said camera; and

a system controller operative for receiving the image output by said camera and for controlling at least one of said motion control system and a position of said substrate as a function of said image whereupon said camera is positioned to view the light beam output by said light source via a hole in said substrate.

**20**. A vacuum deposition method comprising:

(a) magnetically clamping a substrate between a chuck and a shadow mask;

(b) depositing a material on said substrate via at least one opening in said substrate; and

(c) releasing the magnetic clamp on said substrate whereupon at least one of said chuck and said shadow mask moves into spaced relation with said substrate.

* * * * *