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(54) **PLASMA VAPOR DEPOSITION WITH COIL SPUTTERING**

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This patent is subject to a terminal disclaimer.

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(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 08/971,867, filed on Nov. 19, 1997, now Pat. No. 6,375,810, which is a continuation-in-part of application No. 08/907,382, filed on Aug. 7, 1997, now abandoned.

(51) **Int. Cl.**[7] **C23C 14/34**

(52) **U.S. Cl.** **204/192.12**; 204/192.13; 204/192.15; 204/192.32; 204/192.33; 204/192.35; 204/192.1; 204/298.06; 204/298.07; 204/298.08; 204/298.11; 204/298.12; 204/298.13; 204/298.15; 204/298.16; 204/298.03

(58) **Field of Search** .... 204/298.06, 298.07, 204/298.08, 298.11, 298.12, 298.13, 298.15, 298.16, 298.03, 192.12, 192.13, 192.15, 192.32, 192.33, 192.35, 192.1; 118/723 I, 723 IR; 156/345.48

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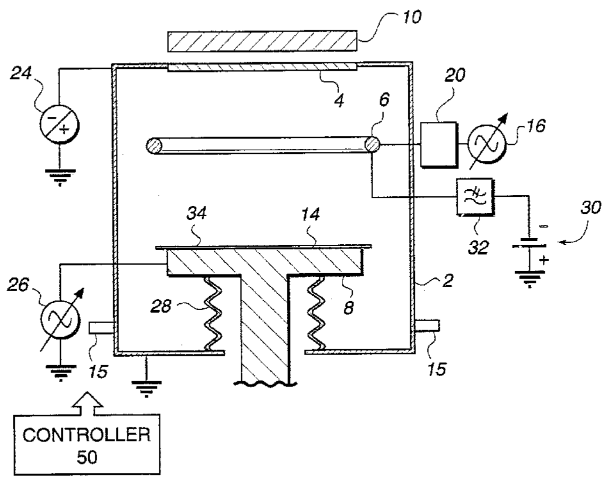
(57) **ABSTRACT**

A method and apparatus for depositing a layer of a material which contains a metal on a workpiece surface, in an installation including a deposition chamber; a workpiece support providing a workpiece support surface within the chamber; a coil within the chamber, the coil containing the metal that will be contained in the layer to be deposited; and an RF power supply connected to deliver RF power to the coil in order to generate a plasma within the chamber, a DC self bias potential being induced in the coil when only RF power is delivered to the coil. A DC bias potential which is different in magnitude from the DC self bias potential is applied to the coil from a DC voltage source.

In order to place a deposition chamber of a physical vapor deposition apparatus in which metal or other material is sputtered from a target and a coil in condition to effect deposition of a layer consisting of the sputtered material on a substrate subsequent to deposition, in the apparatus, of a layer containing a reaction compound of the sputtered material, the chamber is filled with a non-reactive gas and a voltage is applied to sputter from the target and coil any reaction compound which has coated the target and coil during deposition of the layer containing the reaction compound of the sputtered metal.

53 Claims, 2 Drawing Sheets



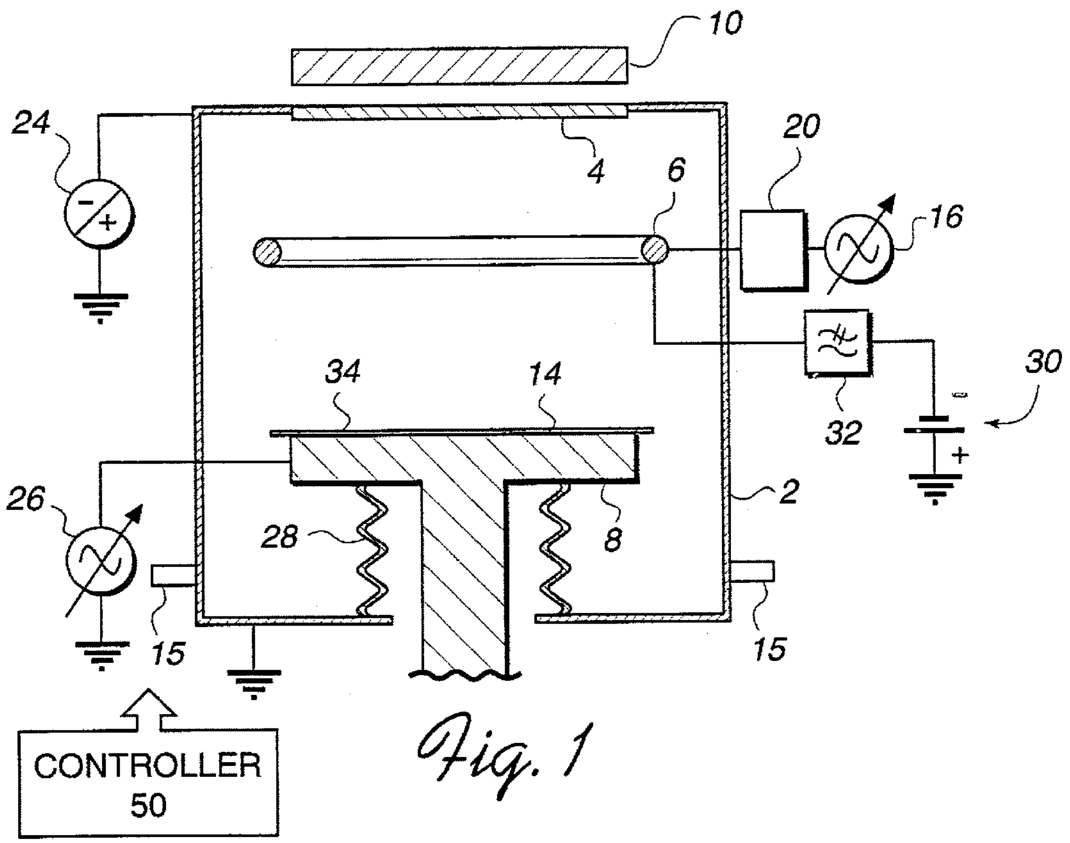

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Fig. 1

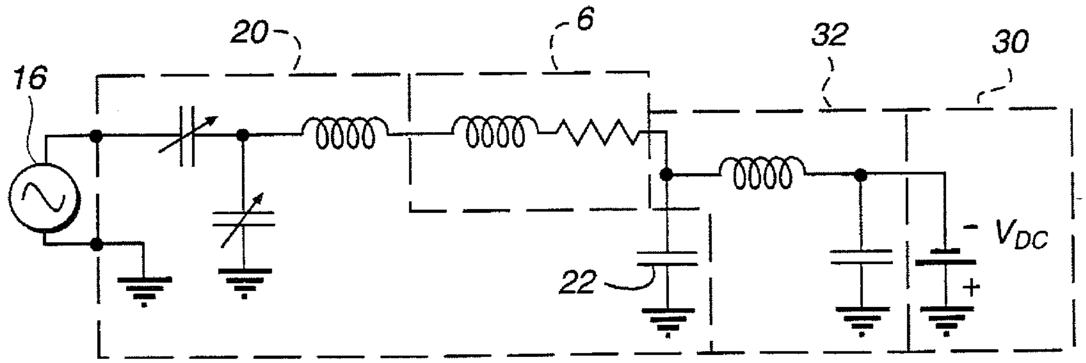
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Fig. 2

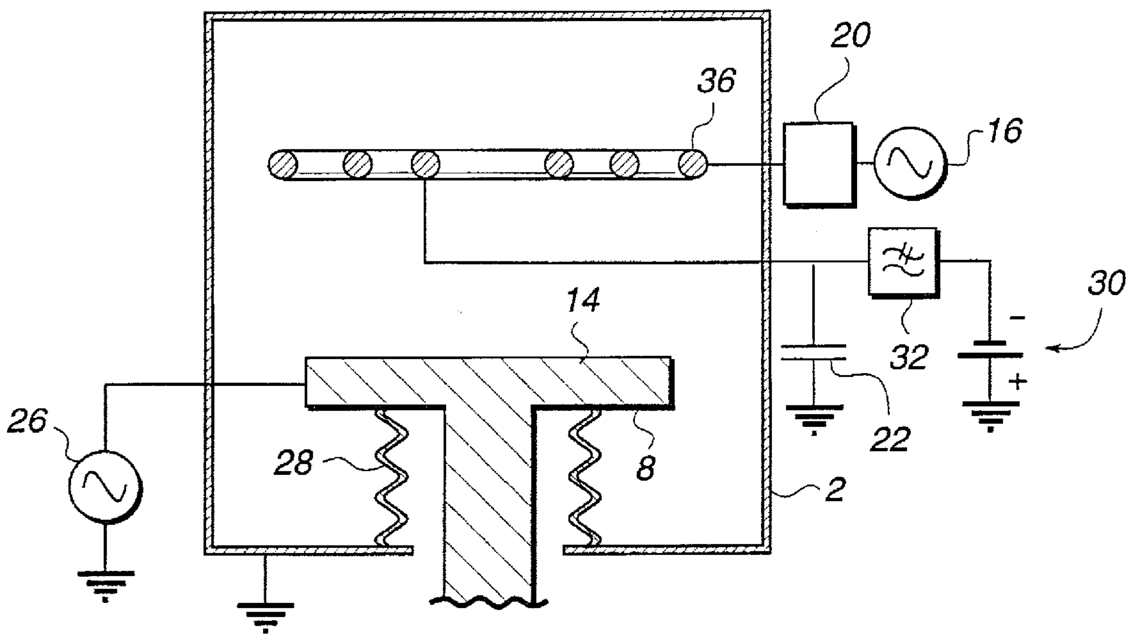

Fig. 3

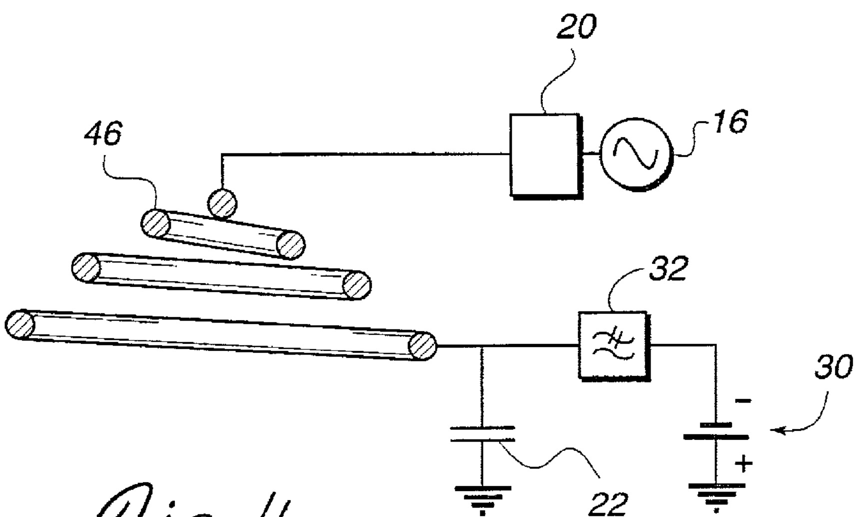

Fig. 4

PLASMA VAPOR DEPOSITION WITH COIL SPUTTERING

CROSS-REFERENCE TO RELATED APPLICATIONS

This is a continuation of my application Ser. No. 08/971,867, filed Nov. 19, 1997 now U.S. Pat No. 6,375,810, entitled PLASMA VAPOR DEPOSITION WITH COIL SPUTTERING, which is a continuation-in-part of application Ser. No. 08/907382, filed Aug. 7, 1997, now abandoned entitled PLASMA VAPOR DEPOSITION WITH COIL SPUTTERING, Attorney Docket 1957/PVD/DV.

BACKGROUND OF THE INVENTION

The present invention relates to the deposition of layers, or films, of metals and metal compounds on a workpiece, or substrate, during fabrication of integrated circuits, display components, etc. In connection with the fabrication of integrated circuits, the substrate may be constituted by one or more semiconductor wafers, while in the case of fabrication of a display, such as a liquid crystal display, the substrate may be one or more glass plates. The substrate could also be a hard disc that will be used for data storage, or read/write heads for a disc drive.

It is known to deposit layers on such substrates by processes such as physical vapor deposition. By way of example, as described in copending application Ser. No. 08/680,335 abandoned , filed Jul. 10, 1996 (Attorney Docket No. 1390CIP/PVD/DV), entitled "Coils for Generating a Plasma and for Sputtering" by Jaim Nulman et al., which is assigned to the assignee of the present application and incorporated herein by reference in its entirety, processes of this type may be performed in apparatus including a deposition chamber which contains a target, a coil and a support for the substrate. The target is made of a material such as a metal which will form a metal layer or the metal component of a metal compound layer. The coil will be supplied with an RF current that will generate, within the chamber, an RF electromagnetic field.

When a gas is introduced into the chamber at an appropriate pressure, a dense plasma (10^{11}–10^{13} ions/cm^3) may be ignited inside the chamber by the RF electromagnetic field. The target may be associated with a magnetic field producing device, such as a magnetron, and may be biased by a DC or RF voltage applied to the target from a voltage source. The magnetic field traps electrons, while the DC bias voltage on the target attracts ions to the target. These ions dislodge, or sputter, atoms or clusters of atoms of material from the target. The sputtered atoms travel toward the support and a certain proportion of these atoms are ionized in the plasma. The support provides a surface for supporting the substrate and may be biased, usually by an AC source, to bias the substrate with a polarity selected to attract ionized target material to the substrate surface. The bottom coverage of high aspect ratio trenches and holes on the substrate can be improved by this substrate bias. Alternatively, the chamber may sputter target material without an RF coil or other devices for generating an ionizing plasma such that substantially all the material deposited is not ionized.

Although the RF electromagnetic field is generated by applying an alternating RF current to the coil, a DC potential may be induced in the coil as described in the aforementioned copending application Ser. No. 08/680,335. This potential which may be referred to as a self bias, combines with the RF potential on the coil. The combined DC and RF potentials have the net effect of attracting ions from the plasma to the coil. If the coil is made of the same material as the target, the coil can constitute an additional source of deposition material which will be sputtered from the coil by ions attracted from the plasma to be deposited on the substrate.

If a film consisting essentially of only the sputtered material is to be formed on a substrate, then the gas within the chamber is preferably nonreactive with respect to the sputtered atoms. If, on the other hand, a compound film formed by a chemical reaction of the target material with another constituent is to be formed, the gas introduced into the chamber may have a composition selected to react with the sputtered target material ions and atoms to form molecules of the compound, which are then deposited on the substrate. Alternatively, the gas may react with the target material while or after it is deposited.

For example, plasma and nonionizing plasma sputtering deposition processes of the type described above can be used to deposit either a pure metal or metal alloy, such as titanium, tantalum, aluminum, copper, aluminum-copper, etc., or a metal compound, such as titanium nitride (TiN), aluminum oxide (Al_2O_3), etc. Also, other non metallic materials may be deposited such as silicon and silicon dioxide. For deposition of a pure metal or metal alloy, the target, and possibly the coil, will be made of this metal and the plasma gas is preferably a non-reactive gas, i.e. a gas such as argon, helium, xenon, etc., which will not react with the metal. For deposition of a metal compound, the target, and possibly the coil, will be made of one component of the compound, typically the metal or metal alloy, and the chamber gas will include a reactive gas composed of, or containing, the other component or components of the compound, such as nitrogen or oxygen. The sputtered metal reacts with gas atoms or molecules to form the compound, molecules of which are then deposited on the substrate. In the same manner, a nonmetallic target material may be sputtered in a nonreactive environment to deposit relatively pure target material onto the substrate. Alternatively, the target material may be sputtered in a reactive environment to produce on the substrate a layer of a compound of the target material and a reactive component. Hereinafter, a compound formed of a target or coil material and a reactive component will be referred to as a reaction compound, whether the sputtered material is metallic or otherwise.

One factor determining the performance of such apparatus is the density of gas, and hence the density of the plasma, in the chamber. A relatively dense plasma can provide an increased ionization rate of the sputtered material atoms, thus improving bottom coverage of trenches and holes on the substrate. However, under high pressure conditions, material sputtered from the target tends to be deposited preferentially in a central region of the substrate support surface. Such nonuniformity can often increase at higher deposition rates or higher pressures.

This nonuniformity is disadvantageous because the thickness of the deposited layer preferably should correspond to a nominal value, within a narrow tolerance range, across the entire support surface. Therefore, when the substrate is, for example, a wafer which will ultimately be diced into a plurality of chips, and there is a substantial variation in the thickness of the layer across the wafer surface, many of the chips may become rejects that must be discarded.

As described in the aforementioned copending application Ser. No. 08/680,335, it has been recognized that material sputtered from the coil may be used to supplement the deposition material sputtered from the primary target of the chamber. Because the coil can be positioned so that material sputtered from the coil tends to deposit more thickly at the periphery of the wafer, the center thick tendency for material sputtered from the primary target can be compensated by the edge thick tendency for material sputtered from the coil. As a result, uniformity can be improved.

The quantities of material sputtered from the coil and the target are a function of several factors including the DC power applied to the target and the RF power applied to the coil. However, the freedom to adjust these and other factors may be limited in some applications by the requirements of other process parameters which are often interdependent. Thus, a need exists for further control over the quantity of material sputtered from the coil to facilitate further increases in the degree of uniformity of deposition that may be achieved.

In addition, when such apparatus is used to deposit a reaction compound layer, some of the reaction compound typically also coats the target and the coil. For example, when titanium nitride is deposited in a chamber having a titanium metal target in a nitrogen atmosphere, titanium nitride typically coats the target and coil. Therefore, if it were then attempted to deposit a pure target material layer, i.e., a layer of just titanium, in the same apparatus, the reaction compound molecules of titanium nitride would likely also be sputtered from the target, and also from the coil, and thus could contaminate the titanium metal layer. Therefore, it has generally not been practical to sputter deposit a metal or metal alloy layer from a target of the same material immediately after having deposited a metal compound layer in the same apparatus.

Some efforts have been made to deal with this drawback by sputtering away the metal compound layer coating on the target, and covering over the metal compound layer coating on the coil with a layer of the metal sputtered from the target, this procedure being known as "pasting". However, such attempts have generally been found to be unacceptably costly and time-consuming, and otherwise unsatisfactory.

Therefore, facilities in which layers of a metal and layers of a compound of that metal are to be deposited on substrates are typically equipped with two apparatuses, each for depositing a respective type of layer. This, of course, may entail twice the investment cost associated with one apparatus. Moreover, in production systems having multiple chambers coupled to a central transfer chamber, valuable perimeter space of the transfer chamber is occupied by an extra chamber that could otherwise be used by another chamber to increase throughput or provide additional processes.

BRIEF SUMMARY OF THE INVENTION

It is an object of the present invention to alleviate the above difficulties.

A more specific object of the invention is to improve the uniformity with which a layer of material is deposited on a substrate.

Another object of the invention is to achieve such improvement in uniformity without any significant increase in the cost or complexity of the deposition apparatus.

Still another object of the invention is to improve deposited film uniformity while, at the same time, improving apparatus throughput.

Still another object of the invention is to improve deposited film uniformity while at the same time reducing the cost and complexity of the deposition apparatus.

Still another object of the invention is to allow added control of the rate of deposition of material on a substrate.

A further specific object of the invention is to facilitate deposition of a layer of a target material such as an elemental metal or metal alloy in a single deposition apparatus a short time after completion of deposition of a layer of a reaction compound of the target material and another constituent.

A still more specific object of the invention is to rapidly remove reaction compound material which has been deposited on the target or coil in a deposition chamber subsequent to a reaction compound layer deposition process and prior to a target material layer deposition process which does not include a reactive constituent.

The above and other objects are achieved, according to the present invention, by a method and apparatus for sputter depositing a layer on a substrate in which following deposition of a layer of reaction compound formed from constituents which includes a reactive material and a material sputtered from a target or coil, a layer of material sputtered from the same target or coil may be deposited in the same chamber in which the subsequent layer is substantially free of contamination by the reaction compound or the reactive material. In the illustrated embodiment, this may be achieved by removing the reactive material from the sputter chamber following the deposition of the reaction compound, introducing a non-reactive gas into the enclosure, and sputtering substantially all reaction compound from the target or coil which provided the source of the sputtered material. As a consequence, the same chamber is then ready to deposit another layer except that the layer may be a layer consisting essentially of only material sputtered from the source. In this manner, a chamber may be used to deposit a metal compound such as titanium nitride and then after sputter cleaning, be ready to deposit a layer of relatively pure titanium in the same chamber without substantial contamination by titanium nitride.

This aspect of the invention is particularly applicable to apparatus which includes a chamber containing a sputtering target and a plasma generating coil. According to the invention, a suitable voltage is applied to the coil, while the chamber is filled with a non-reactive gas and does not contain any substrate, to produce a plasma which will rapidly sputter deposited metal compound material from the target, and possibly also from the coil.

The above and other objects are further achieved, according to the present invention, by a method and an apparatus for depositing a layer of a material which contains a metal on a workpiece surface in which both RF energy is supplied to a coil to generate a plasma to ionize the deposition material, and a separate DC bias is applied to the coil to control the coil sputtering rate. In the illustrated embodiment, a DC voltage source is coupled to the coil through an RF filter to provide a DC bias potential which is different in magnitude from the coil DC self bias potential which results from the applied RF power. In this manner, the coil bias potential and hence the coil sputtering rate may be controlled with a degree of independence from the RF power applied to the coil.

In another aspect of the invention, the coil may be shaped and positioned to permit use as the sole source of sputtered material within said chamber while maintaining good uniformity. As a consequence, in some applications, the need for a separate target and associated magnetron may be eliminated.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

FIG. **1** is a simplified, elevational, cross-sectional view of deposition apparatus constructed according to one embodiment of the invention.

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