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(54) **MAGNETIC FOCUS RINGS FOR IMPROVED COPPER PLATING**

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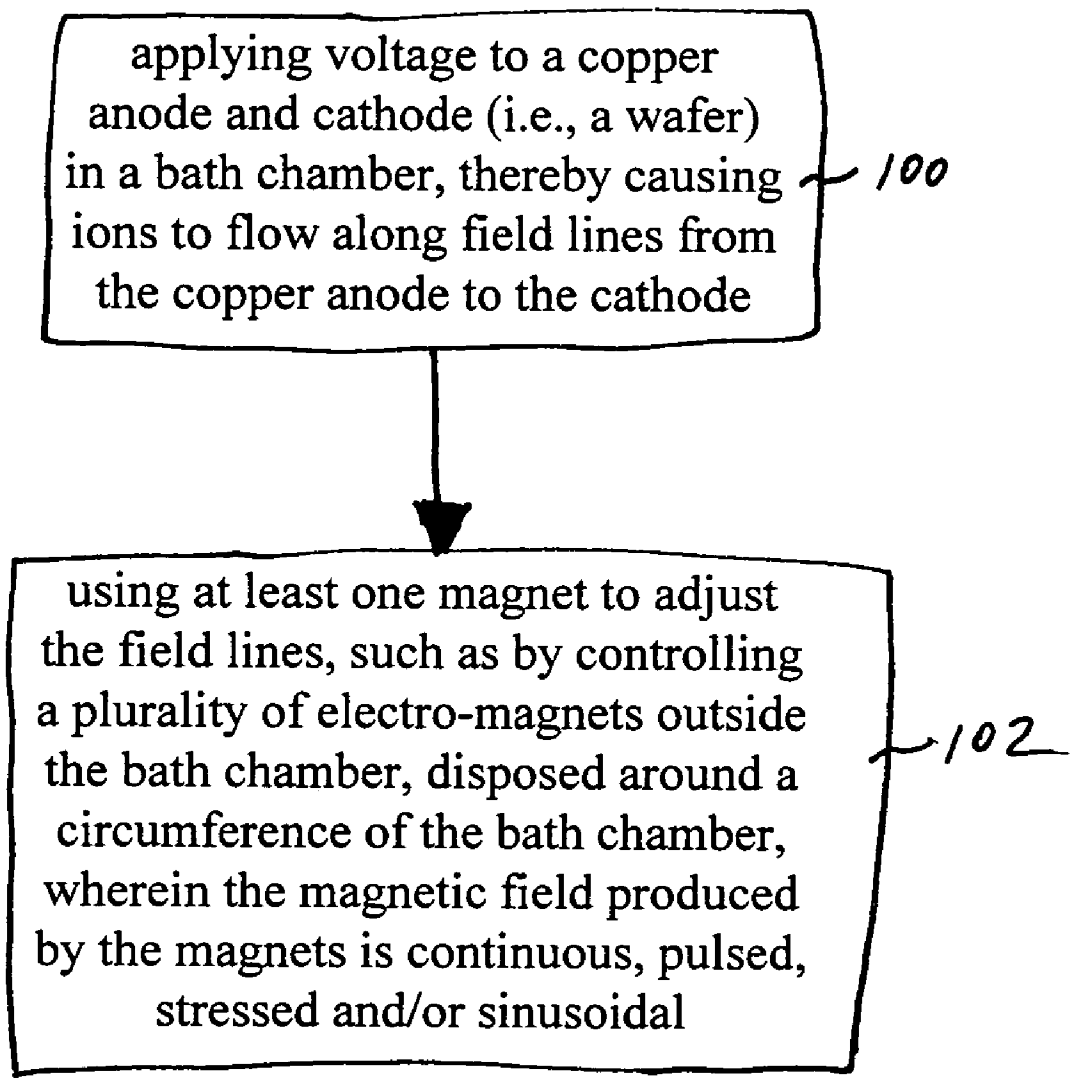
(57) **ABSTRACT**

A method and system wherein magnets are employed on the outside of a plating bath chamber to control the field lines that are used during the plating process. By being able to control the field lines during the plating process, improved gap fill and uniformity can be achieved. The magnetic field acting on the bath can be continuous, pulsed, stressed (i.e., the shape of the field can be changed), sinusoidal, etc. The magnetic field can be modulated as function of time to produce a desired copper uniformity on the wafer. It is anticipated that there is no limit to how the shape of the magnets or magnetic field can be configured and controlled to achieve the desired result for both fill of deep contacts and the uniformity needed to match the succeeding polishing process.



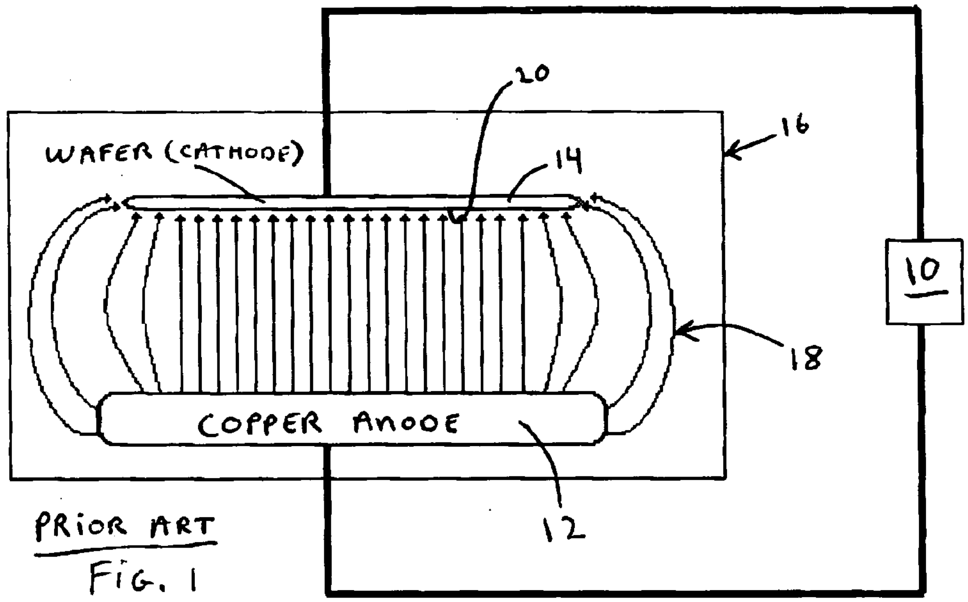

20
16
WAFER (CATHODE)
14
10
18
COPPER ANODE
12
PRIOR ART

Fig. 1

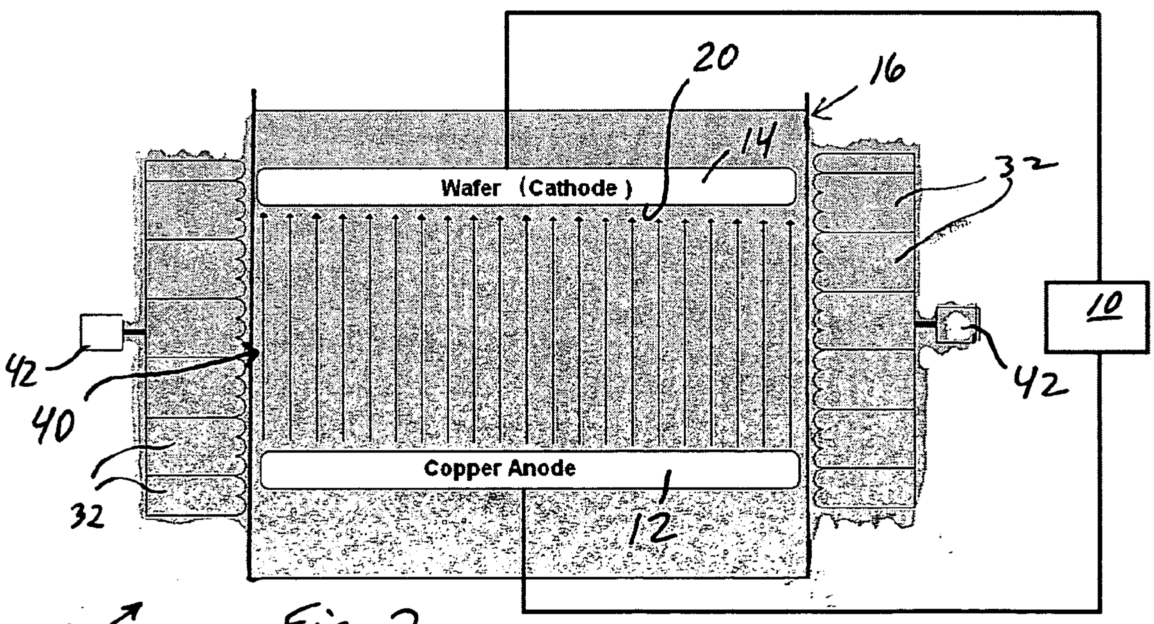

20
16
14
Wafer (Cathode)
32
10
42
42
40
Copper Anode
32
12
30

Fig. 2

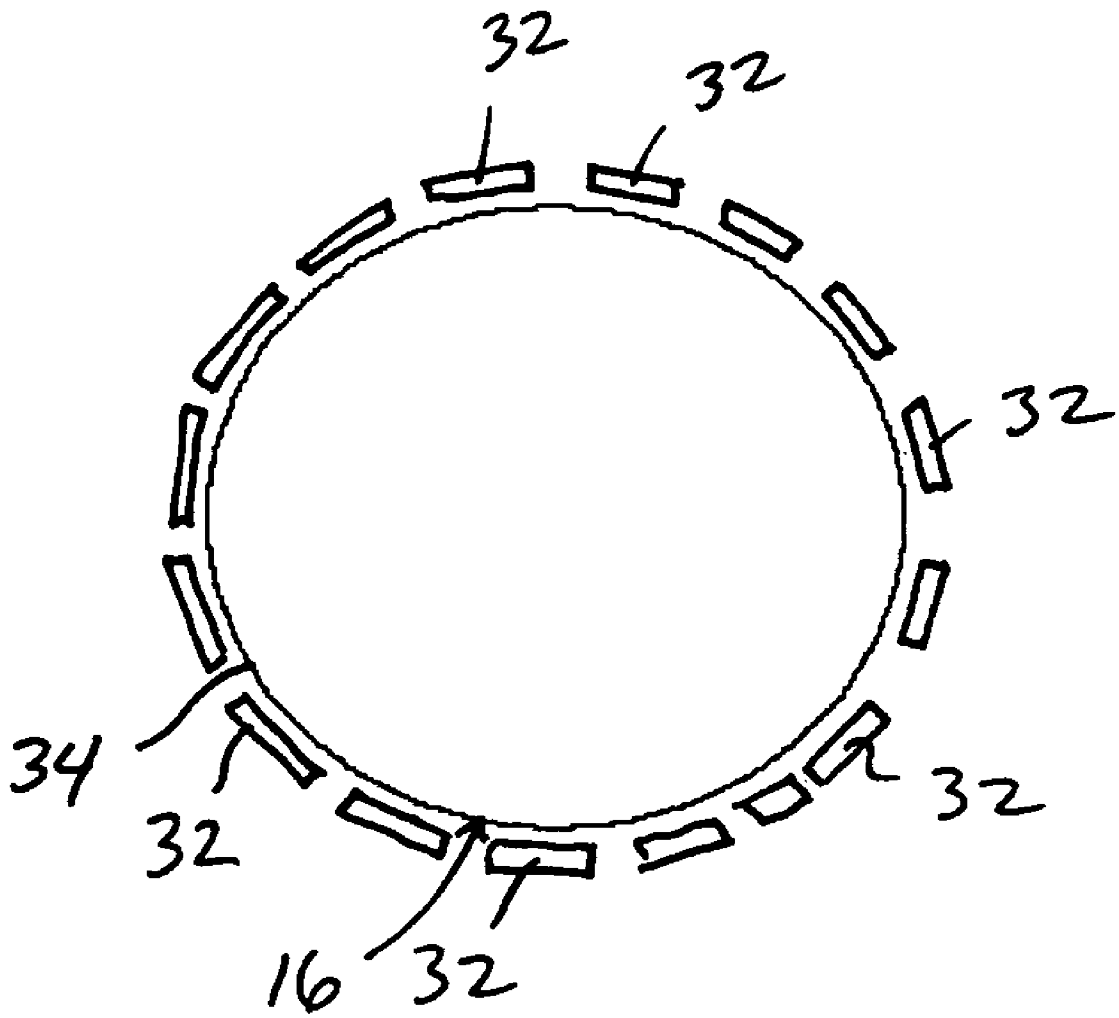


Fig. 3

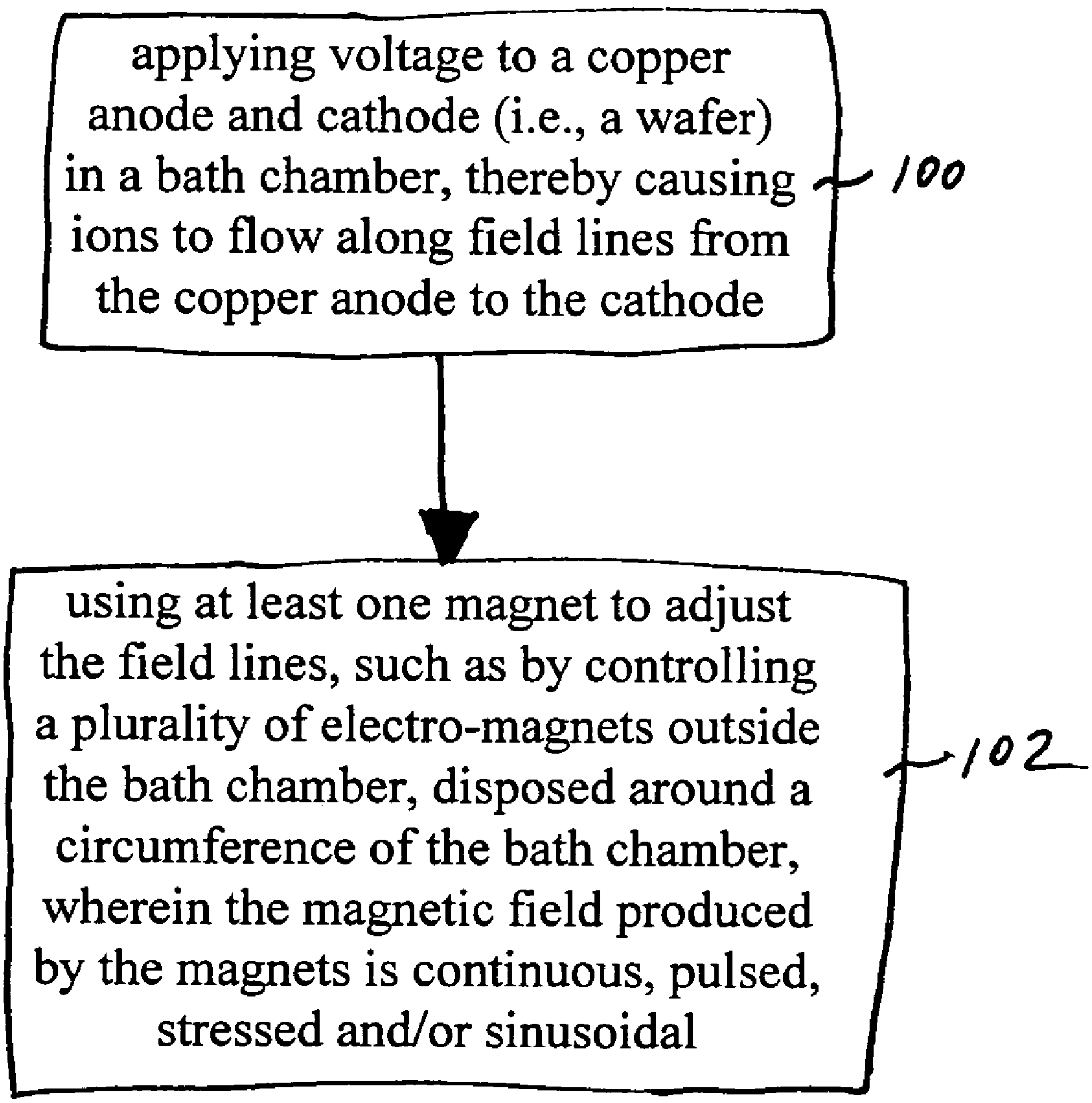

applying voltage to a copper anode and cathode (i.e., a wafer) in a bath chamber, thereby causing ions to flow along field lines from the copper anode to the cathode
100
using at least one magnet to adjust the field lines, such as by controlling a plurality of electro-magnets outside the bath chamber, disposed around a circumference of the bath chamber, wherein the magnetic field produced by the magnets is continuous, pulsed, stressed and/or sinusoidal
102

Figure 4

MAGNETIC FOCUS RINGS FOR IMPROVED COPPER PLATING

BACKGROUND

[0001] The present invention generally relates to methods and systems for depositing metal on a substrate, such as depositing copper on a semiconductor wafer. The present invention more specifically relates to the use of a magnetic filed, such as with magnetic focus rings, to improve copper plating.

[0002] In the semiconductor industry, copper wire interconnects are becoming the process of record for 0.13 micron processing node and smaller. The current technology used for this process is electro-chemical-deposition (ECD). Many companies manufacture tools for this process. The final copper uniformity of the deposition needs to match the uniformity of the CMP process as much as possible from center to edge before the wafer goes into the post polishing process (either chemical mechanical polishing (CMP) or electro-polishing). If the non-uniformity of the final film and polishing processes are not matched, there are problems with the devices. Another problem is gap fill. As dimensions get smaller, technology is relying more on the chemistry to assist gap fill. However, voids are still a major problem with regard to the new technologies which are being used.

[0003] Typically, current tool designs are very similar to each other, except for differences in the design of the plating cell head which holds the wafer (and which operates as the cathode in the plating process), the cell body (which is the bath tank for the plating solution), and the anode (which is the source of the copper ions which become deposited on the wafer). In the industry, tool suppliers provide a plumbing, re-circulation, and filtration system for supplying the electrolyte solution to the surface of the wafer in the presence of an electric field. As shown in **FIG. 1**, a DC source **10** is used to apply a field from a copper anode **12** to a wafer (the cathode) **14** in a plating bath chamber **16**, and Cu2+ copper ions follow field lines **18** to the surface **20** of the wafer **14**. In attempts to control the uniformity, each of the vendors that manufacture a tool for this process has designed a different cell head, a different bath structure, and different anode configurations. However, all of these designs still yield a level of non-uniformity that must be dealt with in future processing steps. Other attempts using different chemical formulations have also been devised to deal with the problems of non-uniformity of deposit and the presence of voids.

[0004] Generally, existing solutions have not solved the uniformity and gap fill problems associated with deposition of copper on a semiconductor wafer. In fact, some of the designs have introduced additional problems that are difficult to eliminate, such as edge particles caused by the contact ring, or bulk defects caused by the chemistry.

OBJECTS AND SUMMARY

[0005] An object of an embodiment of the present invention is to provide a method and system which can be used to deposit copper uniformly onto a wafer.

[0006] Another object of an embodiment of the present invention is to provide a method and system which deposits copper onto a wafer such that there is no gap fill problem.

[0007] Briefly, and in accordance with at least one of the foregoing objects, an embodiment of the present invention provides a method and system wherein magnets are employed proximate, such as on the outside of, a plating bath chamber to control the field lines that are used during the plating process. By being able to control the field lines during the plating process, improved gap fill and uniformity can be achieved.

[0008] The magnetic field acting on the bath can be continuous, pulsed, stressed (i.e., the shape of the field can be changed), sinusoidal, etc. The magnetic field can be modulated as function of time to produce a desired copper uniformity on the wafer. It is anticipated that there is no limit to how the shape of the magnets or magnetic field can be configured and controlled to achieve the desired result for both fill of deep contacts and the uniformity needed to match the subsequent polish process.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The organization and manner of the structure and operation of the invention, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in connection with the accompanying drawing, wherein:

[0010] **FIG. 1** illustrates a prior art system for depositing copper on the surface of a semiconductor wafer;

[0011] **FIG. 2** illustrates a system for depositing copper on the surface of a semiconductor wafer, wherein the system is in accordance with an embodiment of the present invention;

[0012] **FIG. 3** provides a top view, showing magnets positioned around the circumference of the bath chamber;

[0013] **FIG. 4** provides a flow chart of a method which can be used in connection with the system shown in **FIG. 2**, wherein the method is in accordance with an embodiment of the present invention.

DESCRIPTION

[0014] While the invention may be susceptible to embodiment in different forms, there are shown in the drawings, and herein will be described in detail, specific embodiments of the invention. The present disclosure is to be considered an example of the principles of the invention, and is not intended to limit the invention to that which is illustrated and described herein.

[0015] **FIG. 2** illustrates a system **30** for depositing copper on the surface **20** of a semiconductor wafer **14**, wherein the system **30** is in accordance with an embodiment of the present invention. The system **30** provides that magnets **32** are positioned proximate a bath housing **16**. While the magnets **32** may possibly be placed within the bath housing **16** if properly insulated, as shown in **FIG. 3** preferably the magnets **32** are positioned on the outside of the bath housing **16**, around its circumference or outer perimeter **34**. Regardless, the magnets **32** are used to provide a magnetic field to improve uniformity and gap fill. Specifically, a DC source **10** is used to apply a field from a copper anode **12** to a wafer (the cathode) **14** in a plating bath chamber **16**, and Cu2+ copper ions follow field lines **40** to the surface **20** of the wafer **14**. The magnets **32** are used to effectively modify the field lines **40** so that they are more linear between the anode (i.e., the copper) **12** and the cathode (i.e., the wafer) **14** (i.e., compare the field lines **18** illustrated in **FIG. 1** to the field lines **40** illustrated in **FIG. 2**).

[**0016**] The magnets **32** may be permanent magnets and/or controllable electro-magnets. If at least some of the magnets **32** are electro-magnets, a control system **42** is connected to the electro-magnets and is operable to modulate the magnets to provide a desired magnetic filed such that the filed lines **40** between the anode **12** and cathode **14** are tuned as desired to improve both uniformity of copper deposit and improve gap fill. The magnetic field acting on the bath can be continuous, pulsed, stressed (i.e. the shape of the field can be changed), sinusoidal, etc. There is no limit to how the shape of the magnets or magnetic field can be configured and controlled to achieve the desired result for both fill of deep contacts and the uniformity needed to match the polish process.

[**0017**] The typical uniformity problems seen on plated wafers manifests itself as a bulls eye, center to edge pattern. By modulating the intensity of the magnetic field, the shape and intensity of the field lines produced by the power supply connected to the cathode and anode can be altered to produce a desired uniformity pattern on the wafer. The shapes of the magnetic field can also be controlled such that the intensity can be modulated at any area of the bath. The magnetic fields generated would force the field lines to be vertical in both the center of the wafer and at the edge of the bath allowing the migrating copper ions to arrive at the surface of the wafer "more vertical" therefore more successfully in filling the deep gaps in both the center of the wafer and the edge of the wafer.

[**0018**] Preferably, the control system **42** is configured such that the magnetic filed is modulated over time. Improved vertical plating at the edge of the wafer is more important at the beginning of the plating process. As the contacts fill, the high aspect ratio decreases. As this happens, preferably the magnetic filed is modulated so that the field lines are changed to go from "the best fill" to the most desired uniformity to meet the needs of the polish process.

[**0019**] The present invention provides that fixed or electrically controlled magnets are used in association with a plating bath chamber to control the field lines that are used during the plating process. By controlling the field lines during the plating process, improved gap fill and uniformity can be achieved. None of the currently available electroplating tools on the market utilize such a method of field line control for uniformity or gap fill improvement.

[**0020**] **FIG. 4** shows a flow chart of at least one embodiment of this invention. Box **100** explains the basic electroplating process and box **102** explains the improved copper deposition process by the utilization of a controlled magnetic field to improve deposition uniformity.

[**0021**] While embodiments of the present invention are shown and described, it is envisioned that those skilled in the art may devise various modifications of the present invention without departing from the spirit and scope of the appended claims.

What is claimed is:

1. A method for using an anode to plate a cathode with ions in a bath chamber, comprising: applying a voltage to the anode and the cathode, the anode and cathode being disposed in the bath chamber, thereby causing ions to flow along field lines from the anode to the cathode in the bath chamber and plate the cathode; and using at least one magnet to adjust the field lines.

2. A method as recited in claim 1, wherein the anode comprises copper and the cathode comprises a wafer.

3. A method as recited in claim 1, wherein the step of using at least one magnet to adjust the field lines comprises using a plurality of permanent magnets.

4. A method as recited in claim 1, wherein the step of using at least one magnet to adjust the field lines comprises using a plurality of electro-magnets.

5. A method as recited in claim 1, wherein the step of using at least one magnet to adjust the field lines comprises using a control system and a plurality of electro-magnets connected to the control system.

6. A method as recited in claim 1, wherein the step of using at least one magnet to adjust the field lines comprises using a plurality of magnets which are disposed outside of the bath chamber.

7. A method as recited in claim 1, wherein the step of using at least one magnet to adjust the field lines comprises using a plurality of magnets which are disposed outside of the bath chamber, around a circumference of the bath chamber.

8. A method as recited in claim 1, wherein the step of using at least one magnet to adjust the field lines comprises using a plurality of magnets and controlling the magnets such that the magnets provide a magnetic field which is at least one of continuous, pulsed, stressed and sinusoidal.

9. A method as recited in claim 1, wherein the step of using at least one magnet to adjust the field lines comprises using a plurality of magnets and controlling the magnets such that the magnets provide a magnetic field which is modulated over time.

10. A plating system comprising: a bath chamber; an anode disposed in the bath chamber; a cathode disposed in the bath chamber; a voltage source connected to the anode and cathode, wherein application of voltage causes ions to flow along field lines from the anode to the cathode in the bath chamber and plate the cathode; and at least one magnet disposed proximate the bath chamber, wherein said at least one magnet adjusts the field lines.

11. A system as recited in claim 10, wherein the anode comprises copper and the cathode comprises a wafer.

12. A system as recited in claim 10, wherein said at least one magnet comprises a plurality of permanent magnets.

13. A system as recited in claim 10, wherein said at least one magnet comprises a plurality of electro-magnets.

14. A system as recited in claim 13, further comprising a control system connected to the plurality of electro-magnets.

15. A system as recited in claim 10, wherein said at least one magnet comprises a plurality of magnets which are disposed outside of the bath chamber.

16. A system as recited in claim 10, wherein said at least one magnet comprises a plurality of magnets which are disposed outside of the bath chamber, around a circumference of the bath chamber.

17. A system as recited in claim 14, wherein the control system is configured to control the electro-magnets such that the electro-magnets provide a magnetic field which is at least one of continuous, pulsed, stressed and sinusoidal.

18. A system as recited in claim 14, wherein the control system is configured to control the electro-magnets such that the electro-magnets provide a magnetic field which is modulated over time.

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