(54) **MULTI-STATION SPUTTERING AND CLEANING SYSTEM**

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(57)   **ABSTRACT**

A multi-chamber processing system is described for depositing materials on multiple workpieces (wafers, display panels, or any other workpieces) at a time in a vacuum chamber. The system includes a sputtering chamber and a separate pre-clean chamber, where wafers can be transferred between the two chambers by a robotic arm without breaking a vacuum. The wafers are mounted one-by-one onto a rotating pallet in the pre-cleaning chamber and sputtering chamber. The pallet is firmly fixed to a rotatable table in the sputtering chamber. Copper tubing in the table couples RF energy to the wafers, and a liquid running through the copper tubing controls the temperature of the wafers. Multiple targets, of the same or different materials, may concurrently deposit material on the wafers as the pallet is rotating. Multiple magnets (one for each target) in the magnetron assembly in the sputtering chamber oscillate over their respective targets for uniform target erosion and uniform deposition on the wafers. An electrically insulated target backing plate between each magnet and a target has a liquid channel running through it for controlling temperature. The distance between the magnets and the targets is made very small by a thin aluminum plate fixed to the bottom segment of the target backing plate by a dip brazing process. Various shields are described to prevent cross-contamination from the targets and prevent the sputtered target material from entering gaps in the chamber and shorting out insulators.
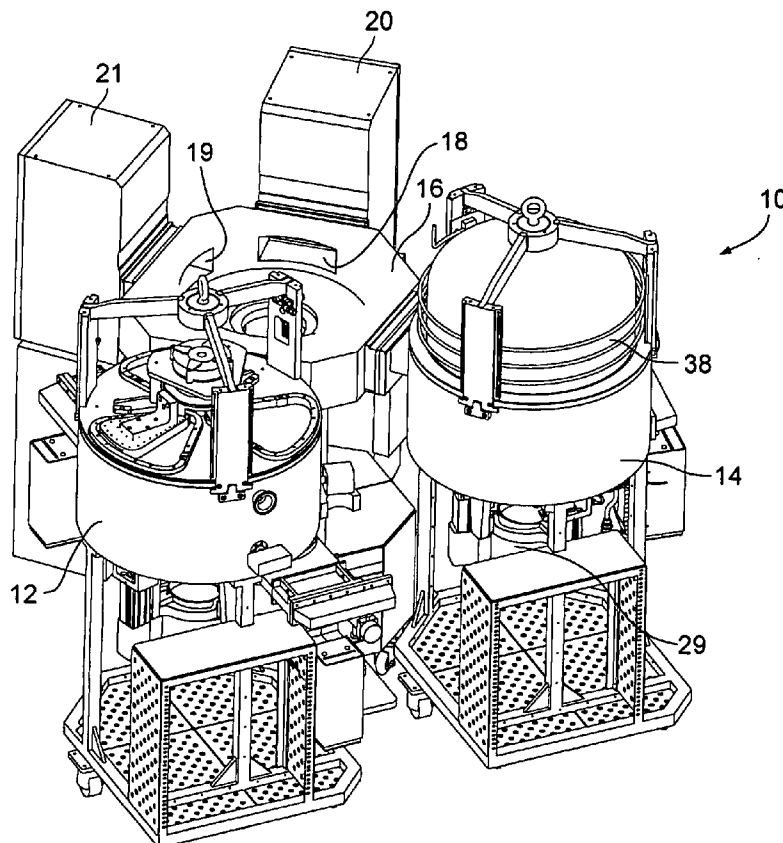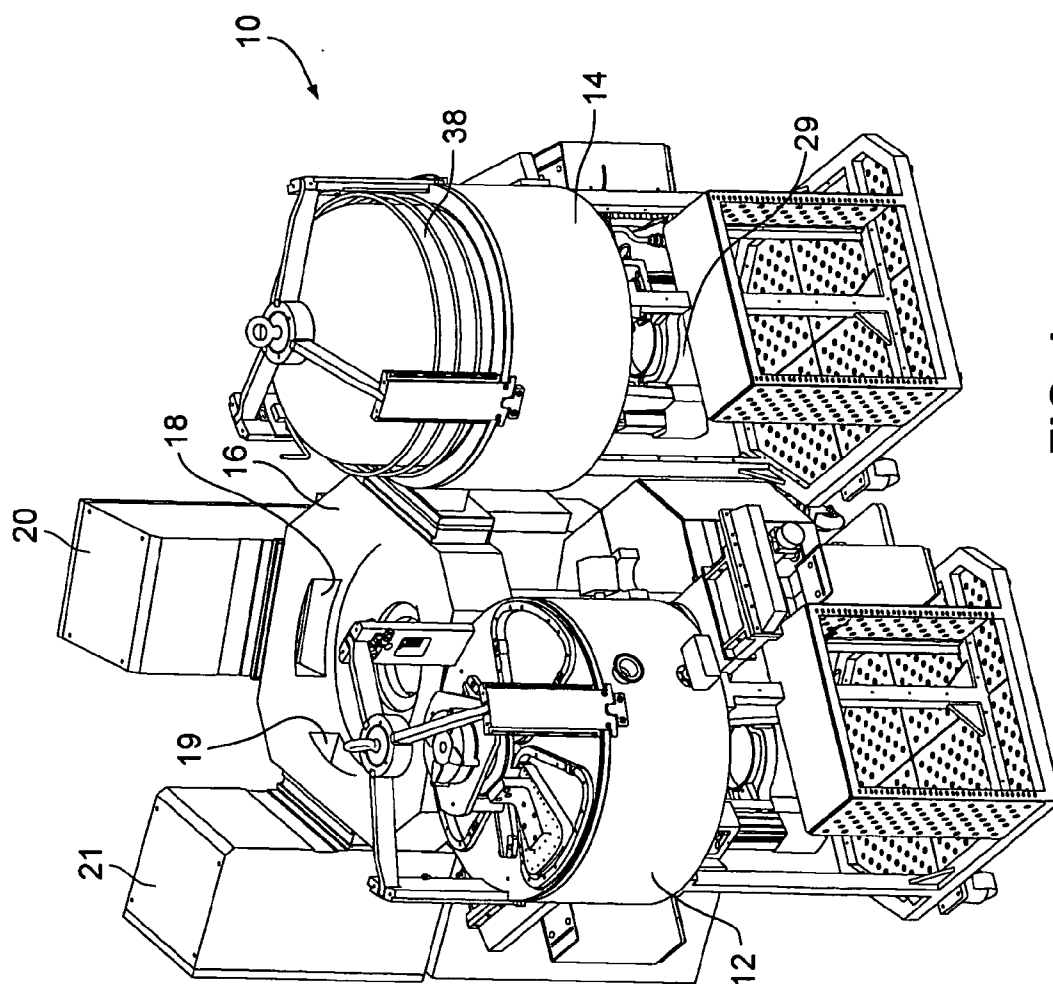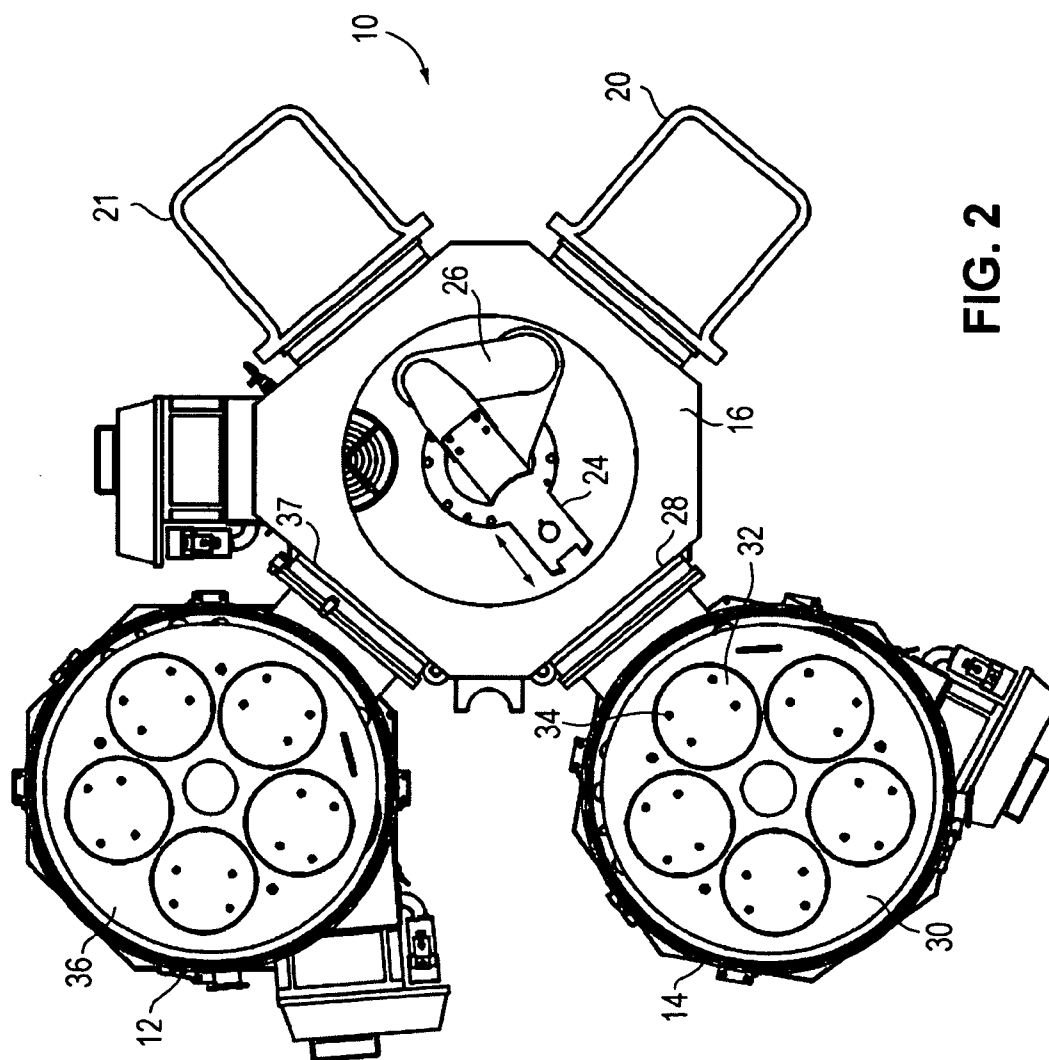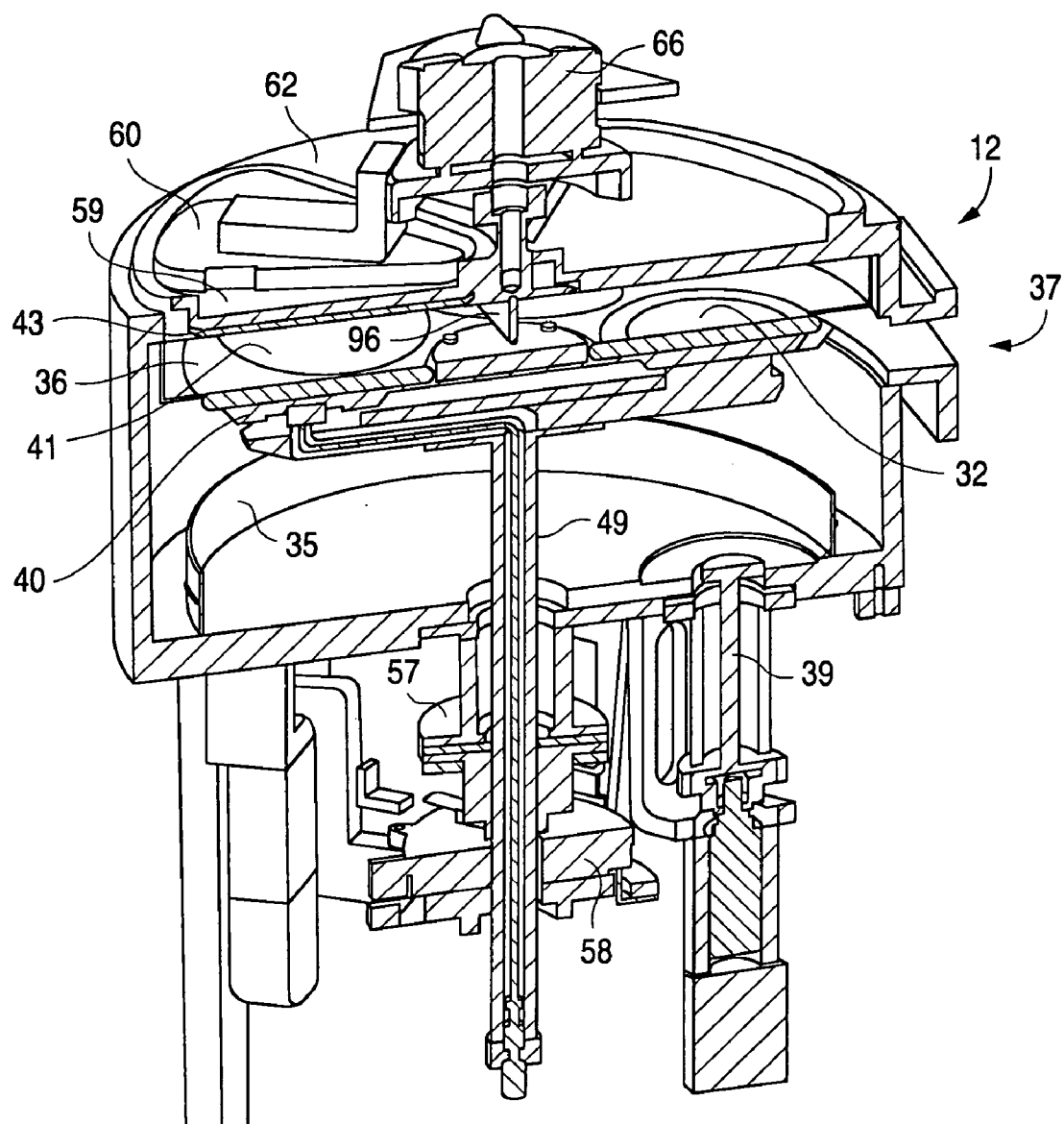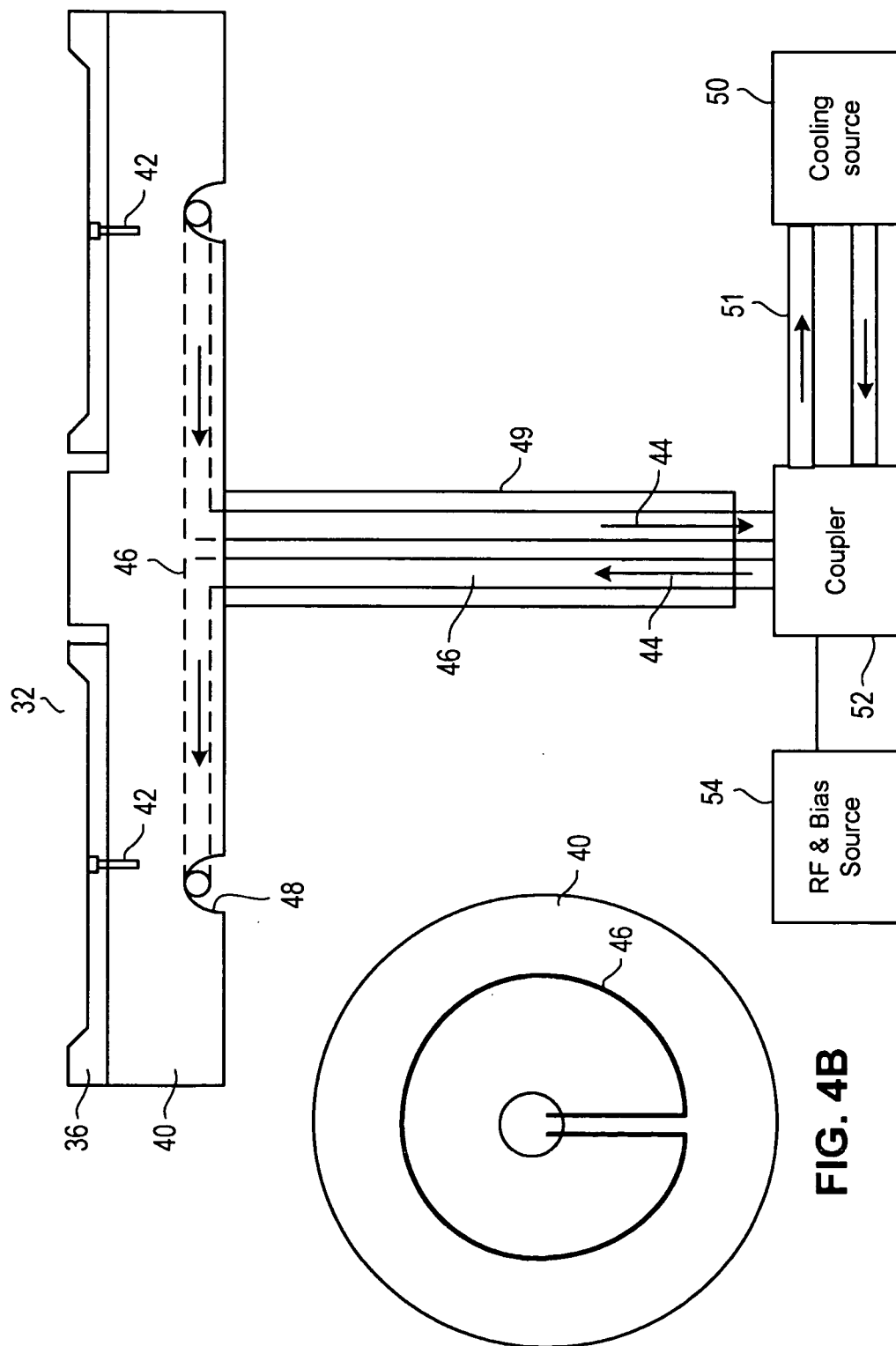
FIG. 1

FIG. 2

FIG. 3

FIG. 4A

FIG. 4B

FIG. 5A   **FIG. 5B**

66

60

67

59

62

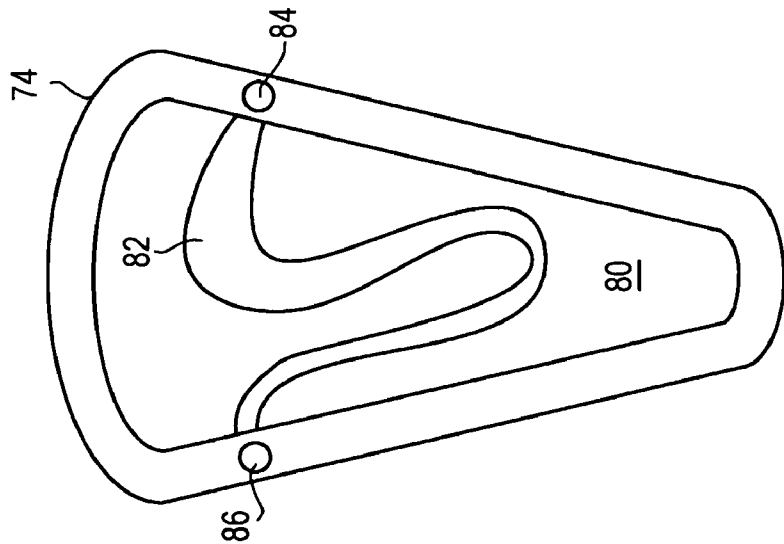**FIG. 6A**

60
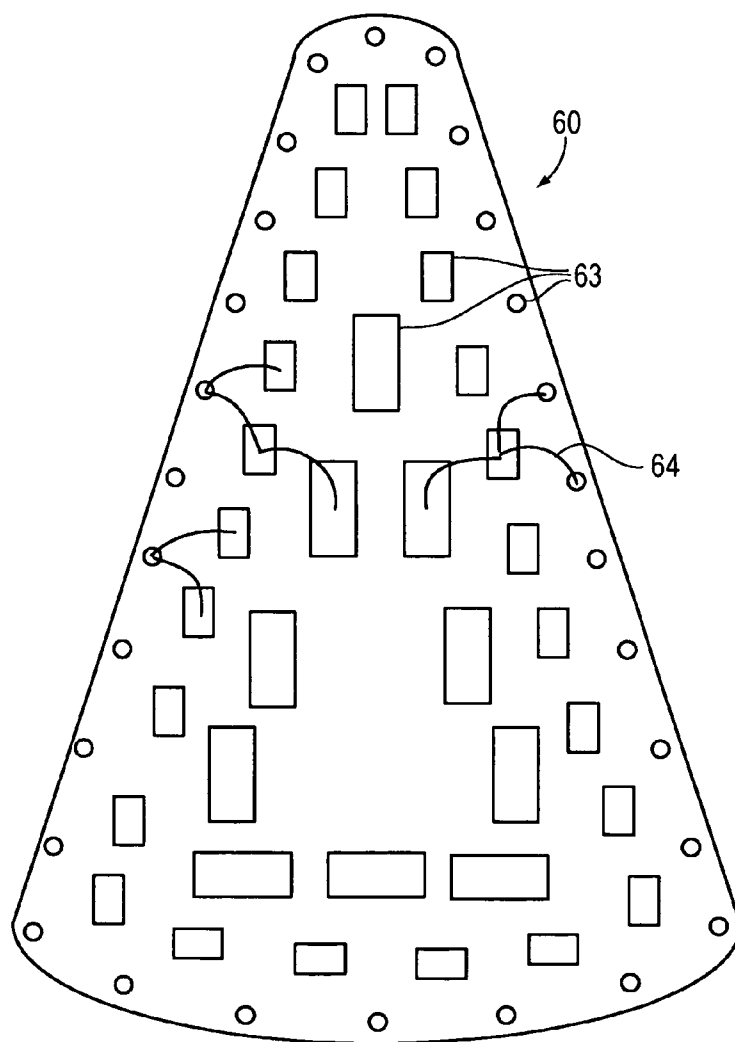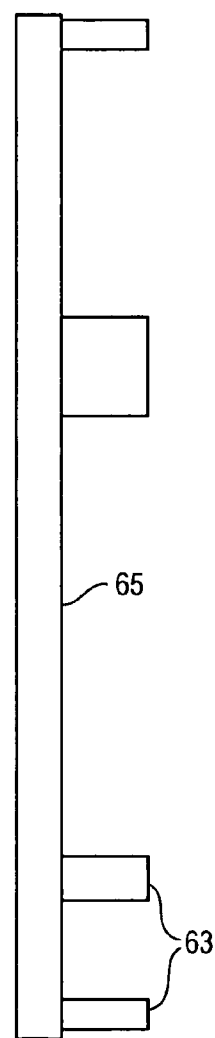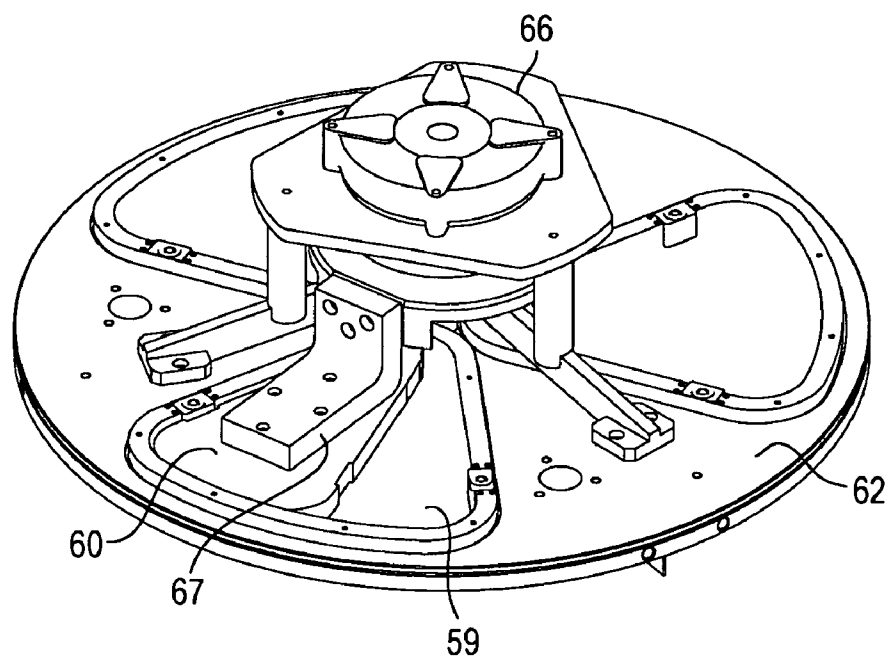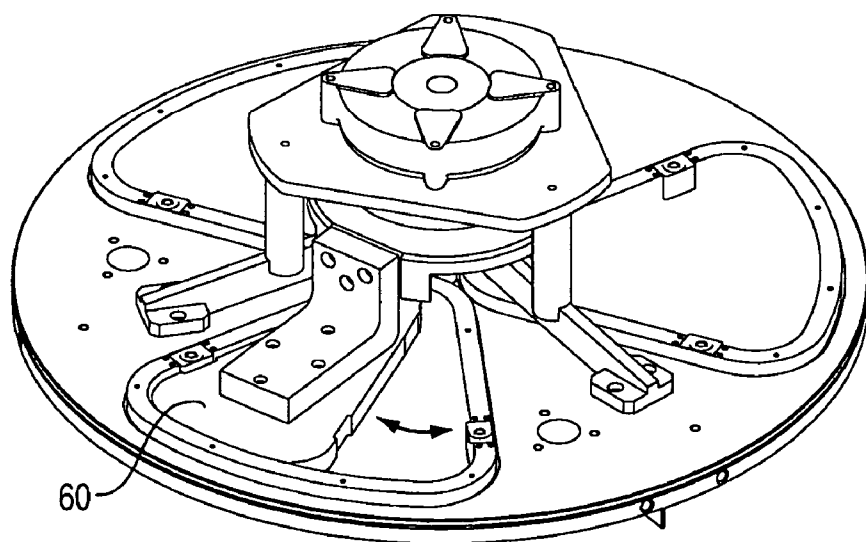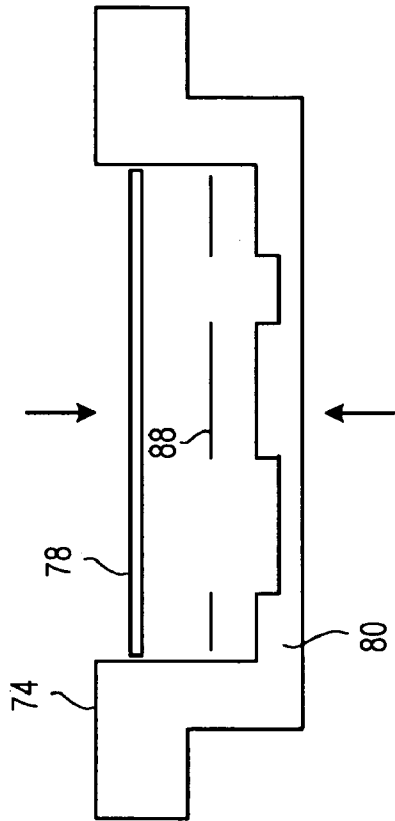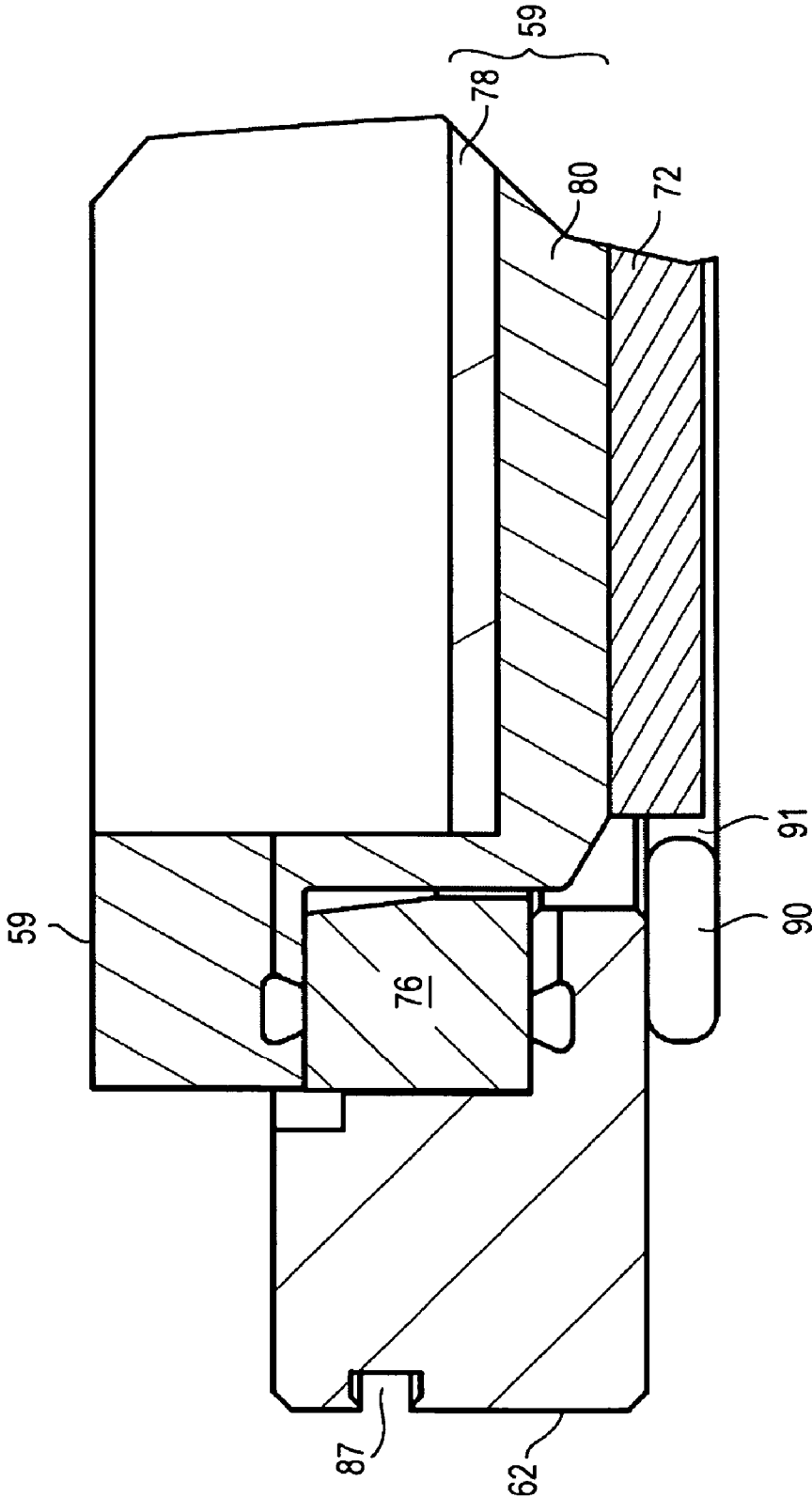
FIG. 6B
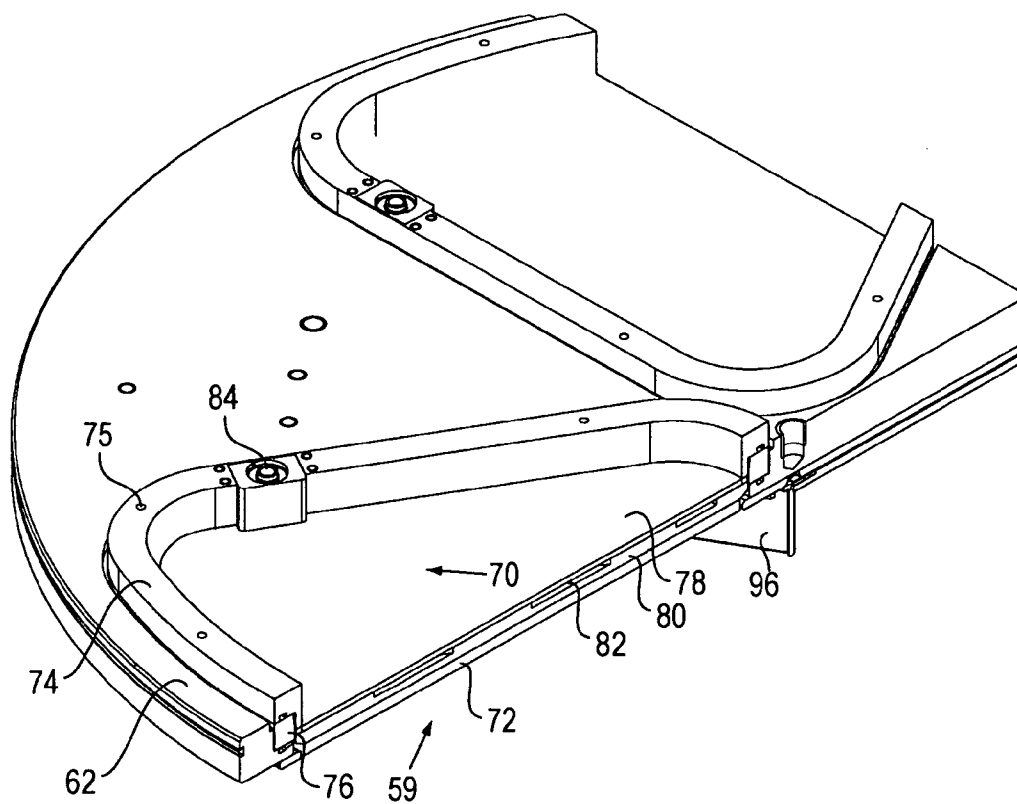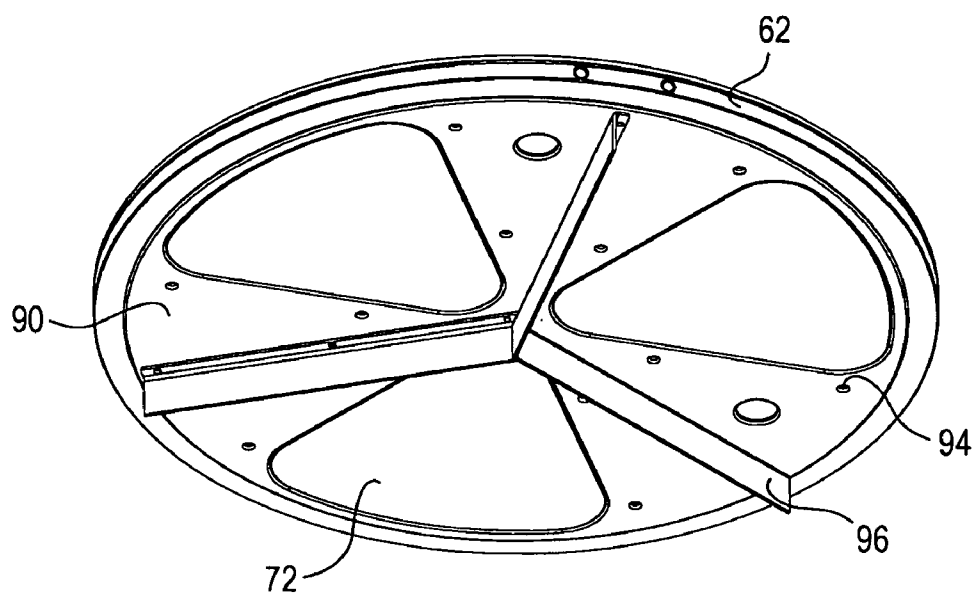
FIG. 7

FIG. 9

FIG. 8

FIG. 10

FIG. 11

MULTI-STATION SPUTTERING AND CLEANING SYSTEM

FIELD OF THE INVENTION

[0001] This invention relates to deposition systems for semiconductor wafers and other workpieces and, in particular, to sputtering systems.

BACKGROUND

[0002] A sputtering system is widely used in the semiconductor manufacturing industry for depositing materials on semiconductor wafers. Sputtering is sometimes referred to as physical vapor deposition, or PVD. In a sputtering operation, thin films comprising materials such as Al, Au, Cu, Ta are deposited in a vacuum on silicon wafers or other substrates. To make a stack of thin films of different materials, one common practice is to use multiple single-wafer process chambers wherein each chamber deposits only one material on one substrate at a time. For a tri-layer structure comprising Ti/Cu/Au, three separate single-wafer process chambers are required to sequentially deposit Ti, Cu and Au onto the substrate. The dedication of an individual process chamber to specific material deposition adds equipment costs and processing costs. The limitation of single-wafer transfer between chambers slows down the system throughput.

[0003] Various other drawbacks are found in typical sputtering systems. These drawbacks relate to inefficient magnetron operation, non-uniform coverage, poor temperature control of the wafers, contamination of the wafers and other components, and non-uniform target erosion, among other things.

SUMMARY

[0004] A multi-chamber batch processing system is described for depositing materials on multiple workpieces in a vacuum chamber.

[0005] The system includes a sputtering chamber and a separate pre-clean chamber, where wafers can be transferred between the two chambers by a robotic arm without breaking a vacuum. In one embodiment, 4-6 wafers are processed at a time in each chamber.

[0006] Having a separate pre-clean chamber, such as an inductively coupled plasma (ICP) chamber, increases throughput, provides a faster etch rate, results in less contamination of the sputtering chamber, and results in less damage to the electronic circuits on the wafer. Further, since there is no need for a shutter for isolating sputtering targets during the pre-clean process, there is no added contamination from a shutter during the sputtering process.

[0007] The wafers are mounted one-by-one from a load lock to a rotating pallet in the ICP chamber. In one embodiment, the pallet is aluminum. The aluminum is anodized (or another insulator is formed) to provide an insulating film on its surface. This prevents the pallet from being etched in the ICP chamber, avoiding particulates from the pallet contaminating the wafers.

[0008] The robotic arm transfers the wafers one-by-one to the sputtering chamber from the ICP chamber without the wafers being exposed to the atmosphere, thus avoiding undesirable chemical reactions on the wafer surface, e.g: oxides.

[0009] The wafers are mounted on a direct-drive rotating pallet in the sputtering chamber. The pallet is firmly fixed to a rotatable table in the sputtering chamber to provide good thermal and electrical conductivity between the pallet and the table. Copper tubing in the table couples RF energy to the wafers, and a coolant running through the copper tubing controls the temperature of the wafers.

[0010] Multiple targets, of the same or different materials, may concurrently deposit material on the wafers as the pallet is rotating. This enables higher throughput, creates a uniform deposition, and can be used to deposit films of varying compositions on the workpieces.

[0011] Multiple magnets (one for each target) in the magnetron assembly in the sputtering chamber oscillate (0.5-10 second period) over its associated target for uniform target erosion and uniform deposition on the wafers. Each magnet is composed of many small magnets, whose arrangement and relative sizes are selected to optimize the target erosion and increase throughput.

[0012] A target backing plate between each magnets and a target has a coolant channel running through it. The distance between the magnets and the targets is made very small by a thin aluminum plate fixed to a bottom segment of the target backing plate by a dip brazing process. This small distance increases the magnetic coupling and thus density of plasma, leading to improved deposition rates and target utilization.

[0013] Various shields are described to prevent cross-contamination from the targets and prevent the sputtered target material from entering gaps in the chamber and shorting out insulators.

[0014] Other novel features of the system are described.

[0015] The system may also be used for depositing material on LCD panels (e.g., conductors for a thin film array) and other workpieces.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 is a perspective view of the multi-chamber sputtering and cleaning system with covers removed to show some internal components.

[0017] FIG. 2 is a top down view of the multi-chamber system exposing the rotating pallets and robotic arm in the transport module.

[0018] FIG. 3 is a cutaway view of the sputtering chamber.

[0019] FIG. 4A is a cross-sectional view of the rotating shaft, table, and pallet in the sputtering chamber.

[0020] FIG. 4B is a bottom view of the table showing a copper tube for RF coupling and coolant flow.

[0021] FIG. 5A illustrates the distribution of some magnetic flux lines in the permanent magnet used in the magnetron.

[0022] FIG. 5B is a cross-sectional view of the magnet of FIG. 5A.

[0023] **FIG. 6A** is a perspective view of the magnetron assembly, forming a top portion of the sputtering chamber, with the oscillating magnet in a middle position.

[0024] **FIG. 6B** is a perspective view of the magnetron assembly with one oscillating magnet at its leftmost position.

[0025] **FIG. 7** is a perspective cross-sectional view of a portion of the top plate and target backing plate (for supporting the target and magnets) of the sputtering chamber.

[0026] **FIG. 8** is a top down view of the target backing plate without its thin cover, showing a coolant channel.

[0027] **FIG. 9** is an exploded cross-sectional view illustrating a dip brazing process for forming the target backing plate between the magnet and the target.

[0028] **FIG. 10** is a cross-sectional view of the top plate and target backing plate with a mounted target.

[0029] **FIG. 11** is a perspective view of the underside of the top plate showing the targets and cross-contamination shields.

[0030] Elements with the same numbers in the various figures are the same.

DETAILED DESCRIPTION

[0031] **FIG. 1** illustrates a multi-chamber sputtering and pre-clean system **10** for workpieces such as semiconductor wafers, LCD panels, and other workpieces requiring the deposition of thin films. Examples of thin films include Al, Cu, Ta, Au, Ti, Ag, Sn, NiV, Cr, TaNx, Hf, Zr, W, TiW, TiNx, AlNx, AlOx, HfOx, ZrOx, TiOx, and alloys of two or more of these elements. The top covers of the sputtering chamber **12**, pre-clean chamber **14**, and wafer transport module **16** have been removed. The robotic arm in the wafer transport module **16** is not shown in **FIG. 1** in order to see the access ports **18**, **19** from load locks **20**, **21**.

[0032] Typical wafer sizes are 6, 8, and 12 inches, and the system is customized for the particular workpieces for processing.

[0033] **FIG. 2** is a top down view of the system **10**, where the wafer-supporting pallets are revealed in chambers **12** and **14**. The robotic arm **24** is shown in the transport module **16**.

[0034] To load wafers into the system **10** for thin film deposition, a stack of wafers supported in a cassette is placed in load lock **20**. The cassette supports each wafer by its edge. A vacuum is then created in load lock **20** and transport module **16** by a vacuum pump. The vacuum pumps used in the system can create pressures below 0.001 milli-torr.

[0035] The robot arm **24** rotates to align itself with the load lock **20**, and arm **24** is inserted into load lock **20** by rotation of an arm **26**. The cassette is positioned by an elevator so that the bottom wafer is slightly above arm **24**. The elevator then lowers the cassette so that the wafer is supported entirely by arm **24**. Arm **24** is then pulled back into the transport module **16**, and arm **24** is aligned with port **28** of the pre-clean chamber **14**. The pre-clean chamber **14** is isolated from the transport module **16** by a slit valve (not shown). The pressure in the pre-clean chamber **14** is brought down by a vacuum pump **29** (**FIG. 1**) to the same pressure (base pressure) as in the transport module **16**, and the slit

valve is opened. Arm **24** extends the wafer over a rotatable pallet **30** in chamber **14**. Pallet **30** rotates to align a wafer support area **32** below the wafer. The wafer support area **32** is an indented area in pallet **30** sized to accommodate the particular wafers being processed. In another embodiment, electrostatic chucks (ESC) are used to support the wafer. An ESC provides added flexibility in biasing the wafer, and each ESC may be separately controlled. An ESC may also provide better thermal conductance between the wafer and the pallet **30** due to a strong clamping action on the wafer.

[0036] Four pins below pallet **30** are raised to extend through four holes **34** in the wafer support area **32** to lift the wafer off arm **24**. Arm **24** is withdrawn, and the pins are lowered so that the wafer is seated in the indentation and the entire back surface of the wafer is in contact with pallet **30**. This is important for temperature control and biasing, to be described later.

[0037] The robotic arm **24** then goes back to get another wafer from the cassette, and the pallet **30** rotates to align the next wafer support area **32** with the port **28**. The transfer process is repeated until five wafers are placed on pallet **30**. In a preferred embodiment, pallet **30** has four to six wafer support areas **32** but there may be more or fewer areas as desired.

[0038] During the process of loading the pre-clean chamber **16**, arm **24** may also be removing cleaned wafers from pallet **30** and placing them on a similar pallet **36** in the sputtering chamber **12**. The sputtering chamber **12** has a port **37** and slit valve similar to those of the pre-clean chamber **14**. The loading process onto pallet **36** is the same as the loading described above.

[0039] Pre-cleaning of the wafers is important to remove impurities, e.g: oxides, from the wafer's surface so that metal films deposited in the sputtering chamber are not electrically insulated from the wafer. By performing pre-cleaning in chamber **14**, part of a multichamber vacuum environment to which sputtering chamber **12** is connected, the wafers can be transported from the cleaning chamber **14** to the sputtering chamber **12** without being exposed to the atmosphere (or otherwise contaminated), so impurities do not form on the workpiece during the transportation time. Further, vacuum pump-down cycles are reduced since a vacuum is maintained in the multi-chamber system during transfer of the cleaned wafers to the sputtering chamber. Only when a cassette is full in load lock **21** or when a cassette is empty in load lock **20** does the system need to break the vacuum to remove or introduce wafers from and to the system.

[0040] In some sputtering systems, the pre-clean is performed in the same chamber as the sputtering (in situ). This results in a compromised design of the equipment and causes etched particles to accumulate on the chamber walls and other portions. Such particles contaminate the wafer during the sputtering process and shorten time between maintenance cycles. Further, since there is no need for a shutter for isolating sputtering targets during the pre-clean process, there is no added contamination from a shutter during the sputtering process.

[0041] In the preferred embodiment, the pre-clean chamber **14** uses inductively coupled plasma (ICP) for etching the wafer. A coil **38** (**FIG. 1**) at the top of chamber **14** is

energized with an external RF source (e.g., at 13.56 MHz) to create an excitation field in the chamber **14**. Argon gas flows through the chamber **14** from an external gas source. The argon atoms in the chamber **14** are ionized by the RF energy so are charged. The wafers are biased by a DC biasing source coupled to the aluminum pallet **30** so that the ions are attracted to the wafers and etch the wafers. Other gases may be used depending on the desired etch rate and materials to be etched. The etching is a cleaning process rather than a process to etch features in the wafer materials so the energy levels may be low. This avoids damaging circuit devices and features already formed in the wafer. ICP etching is a well known process so additional detail is not necessary for describing the chamber **14** and its operation.

[0042] The aluminum pallet **30** in the pre-clean chamber **14** is anodized to provide an electrically insulating film on its surface. This reduces the etch rate of pallet **30** when the wafers are being cleaned in the ICP chamber, avoiding particulates from the pallet contaminating the wafers. The anodized surface may be obtained by heating pallet **30** in an oxygen atmosphere, depositing a layer of aluminum oxide, or plasma spraying a layer of aluminum oxide. An insulating surface of pallet **30** may also be obtained by depositing a ceramic coating, or other insulating films. A thicker insulating film reduces the effective bias at the pallet surface and thus reduces the etching rate of the pallet. In one embodiment, the insulating film is greater than 2 mils (0.05 mm).

[0043] In another embodiment, a material may be deposited on pallet **30** that is desired to be deposited on the wafers during the pre-clean process. The plasma clean will then dislodge the material from pallet **30** and coat the wafers with the material.

[0044] After the pre-clean process, in which any unwanted native oxide has been etched off the wafer surface, the robot arm **24** transports the five wafers, one-by-one, into the sputtering chamber **12**. **FIG. 3** is a cutaway view of the sputtering chamber **12** with its cover removed. The below description of the pallet **36** and table **40** in the sputtering chamber **12** also applies to the pallet **30** and table in the pre-clean chamber.

[0045] **FIG. 3** illustrates pallet **36** mounted on a rotatable table **40**. Pallet **36** and table **40** may be formed of aluminum. Pallet **36** may be continuously rotated at any speed or may be temporarily stopped to control the deposition of a sputtered material from a target **43** overlying a wafer. A wafer **41** is shown in one of five wafer supporting areas **32**.

[0046] Pin bellows **39** is shown in **FIG. 3** for pushing up the four pins (not shown), described above, into the wafer support area **32** for transferring the wafer to and from the robotic arm **24**. The pin bellows **39** may be controlled pneumatically or driven directly by a motor.

[0047] A chamber shield **35** prevents contaminants from accumulating on the chamber wall.

[0048] **FIG. 4A** is a cross-sectional view of pallet **36** and table **40**. Pallet **36** is about ¼ to ½ inch (6.3-12.7 mm) thick, and table **40** is about 1 inch (25.4 mm) thick. Pallet **36** is a single piece that is fixed to table **40** by a countersunk screw **42** at the indentation in each wafer support area **32** so that the wafers block the sputtered materials being deposited on screws **42**. Pallet **36** may be removed for cleaning by unscrewing screws **42**.

[0049] The entire back surface of each wafers is thus in electrical and thermal contact with pallet **36**, which is in turn in electrical and thermal contact with table **40**.

[0050] Controlling the temperature of the wafers is important during the sputtering process to obtain a predicable and reliable thin film. The temperature of the wafers is controlled by flowing a coolant **44** (**FIG. 4A**) through a copper tube **46** in direct contact with table **40**. In one embodiment, the copper tube **46** is brazed to table **40**. The copper tube **46** runs in a groove **48** around the table **40**, as shown in **FIG. 4B**, which is a bottom view of table **40**.

[0051] The copper tube **46** extends up through a rotating shaft **49** attached to table **40**.

[0052] An external cooling source **50** cools the coolant (e.g., water) and recycles the coolant back to table **40**. Flexible tubing **51** from the cooling source **50** attaches to a rotatable coupler **52** for providing a sealed coupling between the rotating copper tubes **46** (input and output) and the stationary tubing **51** to/from the cooling source **50**.

[0053] In another embodiment, the cooling source may be replaced or augmented by a heating source to increase the workpiece temperature independent of the ICP or sputtering process.

[0054] An RF and bias source **54** is electrically coupled to the copper tube **46** by the rotatable coupling **52** to energize table **40** and thus energize pallet **36** and the wafers for the sputtering process. In another embodiment, table **40** is grounded, floated, or biased with only a DC voltage source.

[0055] When the chamber **12** is evacuated and back filled with a certain amount of Ar gas at a certain pressure (for example, 20 milli-torr) and the gas is energized with a DC source, an RF source, or a combination of the two sources, an electromagnetic field is coupled inside chamber **12** to excite a sustained high density plasma near the target surface. The plasma confined near the target surface (described later) contains positive ions (such as Ar+) and free electrons. The ions in the plasma strike the target surface and sputter material off the target. The wafers receive the sputtered material to form a deposited layer on the surface of the wafers. In one instance, up to twenty kilowatts of DC power can be provided on each target. In such a case, each target can deposit approximately 1 micron per minute of copper, simultaneously, on multiple work pieces.

[0056] The chamber **12** wall is typically electrically grounded in processing operations.

[0057] A bias voltage on the wafers can drive a flux of an electrically charged species (Ar+ and/or atomic vapor sputtered off the target) to the wafers. The flux can modify the properties (for example, density) of the sputtered material to the wafers.

[0058] Generating a plasma for sputtering and the various biasing schemes are well known, and any of the known techniques may be implemented with the described sputtering system.

[0059] In a preferred embodiment, the chamber gas is provided by a distribution channel at the bottom of the chamber **12**, rather than from the top, which reduces particle

contamination during the sputtering process and allows optimization of the magnetron assembly (described later).

[0060]   FIG. 3 illustrates a motor **58** for rotating shaft **49**. Shaft **49** is directly coupled to the motor **58** so that pallet **36** is directly driven by motor **58**. This greatly increases the accuracy of positioning pallet **36** over a belt drive or a gear drive. In the embodiment of **FIG. 3**, motor **58** surrounds shaft **49** and has a central rotating sleeve fixed to shaft **49**. Motor **58** may be a servo or stepper motor. In one embodiment, the motor is a servo motor that uses an absolute encoder attached to shaft **49** to determine the angular position of shaft **49**. In an absolute encoder, a disc with fine optical markings uniquely identifies the angular position without the need for counting pulses or determining a home position. For example, the disc may be glass covered with an opaque film with a number of etched concentric rings taking the form of different length transparent dashes. The set of light openings at each radial position across the rings creates a unique digital code. A motor controller, using an LED and phototransistors, senses the optical markings at each radial position and uses that information to position shaft **49** for wafer loading and unloading and to control the RPM of pallet **36** during the deposition process (typically 5-30 RPM).

[0061]   A seal **57** provides a seal around shaft **49** in order to maintain a low pressure in chamber **12**.

[0062]   The sputtering chamber **12** uses a magnetron assembly, outside the vacuum, to further control the bombardment of the target by the plasma. In a typical system a fixed permanent magnet is located behind the target (serving as a deposition source) so that the plasma is confined to the target area. The resulting magnetic field forms a closed-loop annular path acting as an electron trap that reshapes the trajectories of the secondary electrons ejected from target into a cycloidal path, greatly increasing the probability of ionization of the sputtering gas within the confinement zone. Inert gases, specifically argon, are usually employed as the sputtering gas because they tend not to react with the target material or combine with any process gases and because they produce higher sputtering and deposition rates due to their high molecular weight. Positively charged argon ions from the plasma are accelerated toward the negatively biased target and impact the target, resulting in material being sputtered from the target surface.

[0063]   FIG. 5A illustrates one of the three magnets **60** overlying a target backing plate **59** (**FIG. 3**), supported by a grounded top plate **62** (**FIG. 3**) in the sputtering system. Magnet **60** has a triangular or delta shape with rounded corners. In one embodiment, the thickness of magnet **60** is between 0.5-1¼ inch thick (12-31 mm). In the example of **FIG. 5A**, there are three rings (nested patterns) of individual magnets **63**, where adjacent rings have opposite poles so that a magnetic field spans across one ring to the next. Some magnetic field lines **64** are shown. Since there are three rings of magnets, there are two racetracks of field lines. These magnetic fields pass through the target backing plate **59** and intersect the target **43** attached to the underside of the target backing plate **59** in **FIG. 3**. The plasma density at the target (and thus the erosion rate) is greatest at the highest magnetic field intensity. The sizes, shapes, and distribution of the individual magnets **63** are selected to create a uniform erosion of the target, as described below.

[0064]   FIG. 5B is a cross-sectional view of one embodiment of the magnet **60**. The magnets **63** are mounted to a magnetic backing plate **65**, also known as a shunt plate, formed of a ferrous material. The shape and magnetic properties of the shunt plate **65** may be altered to optimize the performance of magnet **60**.

[0065]   The magnet **60** may also be an electromagnet.

[0066]   FIG. 6A illustrates the magnetron portion of the sputtering chamber **12**, where one magnet **60** is shown above a target (not shown). Two other identical magnets would be located above two other targets centered at 120 degree intervals. A servo motor **66** using an absolute encoder, similar to the motor **58** for the shaft **49** that rotates table **40**, is controlled by a motor controller to oscillate the three magnets **60** back and forth in unison over their associated targets at an oscillating period of between 0.5-10 seconds. The magnets **60** are oscillated so that the magnetic fields are not always at the same position relative to the target. By distributing the magnetic fields evenly over the target, target erosion is uniform.

[0067]   If the oscillation is too slow, then there may be time for particles of one material to accumulate on portions of a target of a different material in areas not subjected to the magnetic fields for a prolonged period. When the magnet eventually scans over that portion of the target, the sputtered material will undesirably constitute the mixed materials (varying the stochiometry of the sputtered material). The 0.5-10 second period is adequate for stochiometrically sensitive reactive films sputtered onto the workpiece. The oscillation period may be slower for non-stochiometrically sensitive reactive films sputtered onto the workpiece.

[0068]   An insulating bracket **67** secures each magnet **60** to motor **66** so that there is a minimum gap between the oscillating magnet **60** and the target backing plate **59**.

[0069]   Since there is no field in the middle portion of magnet **60**, the magnet **60** must scan a distance of at least half its width (and preferably almost its entire width) so that the middle portion of the target experiences the same magnetic fields as other portions of the target.

[0070]   The individual magnets **63** along the edge of magnet **60** are smaller that the inner magnets so that the magnetic field extends close to the edge of magnet. The span of a magnetic field can be approximated by the distance between the centers of the two opposite poles. Hence, the diameters of the outer magnets **63** are made small (e.g., 0.5-1 cm). The inner rings of magnets **63** may be larger. In the example, the inner magnets **63** are rectangular to shorten the distance between the inner magnets and the outer magnets.

[0071]   The size of magnets **60** depends on the size of the wafers, which determines the size of the targets. In one embodiment, a magnet **60** is about 10.7 inches (27 cm) long and about 3 inches (7.6 cm) wide at it widest part. An eight inch wafer may use a target that is from 10-13 inches long in the radial direction. A twelve inch wafer may use a target that is from 13-18 inches long in the radial direction. These target and magnet length dimensions are very small compared to the prior art. These small dimensions mean more efficient chamber volume, thus a smaller footprint; and also smaller and more efficient targets, resulting in lower costs for the targets and system. Generally, the target and magnet

length perpendicular to the scanning direction is between 1.1 and 1.5 times the smallest dimension of the workpiece surface facing the target.

[0072] **FIG. 6A** illustrates magnet **60** at a middle position during an oscillation, while **FIG. 6B** illustrates magnet **60** at a leftmost position during the oscillation.

[0073] To maximize the magnetic fields around the target, the distance between a magnet **60** and a target should be minimized. Further, the target backing plate **59**, with magnet **60** on one side and a target on the other side, needs to be cooled due to the hot plasma in the chamber **12**.

[0074] **FIG. 7** is a perspective cross-sectional view of the top plate **62** and target backing plate **59**, both formed of aluminum. The thickness of the top plate **62** is about 1⅜ inch (35 mm). The magnet **60** oscillates in the recessed area **70** of the target backing plate **59**. The target **72** is approximately the shape of the recessed area **70** and is secured to the target backing plate **59** by solder, a braze, a conductive epoxy, copper diffusion, or other known technique.

[0075] The target backing plate **59** (comprising the recessed area **70** and the raised area **74** around the recessed area **70**) and the target **72** are electrically connected to a negative bias voltage source in order for the plasma to be concentrated in the area of the target **72**. A wire (not shown) carrying a negative bias voltage is connected by a screw to the raised area **74** using one of the screw holes **75**. Target **72** is also referred to as the cathode, since it is negatively biased. The top plate **62** supporting the target backing plate **59** is electrically grounded. An insulator ring **76** (e.g., a synthetic rubber ring, or other elastic material) electrically insulates the target backing plate **59** from the grounded portion. The ring **76** also mechanically supports the target backing plate **59**. It is important to prevent conductive sputtered particles from contacting ring **76** to prevent a short between the target backing plate **59** and the grounded portion.

[0076] The thickness of the recessed area **70** (the distance between magnet **60** and target **72**) should be thin to maximize the magnetic coupling to the target **72**. In one embodiment, the thickness is between 0.5-0.75 inch (12.7-19 mm). The top of the recessed area **70** is a thin aluminum plate **78** (e.g., 0.7-3 mm) that is dip brazed to the bottom segment **80** of the recessed area **70**. Between the plate **78** and bottom segment **80** is a coolant (e.g., water) channel **82**, shown in **FIG. 8**. A heated liquid may also be run through channel **82**.

[0077] **FIG. 8** illustrates a simplified channel **82** formed in the bottom segment **80** between a coolant input port **84** (also see **FIG. 7**) and a coolant output port **86**. Flexible tubing (not shown) connects each port **84/86** for each magnet to an external coolant source so that each recessed area **70** is independently cooled by a coolant flowing through the channel **82**. As shown in **FIG. 8**, the channel **82** is in a serpentine pattern and in a shape such that the area of the channel **82** varies based on the amount of cooling needed to maintain the same temperature over the entire recessed area **70**. In one embodiment, the thickness of the coolant channel **82** is 1-3 mm. The coolant enters at the wide portion of the target backing plate **59** where the temperature is normally the hottest.

[0078] The plate **78** that forms the top surface of the recessed area is dip brazed to the bottom segment **80** as

follows. As shown in **FIG. 9**, a thin aluminum alloy foil **88** (a eutectic material) having the general shape of the bottom segment **80** is interposed between the bottom segment **80** and the thin plate **78**. The eutectic foil **88** has a melting point lower than the melting temperature of the aluminum used to form the bottom segment **80** and thin plate **78**. Various eutectic aluminum alloys can be used. A clamp presses the thin plate **78** and the bottom segment **80** together, and the structure is placed in a molten salt bath at a temperature sufficient to melt the eutectic foil **88** but not hot enough to melt pure aluminum. The melting of the eutectic sheet **88** brazes the thin plate **78** to the bottom segment **80**.

[0079] In one embodiment, the aluminum used for the bottom segment **80** and the thin plate **78** is designated as 6061 aluminum in the trade and has a melting temperature of 1110 degrees F (598 degrees C). The material used for the eutectic foil **88** is designated as 4047 aluminum in the trade and has a melting temperature of 1065 degrees F (574 degrees C). The composition of 4047 aluminum is: Si 11.0-13.0%; Cu 0.3%; Mg 0.1%; Fe 0.8%; Zn 0.2%; Mn 0.15%; Al remainder.

[0080] **FIG. 10** is a cross-sectional view of a portion of the grounded top plate **62**, insulator ring **76**, target backing plate **59** (comprising the thin plate **78** dip brazed to the bottom segment **80**), and target **72**. A groove **87** for a gas seal gasket is formed in the top plate **62**. The magnet **60** and coolant channels **82** are not shown.

[0081] The target **72**, since at a negative bias, must not contact the grounded top plate **62**. Therefore, there must be a gap between the target **72** and the top plate **62**. If this gap is small enough, it creates a dark space where there is not enough space to create a plasma. Sputtered particles from target **72** entering the dark space will accumulate on the insulator **76** and eventually short the target backing plate **59** to the top plate **62**. Given the manufacturing tolerances in the sizes of the top plate **62** and the target **72**, as well as the mounting of the target **72**, it is very difficult to ensure that the gap between the target **72** and the top plate **62** will be a minimum. To close up the dark space and prevent contamination of the insulator **76**, a thin top shield **90** is fixed to the top plate **62** by countersunk screws. **FIG. 10** shows the resulting narrow gap **91**.

[0082] **FIG. 11** is a perspective view of the underside of the top plate **62** and targets **72**, showing the top shield **90**. Since the top shield is thin aluminum or stainless steel and easily stamped to a precise tolerance, the gap between the target **72** and the top plate **62** is easily set to be a minimum (e.g., 1-2 mm). The thickness of the top shield **90** is in the range of ³⁄₁₆-¼ inch (4.7-6.3 mm). The diameter of the top plate **62** is about 28 inches (71 cm). In prior art systems, a separate anode ring for the dark spaces was installed and aligned after the gap between the target and top plate was first determined.

[0083] The top shield **90** also overlies all otherwise-exposed portions of the top plate **62** to prevent the top plate **62** from accumulating sputtered material. (The exposed edge of the top plate **62** in **FIG. 11** rests on top of the chamber wall (shown in **FIG. 3**) so is not exposed in the chamber.) When cleaning of the chamber **12** is necessary, the top shield **90** is easily removed from the top plate **62** (by screws **94** in **FIG. 11**) and cleaned or disposed of. Typically, the top shield **90** will be cleaned up to ten times and then thrown

away. This avoids the much more complex job of removing the top plate **62** for cleaning. Accordingly, a single, inexpensive top shield is used for both creating the dark spaces and protecting the top plate **62**.

[0084] **FIG. 11** also shows cross-contamination shields **96** between each target **72** position for preventing sputtered material from one target from being deposited on a wafer that is not directly under the target as the pallet **36** (**FIG. 3**) rotates. **FIG. 3** shows a portion of a cross-contamination shield **96**. The vertical walls of cross-contamination shields **96** should be less than 10 mm, and preferably less than 3 mm, from the top of the wafers (or other workpieces). The height of the cross-contamination shields **96** depends on the height of the top plate **62** above the wafers, but will normally be about 1-6 inches (2.5-15 cm).

[0085] The described sputtering system allows for all three targets to concurrently sputter the same or different materials on the wafers during a batch process. This increases throughput and allows the sputtering of alloys or layers on the wafers without breaking a vacuum. To select an alloy composition, one target may be one material, and the other two targets may be a second or third material. For depositing stacked layers of distinct materials, then only one material may be deposited at a time (e.g, one target energized at a time or multiple targets of the same material energized at a time). For depositing mixed layers (e.g. alloys of distinct materials), then all targets may be energized at the same time, assuming the targets are of different materials.

[0086] More targets and wafers than shown in the examples may be employed in the system. For example, there may be eight targets. The number of such targets is limited only by the ability to build increasingly narrow magnets, which deliver a suitable magnetic flux on the target surface.

[0087] The tables/pallets on which the wafers are placed may be equipped with heaters to heat the wafers if desired. Heating may be created by resistive heaters mounted to the table or flowing a heated fluid through the copper tubing **46** (**FIG. 4A**). Such heaters are well known. Resistive heaters are described in U.S. Pat. No. 6,630,201, incorporated by reference.

[0088] The system sputters approximately 240 Å of Al for an input energy of 1 kW-minute. In contrast, a typical prior art system, all other conditions being equal, deposits approximately 90 Å of Al for an input energy of 1 kW-minute.

[0089] Conventional aspects of the system that have not been described in detail would be well known to those skilled in the art. U.S. Pat. No. 6,630,201 and U.S. Patent Application Publication 2002/0160125 A1 are incorporated herein by reference for certain conventional aspects primarily related to creating a plasma and supplying gas to a process chamber.

[0090] Although the system has been described with respect to forming a metal film on semiconductor wafers, the system may deposit any material, including dielectrics, and may process any workpiece such as LCD panels and other flat panel displays. In one embodiment, the system is used to deposit materials on multiple thin film transistor arrays for LCD panels.

[0091] Having described the invention in detail, those skilled in the art will appreciate that, given the present disclosure, modifications may be made to the invention without departing from the spirit and inventive concepts described herein. Therefore, it is not intended that the scope of the invention be limited to the specific embodiments illustrated and described.

What is claimed is:

1. A processing system comprising:

at least one load lock for receiving a plurality of workpieces for processing and for storing processed workpieces, the at least one load lock being sealable for being at a low pressure significantly below ambient pressure;

a transport module connected to the at least one load lock, the transport module being sealable for being at the low pressure;

a robotic arm within the transport module for transporting the workpieces from and to the at least one load lock at the low pressure;

a cleaning chamber connected to the transport module, the cleaning chamber being sealable for being at the low pressure, the cleaning chamber comprising a first workpiece support area for supporting a plurality of workpieces at a time for batch cleaning of the workpieces using a plasma;

a sputtering chamber connected to the transport module, the sputtering chamber being sealable for being at the low pressure, the sputtering chamber comprising a second workpiece support area for supporting a plurality of workpieces at a time for batch sputtering on the workpieces, the sputtering chamber comprising a plurality of targets for sputtering target material onto the workpieces using a plasma; and

the robotic arm and system being configured so that the workpieces may be transferred from the at least one load lock, to the cleaning chamber, from the cleaning chamber to the sputtering chamber, and from the sputtering chamber to the at least one load lock without the plurality of workpieces being exposed to ambient pressure.

2. The system of claim 1 wherein a base pressure in the cleaning chamber is lower than the pressure in the transport module during a cleaning operation.

3. The system of claim 1 wherein a base pressure in the sputtering chamber is lower than the pressure in the transport module during a sputtering operation.

4. The system of claim 1 wherein the sputtering chamber comprises:

a low pressure chamber;

a rotatable first pallet in the chamber, the rotatable first pallet having a plurality of workpiece support areas for concurrently supporting a plurality of workpieces on the first pallet;

a plurality of targets having sputtering surfaces facing the first pallet;

a first port for receiving workpieces one at a time for loading one at a time onto the workpiece support areas; and

a first motor for rotating the first pallet such that workpieces oppose different target sputtering surfaces at different times during sputtering operations.

5. The system of claim 4 wherein the cleaning chamber comprises:

a low pressure cleaning chamber;

a rotatable second pallet in the cleaning chamber, the rotatable second pallet having a plurality of workpiece support areas for concurrently supporting a plurality of workpieces on the second pallet for batch cleaning of the workpieces using a plasma;

a second port for receiving workpieces one at a time for loading one at a time onto the workpiece support areas; and

a second motor for rotating the second pallet;

the robotic arm transporting cleaned workpieces one at a time from the second pallet to the first pallet in the sputtering system without exposing the workpieces to ambient pressure.

6. The system of claim 1 wherein the cleaning chamber is an inductively coupled plasma chamber having a plasma generator.

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