ABSTRACT

A plating solution containing 10 to 40 wt % of copper hexafluorosilicate. With the use of this plating solution, a copper thin film which has a low film stress and a low resistivity and which strongly (111)-oriented is plating-deposited on the fine pattern portion a copper seed layer, and film peeling caused by deterioration of an adhesion force between an underlying barrier layer and a copper seed layer even in a heat treatment process and in a chemical mechanical polishing (CMP) process after plating deposition is prevented.
As deposition

Resistivity ($\mu \Omega \cdot \text{cm}$)

Film Stress (MPa)

CuSO$_4$

CuSiF$_6$

EPCu(400nm)/Cu(100nm)/TaN(30nm)/SiO$_2$(200nm)/Si

Fig. 1
Fig. 2

Film Stress (MPa)

- CuSO₄
- CuSiF₆

Deposition Rate (nm/s)

Min.

EPCu(400nm)/Cu(100nm)/TaN(30nm)/SiO₂(200nm)/Si
Fig. 5

Adhesion Force (gf)

Deposition Rate (nm/s)

Max.

EPCu(400nm)/Cu(100nm)/
TaN(30nm)/SiO2(200nm)/Si

CuSiF₆

CuSO₄
Fig. 6

Adhesion Force (gf)

CuSiF$_6$
CuSO$_4$

Max.

Film Thickness (nm)

EPCu(400nm)/Cu(100nm)/
TaN(30nm)/SiO$_2$(200nm)/Si
Fig. 9A

Fig. 9B

Fig. 9C
SEMICONDUCTOR INTEGRATED CIRCUIT AND
A METHOD FOR FORMING THE SAME

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

The present invention relates to an electroplating solution used for depositing a copper wiring layer having a film stress which is important to increase the degree of integration and the speed of a semiconductor integrated circuit.

[0002] 2. Description of the Prior Art

It is known that with a development of micropatterns in a semiconductor integrated circuit the operation speed of such a circuit is determined by a product (CR: time constant) of an interlayer capacity (C) of a multilayer interconnection and a resistance (R) of a micropatterning layer, thus being different from a conventional semiconductor integrated circuit in which the circuit is determined by a speed obtained by an electron traveling time of a MOS transistor.

[0005] A plating technique that uses a copper sulfate aqueous solution used in a conventional printed circuit board as an electrolyte is presently used to deposit a copper layer used in a copper wiring layer of a semiconductor integrated circuit. This technique is directly used to deposit a copper wiring layer of a semiconductor integrated circuit that has a difference in level at a pattern dimension of 0.2 μm or less. In particular, in the U.S.A., such a technique has been used widely in microprocessors.

[0006] However, the conventional copper plating technique that uses a copper sulfate aqueous solution as an electrolyte is developed for a printed circuit board that has a pattern diameter of about 1 mm. In this technique, the film quality (resistivity and orientation characteristics of Cu polycrystal) is incomplete, and the study of Electromigration (EM) resistance is not sufficient.

[0007] In view of these problems, a new plating technique is desired to be developed in place of the current technique that uses a copper sulfate plating solution. As a result, in Japanese Patent Application No. 2000-291585, the present inventors disclosed a plating method of a copper thin film which is characterized in that copper hexafluorosilicate is used as an electrolyte so that a copper thin film having a low resistivity and strongly (111)-oriented is plated and deposited and the copper thin film is plated and deposited on a fine pattern portion having a large aspect ratio with good covering properties.

[0008] However, in copper thin films deposited with the conventional copper sulfate plating solution and a copper hexafluorosilicate plating solution of Japanese Patent Application No. 2000-291585, film stress during plating deposition tend to be high. Accordingly, an adhesion force between an underlying barrier layer and a copper seed layer is deteriorated by distortion, thus causing film peeling in a heat treatment process and in a chemical mechanical polishing (CMP) process after plating deposition. Therefore, a further improvement in the film quality is strongly demanded.

[0009] In order to solve the problem of signal delay derived from micropatterning of a semiconductor integrated circuit, a metal copper (Cu) is used as a wiring material in place of aluminum (Al). It is known that a reduction in sheet resistance of the wiring layer and an improvement of Electromigration (EM) resistance are achieved by the employment of the copper wiring layer. However, when the plating technique that uses a conventional copper sulfate aqueous solution as an electrolyte is used in wiring of a semiconductor integrated circuit that has a latest pattern dimension of 0.2 μm or less and contains a difference in level, a large number of problems occur. In other words, a further reduction in resistivity and a further improvement of the (111)-orientation strength are required.

[0010] The resistivity of a copper wiring layer deposited with copper sulfate is not lower than expected, and a copper diffusion barrier film having a thickness of 10 nm or more must be used in the copper wiring layer that has a small line width. For this reason, the actual wiring resistance becomes high. In addition, it is difficult to plate and deposit a copper wiring layer in a contact hole portion of a semiconductor integrated circuit that has a contact dimension of 200 nm or less and an aspect ratio of 5 or more with preferable covering properties. In the deposition using the copper sulfate plating solution, such dimensions are the lower limit. Therefore, in order to solve the various problems of the copper sulfate plating solution, in Japanese Patent Application No. 2000-291585, the present inventors disclosed a copper hexafluorosilicate plating solution as a new plating solution in place of the conventional copper sulfate plating solution. This solution provides a plating method that deposits a copper thin film that has a low resistivity and strongly (111)-oriented.

[0011] However, in order to form a copper wiring layer on a wiring layer of a semiconductor integrated circuit, as shown in FIG. 9, a heat treatment process for stabilization, a chemical mechanical polishing (CMP) process or the like for flattening, etc. must be performed after plating deposition. A copper thin film deposited by the copper sulfate plating solution and the copper hexafluorosilicate plating solution according to Japanese Patent Application No. 2000-291585 has drawbacks because of its high film stress. In other words, an adhesion force between an underlying barrier layer and a copper seed layer is deteriorated by distortion, thus causing film peeling in the heat treatment process of the copper thin film and in the chemical mechanical polishing (CMP) process performed thereafter.

SUMMARY OF THE INVENTION

[0012] Accordingly, the present invention is to solve the various problems caused by the copper sulfate plating solution.

[0013] It is, therefore, an object of the present invention to provide an electroplating solution which can reduce the stress of a copper thin film deposited by using a copper hexafluorosilicate plating solution, which does not deteriorate an adhesion force between a copper seed layer and an underlying barrier layer even in a heat treatment process and in a chemical mechanical polishing (CMP) process after plating deposition, and which can plate and deposit a copper thin film on a fine pattern portion having a large aspect ratio with good covering properties.

[0014] In other words, the present invention provides an electroplating solution used for depositing a copper wiring
layer that has a film stress which is important to increase the degree of integration and the speed of a semiconductor integrated circuit.

[0015] More specifically, the present invention provides an electroplating solution that can reduce the stress of a copper thin film and deposit such a copper thin film on a fine pattern portion, which has a large aspect ratio, with good covering properties, so that the copper film does not cause any film peeling derived from deterioration of an adhesion force between an underlying barrier layer and a copper seed layer even in a heat treatment process and in a chemical mechanical polishing (CMP) process after plating deposition.

[0016] The present inventors attempted to solve the prior art problems of copper plating performed by a copper sulfate electrolyte, and such attempts was made by way of optimizing various plating conditions such as a current density, an electrode structure, and a plating solution temperature. However, the present inventors found that the problems are not solved except for an improvement in covering properties that us obtained by an additive agent and found also that an improvement of film quality, i.e., a reduction in resistivity and an improvement of (111)-orientation strength, is not accomplished by a current copper sulfate electrolyte. For this reason, the present inventors disclosed in Japanese Patent Application No. 2000-29185 a plating method of a copper thin film that uses a copper hexafluorosilicate aqueous solution as an electrolyte serving as a new plating solution in place of a copper sulfate plating solution to solve the problems caused by copper sulfate plating solutions.

[0017] However, with respect to the problem of film peeling caused by deterioration of an adhesion force between an underlying barrier layer and a copper seed layer in the heat treatment process and in the chemical mechanical polishing (CMP) process after plating deposition, it was found that a film stress in plating deposition caused by film peeling is not reduced sufficiently by the conventional copper sulfate plating solution and the copper hexafluorosilicate plating solution disclosed in Japanese Patent Application No. 2000-291585.

[0018] So as to solve the problem of film peeling caused by the deterioration of the adhesion force, the inventors earnestly continued the study using the copper hexafluorosilicate plating solution as an electrolyte. As a result, the inventors found that a copper thin film that has a low stress can be plating-deposited with a use of an aqueous solution that contains 10 to 40 wt % of copper hexafluorosilicate as an electrolyte and thus completed the present invention.

[0019] More specifically, the present invention is characterized in that an aqueous solution, which is used as an electrolyte, contains 10 to 40 wt % of copper hexafluorosilicate. When the 10 to 40 wt % copper hexafluorosilicate aqueous solution is used as an electrolyte, in comparison to the case in which a conventional copper sulfate and a copper hexafluorosilicate plating solution of Japanese Patent Application No. 2000-291585 are used, a copper thin film that has a low film stress and a low resistivity and which is strongly (111)-oriented can be deposited with good covering properties on a fine pattern of a copper wiring layer of a semiconductor integrated circuit.

[0020] The electroplating solution of the present invention is applicable when a copper thin film is partially or entirely deposited on a printed circuit board, a glass substrate, and a silicon wafer a pattern formed or not formed on their surfaces. When the solution of the present invention is employed, a copper thin film which has a low film stress and a low resistivity and which is strongly (111)-oriented is partially or entirely deposited on a printed circuit board, a glass substrate, and a silicon wafer on which a pattern is formed or not formed.

[0021] The current density during plating is preferably within the range of 0.5 to 1.5 A/dm². When the current density falls within this range, a copper thin film which is good in (111)-orientation strength is deposited with good covering properties. When the current density is less than 0.5 A/dm², the deposition rate is considerably low. When the current density exceeds 1.5 A/dm², then the deposition rate deteriorates because of generation of hydrogen, and defective introduction of hydrogen into the film occur, thus decreasing the reliability of the film.

[0022] The plating solution temperature during plating is preferably within the range of 20 to 40° C. When the plating solution temperature falls within this range, (111)-orientation strength is especially good, and hydrogen is not generated during the plating. In addition, the deposition rate does not decrease, and no void is formed in the film. Therefore, the film has good reliability.

[0023] The amount of an additive agent to be added to the solution during plating is preferably within the range of 0.5 to 1.5 wt %. When the plating is performed with aid addition of an additive agent in the amount that falls within this range, a copper thin film having a low resistivity is formed on the fine contact portion with good covering properties. When the amount of the additive agent is smaller than 0.5 wt %, the resistivity increases, and the covering properties decreases. When the amount of additive agent exceeds 1.5 wt %, a film which is strongly (111)-oriented cannot be obtained, and the film is not preferable in reliability.

[0024] As the additive agent, organic compounds (e.g., sodium mercaptopropane sulfonate (MPSA), polyethylene glycol (PEG), and ethylene diamine (EDA)) which are conventionally used in electroplating can be used. In addition, at least one of these compounds or a mixture of at least two of these compounds can be used.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] FIG. 1 is a graph showing the relationship between the stress and resistivity of copper thin films formed when plating is performed by using the copper hexafluorosilicate plating solution according to the present invention and a conventional copper sulfate plating solution;

[0026] FIG. 2 is a graph showing the relationship between the deposition rate and stress of the copper thin films formed when plating is performed by using the copper hexafluorosilicate plating solution according to the present invention and the conventional copper sulfate plating solution;

[0027] FIG. 3 is a graph showing the relationship between the film thickness and stress of the copper thin films formed when plating is performed by using the copper hexafluorosilicate plating solution according to the present invention and the conventional copper sulfate plating solution;

[0028] FIG. 4 is a graph showing the manners of changes in stress of the copper thin films before and after annealing
when plating is performed by using the copper hexafluoro-
silicate plating solution according to the present invention and the conventional copper sulfate plating solution;

[0029] FIG. 5 is a graph showing the relationship between the deposition rates and adhesion forces of the copper thin films when plating is performed by using the copper hexafluoro-
silicate plating solution according to the present invention and the conventional copper sulfate plating solution;

[0030] FIG. 6 is a graph showing the relationships between the film thickness and adhesion force of the copper thin films deposited when the copper hexafluoro-
silicate plating solution according to the present invention and the conventional copper sulfate plating solution are used;

[0031] FIG. 7 is a graph showing the manner of changes in adhesion force of the copper thin films before and after annealing when the copper thin films are deposited by using the copper hexafluoro-
silicate plating solution according to the present invention and the conventional copper sulfate plating solution;

[0032] FIG. 8 is a graph showing the relationship between the stress and adhesion force of the copper thin films deposited when the copper hexafluoro-
silicate plating solution according to the present invention and the conventional copper sulfate plating solution are used; and

[0033] FIGS. 9A, 9B and 9C are schematic diagrams showing the steps in which an insulating interlayer (SiO₂) formed on an Si wafer is patterned by standard photolithogra-
phy and dry etching using a conventional photoresist, the photoresist is removed, a 30-nm barrier film (Ta) and a 150-nm Cu seed layer are deposited by a sputtering method on the patterned SiO₂ layer, a copper thin film is plating-deposited on the Cu seed layer by using the copper hexafluoro-
silicate plating solution according to the present invention, and, thereafter, the resultant structure is subjected to heat treatment at 400°C and flattened by a chemical mechanical polishing (CMP) method to form a copper wiring layer on the SiO₂ insulating interlayer.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0034] The electroplating solution for a copper thin film according to the present invention deposits a copper thin film, and in such a copper thin film, film peeling that would occur on the interface between an underlying barrier layer and a copper seed layer in a heat treatment process and in a chemical mechanical polishing (CMP) process after plating deposition can be avoided.

[0035] For example, an SiO₂ film was deposited on an Si wafer so as to have a thickness of 200 nm, a TaN film was deposited as a barrier layer so as to have a thickness of 30 nm, and a copper seed layer was deposited on the resultant structure by a sputtering method so as to have a thickness of 100 nm. Thereafter, the concentration of the copper hexafluoro-
silicate plating solution during plating was changed, and a copper thin film was plated and deposited, and then a heat treatment at 400°C was performed for 15 minutes in a nitrogen atmosphere after the plating deposition. Then, the presence/absence of film peeling is checked.

[0036] The result, as shown in Table 1 below, indicates that the problem of film peeling on the interface between the underlying barrier layer and the copper seed layer did not occur after the heat treatment when the concentration of the copper hexafluoro-
silicate plating solution was set within the range of 10 to 40 wt %. In this study, the plating was performed under the conditions that the film thickness of the plating copper thin film was equally set to be 400 nm, 1 wt % of an additive agent (mixture of sodium mercaptopropane sulfonate (MPSA), polyethylene glycol (PEG), ethylene diamine (EDA)) was added, the current density was set to be 1.0 A/dm², and the plating bath temperature was set to be 20°C.

[0037] As seen from the result in Table 1, film peeling did not occur when a solution having a concentration of 5 wt % or less was used, but a plating deposition rate was so low that the concentration was not practical. In addition, the concentration of 45 wt % or higher was found not preferable either. The reason for this is that with such a concentration not only film peeling occurred, but also copper hexafluorosilicate which was an electrolyte was separated due to the solubility of copper hexafluoro-
silicate in water when the plating temperature was 17°C or lower.

### TABLE 1

| Concentration of copper hexafluoro-
silicate aqueous solution during plating (wt %) | Presence/Absence of film peeling on interface between underlying barrier layer and copper seed layer | Presence/Absence of Brilliance of copper thin film during plating deposition |
<table>
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<tbody>
<tr>
<td>5</td>
<td>Absent</td>
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<tr>
<td>45</td>
<td>Present</td>
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[0038] Embodiments of the present invention will be described below.

[0039] As plating conditions for a copper thin film, an SiO₂ film was deposited on an Si wafer so as to have a thickness of 200 nm, a TaN film was deposited as a barrier metal so as to have a thickness of 30 nm, and a copper seed layer was deposited on the resultant structure by a sputtering method so as to have a thickness of 100 nm. A copper hexafluoro-
silicate (CuSiF₄) aqueous solution having a concentration of 20 wt % of the present invention was used as a plating solution. For the comparison purposes, deposition was performed also using a conventional copper sulfate (CuSO₄) plating solution. The film thickness of the plating copper thin film was equally set to be 400 nm, 1 wt % of an additive agent (mixture of sodium mercaptopropane sulfonate (MPSA), polyethylene glycol (PEG), ethylene diamine (EDA)) was added, the current density was set to be 1.0 A/dm², and the plating bath temperature was set to be 20°C. Under the conditions, plating was performed.

[0040] The present invention will be described in more detail below. As a matter of course, the present invention is not limited to the shown examples.

EXAMPLE 1

[0041] FIG. 1 shows the relationships between the stress and resistivity of plating copper thin films deposited under
the same conditions by using the copper hexafluorosilicate plating solution of the present invention and the conventional copper sulfate plating solution. The resistivity of plating copper thin films strongly depends on a film stress. When the stress is low, then the resistivity decreases. A low-resistivity film can be realized by reducing the film stress. With the use of the copper hexafluorosilicate plating solution according to the present invention, a copper thin film that has especially a low stress and a low resistivity is obtained as indicated by white circles. The (111)-orientation of the copper thin film is also improved by the reduction in stress.

EXAMPLE 2

[0042] FIG. 2 shows the relationships between the deposition rate and stress of plating copper thin films, the film thickness of which being equally set to be 400 nm. The stress of a copper thin film deposited at a deposition rate of 3 nm/s by using the conventional copper sulfate plating solution is 41.2 Mpa as indicated by black circles. However, the film stress can be reduced to 39.0 Mpa when the copper hexafluorosilicate plating solution according to the present invention is used as indicated by white circles. As is apparent from the result of FIG. 2, a low-stress film can be plated by the copper hexafluorosilicate plating solution. Therefore, it is apparent that the copper hexafluorosilicate plating solution is effective to reduce the stress of a plating copper thin film. In FIG. 2, “Min.” means “the minimum value.”

EXAMPLE 3

[0043] FIG. 3 shows the relationships between the film thickness and stress of plating copper thin films deposited under the same conditions by using the copper hexafluorosilicate plating solution of the present invention and the conventional copper sulfate plating solution. When the copper hexafluorosilicate plating solution of the present invention is used, the stress is reduced by an increase in film thickness, and a film having a stress which is lower than that of a film obtained by using a copper sulfate plating solution of the prior art is obtained. When the copper hexafluorosilicate plating solution is used, the stress decreased, as shown by white circles, from 38.5 Mpa to 36.0 Mpa because of the increase in film thickness. The reason for this is that the stress generated by the difference between crystal lattices on the interface between the copper thin film and the barrier film becomes moderate by an increase in plating film thickness. In FIG. 3, “Min.” means “the minimum value.”

EXAMPLE 4

[0044] FIG. 4 shows changes in stress of plating copper thin films before and after annealing when the plating copper thin films are deposited under the same conditions by using the copper hexafluorosilicate plating solution of the present invention and the conventional copper sulfate plating solution. Annealing was performed at 400°C for 15 minutes. The stress of the copper thin film formed using the copper hexafluorosilicate plating solution decreased from 38.5 Mpa to 12.5 Mpa by the annealing. The stress decreases from 41.3 Mpa to 20.0 Mpa by annealing in the copper thin film formed using the copper sulfate plating solution. However, even after the annealing, the stress of the copper thin film formed using the copper sulfate plating solution is higher than the stress of the copper thin film formed using the copper hexafluorosilicate plating solution of the present invention. In FIG. 4, “Min.” means “the minimum value.”

EXAMPLE 5

[0045] FIG. 5 shows the relationships between the deposition rates and adhesion forces of plating copper thin films when the film thickness is equally set to be 400 nm. The adhesion force of the copper thin film formed with the copper hexafluorosilicate plating solution increases from 28.5 gf to 31.3 gf as the deposition rate decreases as indicated by white circles. Even in the case in which the copper sulfate plating solution is used, the adhesion force likewise increases with the decrease in deposition rate as indicated by black circles. However, an adhesive force which is almost equal to that obtained when the copper hexafluorosilicate plating solution is used is not obtained when the copper sulfate plating solution is used. In FIG. 2, “Max.” means “the maximum value.”

EXAMPLE 6

[0046] FIG. 6 shows the relationships between the film thickness and adhesion force of plating copper thin films deposited under the same conditions by using the copper hexafluorosilicate plating solution of the present invention and the conventional copper sulfate plating solution. The adhesion force of the copper thin film formed with the copper hexafluorosilicate plating solution increases from 28.8 gf to 35.1 gf with an increase in film thickness as indicated by white circles. Even in the case in which the copper sulfate plating solution is used, the adhesion force likewise increases with an increase in film thickness; however, an adhesive force which is higher than that obtained when the copper hexafluorosilicate plating solution is used is not obtained when the copper sulfate plating solution is used.

EXAMPLE 7

[0047] FIG. 7 shows changes in stress of plating copper thin films before and after annealing when the plating copper thin films are deposited under the same conditions by using the copper hexafluorosilicate plating solution of the present invention and the conventional copper sulfate plating solution. Annealing was performed at 400°C for 15 minutes. Film peeling in annealing poses a serious problem. The adhesion force decreases from 33.0 gf to 30.0 gf in the copper thin film formed by the copper hexafluorosilicate plating solution. When the copper sulfate plating solution is used, the adhesion force decreases from 30.0 gf to 26.7 gf. Accordingly, it is clear that even after annealing the adhesion force obtained with the copper hexafluorosilicate plating solution is higher than the adhesion force obtained with the copper sulfate plating solution.

EXAMPLE 8

[0048] FIG. 8 shows the relationships between the stress and adhesion force of plating copper thin films deposited under the same conditions by using the copper hexafluorosilicate plating solution of the present invention and the conventional copper sulfate plating solution. In the copper thin film formed with the copper hexafluorosilicate plating solution, the adhesion force increases from 31.3 gf to 33.0 gf as the stress decreases from 41.0 gf to 38.0 gf as indicated by white circles. Even in the case in which the copper thin
film formed with the copper sulfate plating solution, the adhesion force likewise increases with a decrease in stress. However, when the copper hexafluorosilicate plating solution is used, a copper thin film having a low stress and a high adhesion force is obtained in comparison with the case in which the copper sulfate plating solution is used. In order to solve the problem of film peeling of a plating copper thin film occurring in chemical mechanical polishing (CMP) and annealing, the decrease in film stress and the increase in adhesion force are extremely important.

EXAMPLE 9

As shown in FIGS. 9A through 9C, an insulating interlayer (SiO₂) formed on an Si wafer was patterned by standard photolithography and dry etching using a conventional photoresist. Thereafter, the photoresist was removed, and a 30-nm barrier film (Ti) and a 150-nm Cu seed layer were deposited by a sputtering method on the patterned SiO₂ layer, and then a copper thin film was plating-deposited on the Cu seed layer by using the copper hexafluorosilicate plating solution according to the present invention. As a result, the copper thin film was deposited on a fine pattern with good covering properties. After the plating deposition, even though the resultant structure was subjected to heat treatment at 400°C and flattened by a chemical mechanical polishing (CMP) method, film peeling did not occur, and a copper wiring layer was formed on the SiO₂ insulating interlayer.

1.5. (canceled).

6: A method for forming a semiconductor integrated circuit having a copper seed layer, comprising a step of electroplating a copper thin film on the copper seed layer by using an aqueous solution of 10 to 40 wt % of copper hexafluorosilicate as an electrolyte.

7: The method for forming a semiconductor integrated circuit having a copper seed layer according to claim 6, further comprising a step of depositing the said copper seed layer on any one of a printed circuit board, a glass substrate and a silicon wafer, wherein said step of depositing the copper seed layer is carried out prior to said step of electroplating the copper thin film.

8: The method for forming a semiconductor integrated circuit having a copper seed layer according to any one of claims 6 and 7, wherein a current having a constant density of 0.5 to 1.5 A/dm² is used during said step of electroplating the copper thin film.

9: The method for forming a semiconductor integrated circuit having a copper seed layer according to and one of claims 6 and 7, wherein said aqueous solution is kept at the temperature of 20 to 40°C during said step of electroplating the copper thin film.

10: The method for forming a semiconductor integrated circuit having a copper seed layer according to claim 8, wherein said aqueous solution is kept at the temperature of 20 to 40°C during said step of electroplating the copper thin film.

11: The method for forming a semiconductor integrated circuit having a copper seed layer according to any one of claims 6 and 7, further comprising a step of adding an additive agent to said aqueous solution during said step of electroplating the copper thin film, wherein said additive agent is in a range of 0.5 to 1.5 wt %.

12: The method for forming a semiconductor integrated circuit having a copper seed layer according to claim 8, further comprising a step of adding an additive agent to said aqueous solution during said step of electroplating the copper thin film, wherein said additive agent is in a range of 0.5 to 1.5 wt %.

13: The method for forming a semiconductor integrated circuit having a copper seed layer according to claim 9, further comprising a step of adding an additive agent to said aqueous solution during said step of electroplating the copper thin film, wherein said additive agent is in a range of 0.5 to 1.5 wt %.

14: The method for forming a semiconductor integrated circuit having a copper seed layer according to claim 10, further comprising a step of adding an additive agent to said aqueous solution during said step of electroplating the copper thin film, wherein said additive agent is in a range of 0.5 to 1.5 wt %.

15: A semiconductor integrated circuit comprising a copper seed layer having a copper thin film thereon, wherein said copper thin film is deposited by using an aqueous solution of 10 to 40 wt % of copper hexafluorosilicate as an electrolyte.

16: The semiconductor integrated circuit according to claim 15, wherein said copper seed layer is deposited on any one of a printed circuit board, a glass substrate and a silicon wafer.

17: The semiconductor integrated circuit according to any one of claims 15 and 16, wherein said copper thin film is deposited by using a current having a current density of 0.5 to 1.5 A/dm².

18: The semiconductor integrated circuit according to any one of claims 15 and 16, wherein said copper thin film is deposited in a condition of keeping said aqueous solution at the temperature of 20 to 40°C.

19: The semiconductor integrated circuit according to claim 17, wherein said copper thin film is deposited in a condition of keeping said aqueous solution at the temperature of 20 to 40°C.

20: The semiconductor integrated circuit according to any one of claims 15 and 16, wherein an additive agent in a range of 0.5 to 1.5 wt % is added to said aqueous solution.

21: The semiconductor integrated circuit according to claim 17, wherein an additive agent in a range of 0.5 to 1.5 wt % is added to said aqueous solution.

22: The semiconductor integrated circuit according to claim 18, wherein an additive agent in a range of 0.5 to 1.5 wt % is added to said aqueous solution.

23: The semiconductor integrated circuit according to claim 19, wherein an additive agent in a range of 0.5 to 1.5 wt % is added to said aqueous solution.

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