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METAL CMP SLURRY COMPOSITIONS THAT FAVOR MECHANICAL REMOVAL OF METAL OXIDES WITH REDUCED SUSCEPTIBILITY TO MICRO-SCRATCHING

Reference to Priority Application

This application is a continuation-in-part (CIP) of U.S. Application Serial No. 10/485,500, filed January 30, 2004, which is a 371 of PCT/KR02/01492, filed August 6, 2002, which derives priority from Korean Application Nos. 2001-47895, filed August 9, 2001, and 2002-28052, filed May 21, 2002, the disclosures of which are hereby incorporated herein by reference.

Field of the Invention

The present invention relates to methods of forming integrated circuit devices and, more particularly, to methods of planarizing metal layers on integrated circuit substrates using chemical-mechanical polishing techniques.

Background of the Invention

Integrated circuit chips frequently utilize multiple levels of patterned metallization and large numbers of electrically conductive vias to provide wiring interconnects between electronic devices embedded within an integrated circuit substrate (e.g., semiconductor substrate). In a typical case, an electrically conductive via may extend vertically through one or more electrically insulating layers to thereby provide an electrical "short" between lower and upper levels of metallization. As illustrated by FIGS. 1A-1C, one conventional technique for forming electrically conductive vias includes forming an electrically insulating layer 12 (e.g., SiO_2) on a surface of a semiconductor substrate 10 having a plurality of active regions (not shown) therein that extend adjacent the surface. Conventional techniques may then be used to define a plurality of contact holes 16 that extend through the electrically insulating layer 12 and expose respective ones of the active regions (e.g., N or P-type diffusion regions). A metal layer 14 (e.g., a tungsten (W) layer) may then be conformally deposited on an upper surface of the electrically insulating layer 12 and into the contact holes 16. As illustrated, this metal layer 14, which may be of sufficient thickness to completely fill the contact holes 16, may nonetheless include a plurality of metallurgical seams 18 that identify where two facing surfaces of the metal layer 14 contact each other within the contact holes 16. These

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seams 18 may be present even in the absence of metal voids within the contact holes 18.

As illustrated by FIG. 1B, a portion of the metal layer 14 residing on the upper surface of the electrically insulating layer 12 may be removed to thereby define a plurality of conductive vias 20. This removal step may include chemically-mechanically polishing the metal layer 14 with a polishing slurry. The polishing step may be performed for a sufficient duration to expose the upper surface of the electrically insulating layer 12. In some instances, the polishing step may result in the formation of open seams 18' that constitute parasitic voids within the conductive vias 20. The formation of the open seams 18' can be an adverse consequence of using a polishing slurry containing chemical etchants that aggressively etch the metal layer 14 during the polishing step. The use of aggressive chemical etchants within the polishing slurry may also result in an excessive etch-back (i.e., recession) of the upper surfaces of the conductive vias 20, as illustrated by FIG. 1C. This excessive etch-back may occur even when the polishing step is followed immediately with a thorough cleaning step upon detecting exposure of the upper surface of the electrically insulating layer 12 during polishing. The occurrence of excessive etch-back of the conductive vias 20 may result in a lack of planarization between the upper surface of the electrically insulating layer 12 and the upper surfaces of the conductive vias 20 and thereby complicate further back-end processing steps.

One technique for chemically-mechanically polishing metal layers at purportedly high chemical etch rates is disclosed in U.S. Patent No. 6,068,787 to Grumbine et al. The '787 patent alleges that a catalytic amount of ferric nitrate, a known oxidant, can be added to another known oxidant (e.g., hydrogen peroxide) to achieve a synergistic effect within a CMP slurry, which results in a high chemical etch rate and a high overall polishing rate for tungsten metal layers. The use of iron as a catalyst to accelerate CMP polishing is also disclosed in U.S. Patent No. 5,948,697 to Hata. U.S. Patent No. 5,709,593 to Guthrie et al. also discloses polishing of metallic, semiconductor and insulating layers using slurries containing reactive agents, abrasives and catalysts. Unfortunately, CMP slurries that cause high chemical etch rates may be susceptible to the excessive etch-back characteristics described above with respect to FIGS. 1A-1C. An article by S. Basak et al., entitled "Electrochemical Aspects of the Chemical Mechanical Planarization of Tungsten," Proceedings of the First International Symposium on Chemical Mechanical Planarization, Electrochemical Society, Vol. 96-

22, pp. 137-148, also discloses using ferric nitrate in combination with hydrogen peroxide in CMP slurries. The use of ferric nitrate and other additives (e.g., complexing agents) in CMP slurries is also disclosed at section 7.3.3 and Table 7.1 of a textbook by M.R. Oliver (Ed.), entitled "Chemical-Mechanical Planarization of Semiconductor Materials," ISBN 3-540-43181-0, Springer-Verlag (2004). One drawback to the use of ferric nitrate in CMP slurries is the generation of free Fe-ions during oxidation, which may remain as contaminants on a planarized surface after polishing and normal cleaning. As described in U.S. Patent No. 5,662,769 to Schonauer et al., these free metal ions may be removed from a semiconductor surface using a ligand such as EDTA, which forms a highly stable complex with metal ions and thereby inhibits deposition of such free metal ions on a planarized surface.

Slurries having relatively high concentrations of abrasives may also be used to increase an overall CMP polishing rate. However, such high concentrations of abrasives may lead to high levels of micro-scratches and other defects on a planarized surface. To address this problem, additional CMP techniques, such as those disclosed in U.S. Patent Publication No. 2002/0061635 to Lee et al., have been developed that eliminate the need for abrasives altogether.

Summary of the Invention

Embodiments of the present invention include metal CMP slurry precursor compositions for semiconductor wafer processing. These slurry precursor compositions may be mixed with appropriate oxidizing agents (e.g., hydrogen peroxide) to achieve metal CMP slurry compositions having relatively low chemical etch rate and relatively high mechanical polishing rate characteristics. The relatively high mechanical polishing rate characteristics are achieved using relatively high concentrations of mechanical abrasive (e.g., ≥8 wt%) in combination with sufficient quantities of a wetting agent to inhibit micro-scratching of underlying surfaces (e.g., insulating layers, conductive vias, ...) being polished. The slurry precursor compositions also include a highly stable metal-propylenediaminetetraacetate (M-PDTA) complex, which may operate to inhibit metal-oxide re-adhesion on the metal surface being polished and/or limit the maximum rate of oxidation of the metal surface by chelating with the metal surface.

In particular, some embodiments of the present invention include a slurry precursor composition for chemical-mechanical polishing of metal layers on semiconductor

substrates. This slurry precursor composition includes an aqueous admixture of at least one pH controlling agent, a carboxylic acid, an abrasive, a metal-propylenediaminetetraacetate (M-PDTA) complex, a wetting agent and deionized water. The pH controlling agent may include at least one of an inorganic acid and a hydroxide and the wetting agent may be diethylene glycol. The quantity of the wetting agent in the aqueous admixture is typically in a range from about 0.4 wt% to about 1.2 wt%. To achieve a relatively high mechanical polishing rate, the quantity of the abrasive in the aqueous admixture preferably exceeds about 8 wt% and, more preferably, is in a range from about 10 wt% to about 12 wt%. The M-PDTA complex may be a Fe-PDTA complex and the quantity of the Fe-PDTA complex in the aqueous admixture may be in a range from about 0.1 wt% to about 0.8 wt%.

Other embodiments of the present invention include slurry compositions for chemical-mechanical polishing of tungsten (W) metal layers on semiconductor substrates. These slurry compositions include an aqueous admixture containing hydrogen peroxide, potassium hydroxide, nitric acid and malic acid. The malic acid is provided in an amount ranging from about 0.4 wt% to about 0.8 wt%. The admixture also contains a silica abrasive in an amount exceeding 8 wt%, an Fe-PDTA complex in an amount ranging from about 0.1 wt% to about 0.8 wt%, diethylene glycol in an amount ranging from about 0.4 wt% to about 1.2 wt% and deionized water.

Still further embodiments of the present invention include methods of forming integrated circuit devices by forming an electrically insulating layer on a surface of a semiconductor wafer and forming a plurality of contact holes in the electrically insulating layer. A layer of tungsten metal is conformally deposited on the electrically insulating layer and into the plurality of contact holes. A chemical-mechanical polishing step is then performed. This polishing step includes polishing the tungsten metal layer using a slurry composition comprising hydrogen peroxide, an abrasive in an amount exceeding 8 wt%, an Fe-PDTA complex in an amount ranging from about 0.1 wt% to about 0.8 wt%, a wetting agent in an amount ranging from about 0.4 wt% to about 1.2 wt% and deionized water. The polishing step is followed by the steps of exposing the electrically insulating layer to a cleaning solution and performing additional back-end processing steps to complete the semiconductor wafer. The semiconductor wafer is then diced into a plurality of semiconductor chips, which may be individually packaged.

Brief Description of the Drawings

FIGS. 1A-1C are cross-sectional views of intermediate structures that illustrate conventional methods of forming conductive vias on semiconductor substrates using chemical-mechanical polishing techniques.

FIG. 2 is a flow diagram that illustrates methods of forming integrated circuit devices according to embodiments of the present invention.

Detailed Description of Preferred Embodiments

The present invention now will be described more fully herein with reference to the accompanying drawings, in which preferred embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as being limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the invention to those skilled in the art. Like reference numerals refer to like elements throughout.

Embodiments of the present invention include metal CMP slurry precursor compositions for semiconductor wafer processing. As illustrated by FIG. 2, methods 200 of forming integrated circuit devices may include at least one chemical-mechanical polishing step 210 that is performed during the course of semiconductor wafer processing. The preferred slurry precursor compositions may be mixed with appropriate oxidizing agents (e.g., hydrogen peroxide) at the time of polishing to achieve metal CMP slurry compositions having relatively low chemical etch rate and relatively high mechanical polishing rate characteristics. The relatively high mechanical polishing rate characteristics are achieved using relatively high concentrations of mechanical abrasive (e.g., ≥8 wt% silica) in combination with sufficient quantities of a wetting agent (e.g., diethylene glycol) to inhibit micro-scratching of underlying surfaces (e.g., insulating layers, conductive vias, ...) being polished. The slurry precursor compositions also include a highly stable metal-propylenediaminetetraacetate (M-PDTA) complex, which may operate to inhibit metal-oxide re-adhesion on the metal surface being polished and/or limit the maximum rate of oxidation of the metal surface by chelating with the metal surface. A preferred M-PDTA complex is Fe-PDTA. This M-PDTA may also operate to inhibit coagulation of the high concentration of abrasive.

In particular, the methods 200 of FIG. 2 include the step of forming an electrically insulating layer on a semiconductor wafer, Block 202. This electrically insulating layer may be formed directly on a surface of the semiconductor wafer or may be formed as an interlayer dielectric layer on one or more underlying layers that are disposed between the interlayer dielectric layer and the surface of the semiconductor wafer. A plurality of contact holes may be formed in the electrically insulating layer, Block 204. These contact holes may be formed using conventional photolithographically defined patterning and etching steps. An optional barrier layer (e.g., Ti/TiN) may then be conformally deposited on an upper surface of the electrically insulating layer and along sidewalls (and bottoms) of the contact holes, Block 206. Thereafter, a metal layer, such as a tungsten (W) metal layer, is deposited on the electrically insulating layer, Block 208. The thickness of this metal layer is sufficient to fill the contact holes.

As illustrated by Block 210, a chemical-mechanical polishing (CMP) step is then performed on the metal layer and barrier layer using the slurry composition described herein. The duration of this step is sufficient to expose an upper surface of the electrically insulating layer and define a plurality of tungsten-based conductive vias within the contact holes. The upper surfaces of these conductive vias are coplanar with the exposed upper surface of the electrically insulating layer. To inhibit recession of the conductive vias within the contact holes, the detection of an end-point of the polishing step is followed immediately with a wafer cleaning step to remove the slurry composition and contaminants from the planarized surface of the wafer. Conventional steps may then be performed to deposit and pattern a blanket layer of metallization into a plurality of electrical interconnects that extend on the planarized upper surface of the electrically insulating layer, Block 212 - 214. The formation of the electrical interconnects may be followed by additional processing steps, including additional insulator deposition and CMP polishing steps. Additional back-end wafer processing and passivation steps may also be performed, Blocks 216 - 218. Thereafter, the semiconductor wafer may be diced into a plurality of semiconductor chips, which may be separately packaged as respective integrated circuit devices, Block 220.

The CMP polishing step, Block 210, includes mixing a slurry precursor composition with at least one oxidizing agent. A preferred oxidizing agent is hydrogen peroxide (H_2O_2). As explained in commonly assigned U.S. Application Serial No. 10/485,500, which is hereby incorporated herein by reference, oxidizing agents other than hydrogen peroxide may also be used in alternative slurry compositions. The slurry precursor composition

includes an aqueous admixture of at least one pH controlling agent, a carboxylic acid (e.g, malic acid), an abrasive (e.g., silica), a metal-propylenediaminetetraacetate (M-PDTA) complex, a wetting agent, which inhibits micro-scratching even in the presence of a high quantity of the abrasive, and deionized water. The pH controlling agent may include at least one of an inorganic acid (e.g., nitric acid) and a hydroxide (potassium hydroxide) and the wetting agent may be diethylene glycol (DEG). Sufficient quantities of the pH controlling agent may be used to achieve a pH for the slurry composition in a range from about 2.4 to about 2.7 at a temperature of 25 °C.

The quantity of the wetting agent in the aqueous admixture is typically in a range from about 0.4 wt% to about 1.2 wt% and, more preferably, about 0.8 wt%. To achieve a relatively high mechanical polishing rate, the quantity of the abrasive in the aqueous admixture preferably exceeds about 8 wt% and, more preferably, is in a range from about 10 wt% to about 12 wt% (and possibly even higher). The abrasive may be silica having a mean size in a range from about 140 nm to about 180 nm. The M-PDTA complex may be a Fe-PDTA complex and the quantity of the Fe-PDTA complex in the aqueous admixture may be in a range from about 0.1 wt% to about 0.8 wt%. The addition of hydrogen peroxide at a concentration of about 2 wt% at the time of polishing can be used to achieve a relatively high overall polishing rate of about 2400-2600 Å/min, with a relatively low static chemical etch rate of only about 12 Å/min (in the absence of mechanical polishing). This relatively low static chemical etch rate advantageously limits recession of the tungsten vias within the contact holes upon completion of the polishing step. In some embodiments, concentrations of the constituents of the slurry composition can be selected to limit the static chemical etch rate to a range from about 5 Å/min to about 15 Å/min. As illustrated by Table 2 of the aforementioned '500 application, this range of static chemical etch rates, which is also referred to as a corrosion rate, is considerably lower than those for conventional slurry compositions including ferric nitrate as an oxidant.

In the drawings and specification, there have been disclosed typical preferred embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being set forth in the following claims.

Examples

Example 1

Polishing Performance Varying With Amount Of Wetting Agent

To a mixture comprising 120 g of commercially available Aerosil 90G (Degussa), 861.8 g of deionized water, 6.0 g of malic acid, 0.1 g of nitric acid, 0.1 g of KOH, and 4.0 g of PDTA-Fe, diethyleneglycol and/or ethyleneglycol serving as a wetting agent were each added in varying amounts of 0.0, 1.0, 4.0, and 8.0 g. Each reaction solution thus obtained was loaded into a 2 L polyethylene flask, stirred at 2,000 rpm for 2 hr, and then dispersed once at 1,200 psi using a high pressure dispersion process. The resultant slurry was filtered using a 1 μm filter, to yield a slurry precursor composition. To assay polishing properties of the slurry precursor composition of the present invention, HTO was deposited to a thickness of 1,000 Å on a poly-Si substrate as a W blanket wafer, and then, TiN and W were deposited to thicknesses of 1,000 Å and 10,000 Å, respectively, to manufacture a sample wafer. Immediately before such a sample wafer was polished, hydrogen peroxide was added to the resultant slurry precursor composition so that its amount was 2 wt% based on the precursor, and then the reaction solution was stirred, to prepare a final slurry composition. Using the slurry composition thus prepared, the sample wafer was polished for 1 min under polishing conditions shown in Table 1, below, and the polishing properties were measured. The results are given in Table 1, below.

Table 1

Wetting Agent		W Polishing Speed (Å/min)	Scratch Defect (ea)	Recession (Å)
Diethyleneglycol	0.0 g	2680	20	183
Diethyleneglycol	1.0 g	2780	18	180
Diethyleneglycol	4.0 g	2860	15	165
Diethyleneglycol	8.0 g	2910	5	154
Ethyleneglycol	4.0 g	2800	14	159
Ethyleneglycol Diethyleneglycol	Each 4.0 g	2850	8	150

[Measurement Method of Physical Properties]

* Polishing Machine Model: 6EC (STRASBAUGH)

* Polishing Conditions

- Pad Type: IC1400/SubaIV Stacked (Rodel)
- Platen Speed: 75 rpm
- Head Speed: 35 rpm
- Pressure: 4 psi
- Back Pressure: 0 psi
- Temperature: 25°C
- Slurry Flow: 250 ml/min

Example 2

Static Chemical Etch Rate Varying With Amount Of Wetting Agent

To a mixture comprising 120 g of commercially available Aerosil 90G (Degussa), 861.8 g of deionized water, 6.0 g of malic acid, 0.1 g of nitric acid, 0.1 g of KOH, and 4.0 g of PDTA-Fe, diethyleneglycol and/or ethyleneglycol serving as a wetting agent were each added in varying amounts of 0.0, 1.0, 4.0, and 8.0 g. Each reaction solution thus obtained was loaded into a 2 L polyethylene flask, stirred at 2,000 rpm for 2 hr, and then dispersed once at 1,200 psi using a high pressure dispersion process. Thereafter, hydrogen peroxide was added to the resultant slurry precursor composition so that its amount was 2 wt% based on the precursor, and then the reaction solution was stirred, to prepare a final slurry composition. Subsequently, a tungsten wafer was dipped into the slurry composition to perform static chemical etch for 30 min. Further, 1.0 g of ferric nitrate was used, instead of PDTA-Fe, to measure static chemical etch. The results are given in Table 2, below.

Table 2

	Wetting Agent		Static Chemical Etch Rate (Å /min)
PDTA-Fe	Diethyleneglycol	0.0 g	20
	Diethyleneglycol	1.0 g	18
	Diethyleneglycol	4.0 g	14
	Diethyleneglycol	8.0 g	7
	Ethyleneglycol	4.0 g	11
	Ethyleneglycol Diethyleneglycol	Each 4.0 g	9
PDTA-Cr	Diethyleneglycol	4.0 g	15
	Diethyleneglycol	8.0 g	12
Ferric Nitrate	Diethyleneglycol	8.0 g	44
	Diethyleneglycol	0.0 g	92

Example 3

Polishing Performance Of Slurry Mixed With Peroxide Varying With Elapsed Time

To a mixture comprising 120 g of commercially available Aerosil 90G (Degussa), 861.8 g of deionized water, 6.0 g of malic acid, 0.1 g of nitric acid, 0.1 g of KOH, and 4.0 g of PDTA-Fe, diethyleneglycol serving as a wetting agent were each added in varying amounts of 0.0 and 8.0 g. Each reaction solution thus obtained was loaded into a 2 L polyethylene flask, stirred at 2,000 rpm for 2 hr, and then dispersed once at 1,200 psi using a high pressure dispersion process. To the resultant slurry precursor composition, hydrogen peroxide was added so that its amount was 2 wt% based on the precursor, and then the reaction solution was stirred, to prepare a final slurry composition. In addition, 1.0 g of ferric nitrate was used, instead of PDTA-Fe, and thus, the polishing process was performed under the above polishing conditions for 1 min, to assay polishing properties. The results are given in Table 3, below.

Table 3

	Elapsed Time (hr)	Diethyleneglycol (g)	W Polishing Rate (Å /min)	Mean Abrasive Size (nm)
PDTA-Fe	0	0.0	2,680	153
		8.0	2,910	153
	2	0.0	2,500	154
		8.0	2,880	153
	6	0.0	2,480	156
		8.0	2,890	155
	12	0.0	2,440	158
		8.0	2,930	154
	24	0.0	2,410	158
		8.0	2,860	156
Ferric Nitrate	0	0.0	3,050	167
		8.0	3,000	166
	24	0.0	2,120	192
		8.0	2,790	172

As mentioned above, the present invention provides a slurry precursor composition for chemical and mechanical polishing, in which a wetting agent is added to the slurry for polishing a metal layer, whereby dispersion stability of the slurry is improved and fewer scratches are generated upon polishing, thus decreasing defect rates. As well, decomposition of peroxide used as an oxidizing agent is prevented, and thus, the low polishing speed of the slurry mixed with peroxide when polishing a metal layer for a long time due to instability of such an oxidizing agent may be improved. Further, when the precursor composition is used along with M-PDTA, a low static chemical etch rate is obtained, thereby preventing recession of conductive via holes.

THAT WHICH IS CLAIMED IS:

1. A slurry precursor composition for chemical-mechanical polishing of metal layers on semiconductor substrates, comprising:
an aqueous admixture containing a pH controlling agent, an abrasive, a metal-propylenediaminetetraacetate (M-PDTA) complex, a wetting agent and water.

2. The slurry precursor composition of Claim 1, wherein said aqueous admixture further comprises a carboxylic acid.

3. The slurry precursor composition of Claim 2, wherein the pH controlling agent comprises at least one of an inorganic acid and a hydroxide.

4. The slurry precursor composition of Claim 1, wherein the wetting agent is diethylene glycol.

5. The slurry precursor composition of Claim 1, wherein a quantity of the abrasive in said aqueous admixture exceeds 8 wt%.

6. The slurry precursor composition of Claim 5, wherein a quantity of the wetting agent in said aqueous admixture is in a range from about 0.4 wt% to about 1.2 wt%.

7. The slurry precursor composition of Claim 6, wherein a quantity of the M-PDTA complex in said aqueous admixture is in a range from about 0.1 wt% to about 0.8 wt%.

8. The slurry precursor composition of Claim 1, wherein a quantity of the wetting agent in said aqueous admixture is in a range from about 0.4 wt% to about 1.2 wt%.

9. The slurry precursor composition of Claim 1, wherein a quantity of the M-PDTA complex in said aqueous admixture is in a range from about 0.1 wt% to about 0.8 wt%.

10. A slurry precursor composition for chemical-mechanical polishing of metal layers on semiconductor substrates, comprising:
an aqueous admixture containing a pH controlling agent, an abrasive in an amount

exceeding 8 wt%, a metal-propylenediaminetetraacetate (M-PDTA) complex in an amount ranging from about 0.1 wt% to about 0.8 wt%, a wetting agent in an amount ranging from about 0.4 wt% to about 1.2 wt% and deionized water.

11. The slurry precursor composition of Claim 10, wherein said aqueous admixture further comprises a carboxylic acid.

12. The slurry precursor composition of Claim 11, wherein the pH controlling agent comprises at least one of an inorganic acid and a hydroxide.

13. The slurry precursor composition of Claim 12, wherein the wetting agent is diethylene glycol.

14. The slurry precursor composition of Claim 10, wherein the wetting agent is diethylene glycol.

15. A slurry precursor composition for chemical-mechanical polishing of tungsten layers on semiconductor substrates, comprising:
an aqueous admixture containing potassium hydroxide, nitric acid, malic acid in an amount ranging from about 0.4 wt% to about 0.8 wt%, a silica abrasive in an amount exceeding 8 wt%, an Fe-PDTA complex in an amount ranging from about 0.1 wt% to about 0.8 wt%, diethylene glycol in an amount ranging from about 0.4 wt% to about 1.2 wt% and deionized water.

16. A slurry composition for chemical-mechanical polishing of metal layers on semiconductor substrates, comprising hydrogen peroxide, at least one pH controlling agent, an abrasive in an amount exceeding 8 wt%, an Fe-PDTA complex in an amount ranging from about 0.1 wt% to about 0.8 wt%, a wetting agent in an amount ranging from about 0.4 wt% to about 1.2 wt% and deionized water.

17. The slurry composition of Claim 16, wherein the wetting agent comprises diethylene glycol.

18. The slurry composition of Claim 16, wherein the hydrogen peroxide is provided in

sufficient quantity to achieve a static wet etch rate in a range from about 5 Å/min to about 15 Å/min when the slurry composition is exposed to a tungsten metal layer at about room temperature.

19. A method of forming an integrated circuit chip, comprising the steps of:
forming an electrically insulating layer on a surface of a semiconductor wafer;
forming a plurality of contact holes in the electrically insulating layer;
depositing a tungsten metal layer that extends on the electrically insulating layer and into the plurality of contact holes; and
polishing the tungsten metal layer using a slurry composition comprising hydrogen peroxide, an abrasive in an amount exceeding 8 wt%, an Fe-PDTA complex in an amount ranging from about 0.1 wt% to about 0.8 wt%, a wetting agent in an amount ranging from about 0.4 wt% to about 1.2 wt% and water.

20. The method of Claim 19, wherein said polishing step is followed by the steps of:
exposing the electrically insulating layer to a cleaning solution; and
dicing the semiconductor wafer into a plurality of semiconductor chips.