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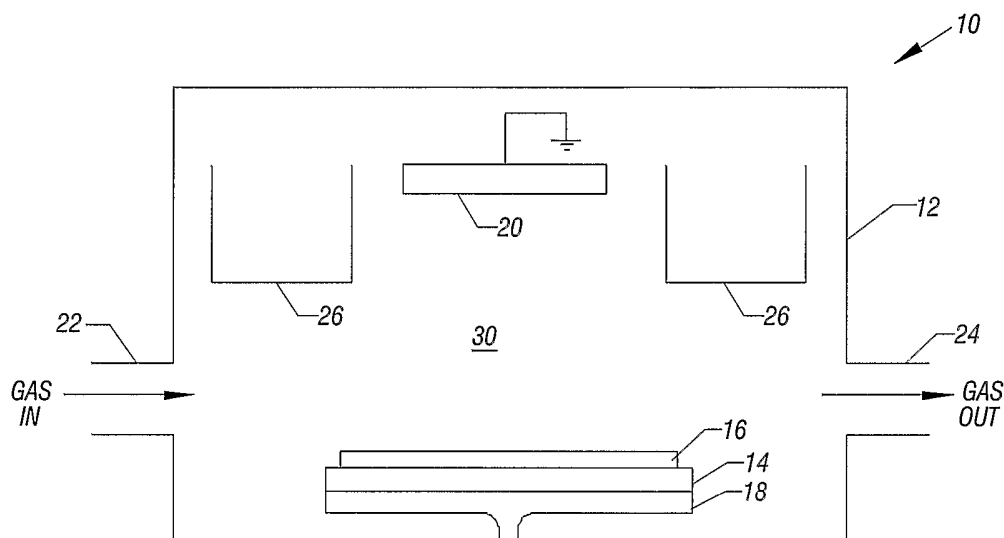
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ning of each regular issue of the PCT Gazette.

(54) Title: APPLICATION OF SONIC ENERGY DURING SPUTTERING OF METAL TO FILL OPENING



(57) Abstract: Metal may be deposited into trenches, vias, or other wafer openings using a physical vapor deposition chamber under vacuum. Sonic energy may be applied directly to the wafer having the openings to be filled. As a result, pinching off of the openings may be reduced or eliminated.

APPLICATION OF SONIC ENERGY DURING SPUTTERING OF METAL TO FILL OPENING

Background

This invention relates generally to techniques for fabricating semiconductor integrated circuits.

In a number of instances, during the manufacture of semiconductor integrated circuits, vias, trenches, or other openings may be formed in a substrate. It may then be desirable to fill those openings with a metal. Depending on the size of the openings, it may be difficult to induce the metal material to completely fill the opening. There may be a number of reasons for this. One possible explanation relates to the adverse affects of surface tension and capillary forces.

In some cases, a bubble or void tends to form within the metal filled via or trench. Thus, the presence of surface tension and capillary forces may result in a void which results in incomplete filling of the trench or via. This filled trench or via with a void is a low quality electrical contact and is called a pinched off trench or via.

Thus, there is a need for a way to improve the filling of openings with metal.

Brief Description of the Drawings

Figure 1 is a schematic depiction of a physical vapor deposition chamber in accordance with one embodiment of the present invention;

Figure 2 shows an initial step in filling a trench or via in accordance with one embodiment of the present invention; and

Figure 3 shows the structure of Figure 2 after subsequent processing in accordance with one embodiment of the present invention.

Detailed Description

5 Vias and trenches with high aspect ratios formed in semiconductor wafers are difficult to fill without pinching off. An aspect ratio is the ratio of vertical depth of the trench, via, or opening to its smallest horizontal width. In accordance with some embodiments of the present
10 invention, sputtered metal physical vapor deposition (PVD) may be utilized to fill high aspect ratio openings.

 Generally, the trenches, vias, or other openings are filled with a metal in a quasi-liquid state called a condensate. Due to the application of sonic energy through
15 the wafer, the effects of surface tension and capillary forces may be reduced. As a result, gap-free metal structures with relatively high aspect ratios may be achieved in some embodiments.

 Referring to Figure 1, a physical vapor deposition
20 chamber 10 may include a wafer 16 mounted on a transducer 14 over a platen 18. In some embodiments, the wafer 16 may be electrostatically held to the transducer 14. The transducer 14 may be a separate layer or may be imbedded within a platen 18.

25 The transducer 14 may apply sonic energy, such as ultra- or megasonic energy, in the range of about 10 to about 2000 kHz, dissipating approximately 1 to 10 watts per square centimeter. In one embodiment, the transducer 14 may be a plurality of piezoelectric drivers.

30 The wafer 16 is maintained within a vacuum within an enclosure 12. A plasma is established in the region 30. A gas of the appropriate species is introduced through a gas inlet 22 and drawn out through a gas outlet 24 to maintain a

vacuum. A target 20 may be grounded and dark space shields 26 may be provided in some embodiments.

Sputtering is not a chemical process, but, instead, is effectively a momentum-based process. The chamber 12 may
5 include a target 20 in the form of a solid slab of the desired fill material to be deposited. Argon gas, introduced through the inlet 22, is ionized to have a positive charge. The positively charged argon ions accelerate towards the grounded target 20. At the target
10 20, those ions dislodge particles from the target 20 that then scatter within the enclosure 12. Some of those scattered particles come to rest on the wafer 16.

Thus, a material may be sputter deposited on the wafer 16 without using a chemical process. The use of physical
15 vapor deposition is applicable to a wide variety of materials.

The material that falls on the wafer 16 to form a metal condensate is briefly in a quasi-liquid state. The transducer 14 is responsible for applying sonic energy
20 through the wafer 16 to the condensate to induce gap-free metal filling of openings defined on the wafer 16. As a result, very complete filling of high aspect ratio vias or trenches may be achieved at relatively low temperatures using any of a wide variety of precursor metals in some
25 embodiments.

Referring to Figure 2, the wafer 16 may be positioned over the transducer 14 in one embodiment. The wafer 16 may include a plurality of vias, trenches, or openings 26, each of which may be filled with condensate 28. After complete
30 filling under agitation from sonic energy applied directly to the wafer 16, the structure may be polished, for example, using chemical mechanical polishing (CMP) to achieve the planarized structure shown in Figure 3. By applying sonic

energy directly, it is intended to refer to applying the energy to a solid structure integral with or physically coupled to said wafer.

5 In some embodiments of the present invention, as the metal condensate 28 is sputtered onto the wafer 16, it is immediately subjected to acoustic streaming upon contact with the wafer 16. The acoustic streaming is a result of the application of sonic energy to the briefly formed quasi-liquid phase condensate 28. This has the effect of reducing
10 the presence of voids and allowing even smaller dimension vias and trenches to be filled. .

While the present invention has been described with respect to a limited number of embodiments, those skilled in the art will appreciate numerous modifications and
15 variations therefrom. It is intended that the appended claims cover all such modifications and variations as fall within the true spirit and scope of this present invention.

What is claimed is:

1. A method comprising:
using physical vapor deposition to sputter a metal
into openings in a semiconductor wafer; and
applying sonic energy directly to the wafer as
5 said metal is being sputtered into said wafer openings.

2. The method of claim 1 including applying sonic
energy in the range of about 10 to about 2000 kHz.

3. The method of claim 2 including dissipation of
approximately 1 to 10 watts per square centimeter.

10 4. The method of claim 1 including using a transducer
coupled to said wafer to apply sonic energy directly to said
wafer.

5. The method of claim 1 including sputtering a metal
into said openings.

15 6. The method of claim 1 including using a vacuum
chamber to deposit said metal.

7. A method comprising:
including sputtering metal into openings formed in
a semiconductor wafer;
20 establishing a vacuum around said wafer during
said sputter deposition; and
applying sonic energy directly to said wafer while
said metal is being sputtered into said openings.

8. The method of claim 7 including applying sonic
25 energy in the range of about 10 to about 2000 kHz.

9. The method of claim 8 including dissipation of approximately 1 to 10 watts per square centimeter.

10. The method of claim 7 including using a transducer coupled to said wafer to apply sonic energy directly to said
5 wafer.

11. The method of claim 7 including sputtering a metal into said openings.

12. The method of claim 7 including securing a transducer to said wafer to generate sonic energy directly
10 to said wafer.

13. The method of claim 7 including filling a trench with metal.

14. The method of claim 7 including filling a via with metal.

15 15. A method comprising:
forming a vacuum;
depositing metal condensate in openings formed in
a semiconductor substrate located within said vacuum; and
perturbing said wafer using sonic energy while
20 said condensate is being deposited in said openings.

16. The method of claim 15 including planarizing said structure after depositing said condensate.

17. The method of claim 15 including using ultra- or megasonic energy applied directly to said wafer.

18. The method of claim 15 including applying the sonic energy to the wafer itself.

19. The method of claim 18 including applying the sonic energy to a solid structure physically coupled to said
5 wafer.

20. The method of claim 19 including coupling a sonic energy transducer to said wafer.

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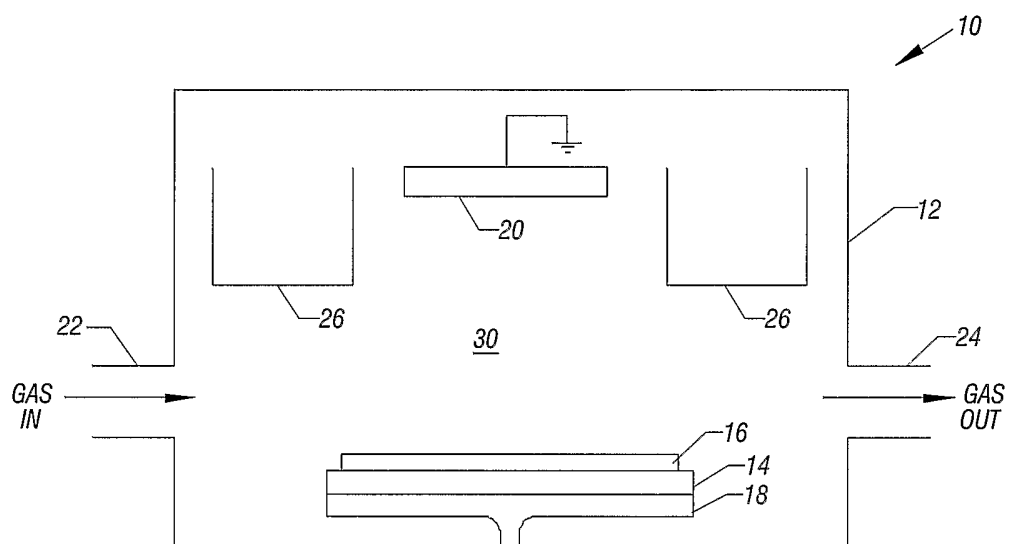


FIG. 1

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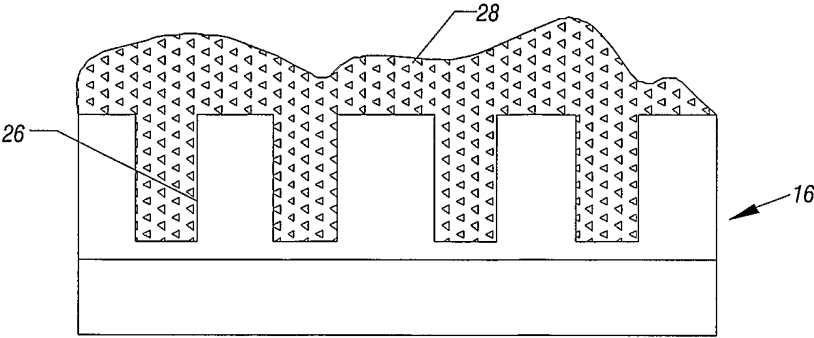


FIG. 2

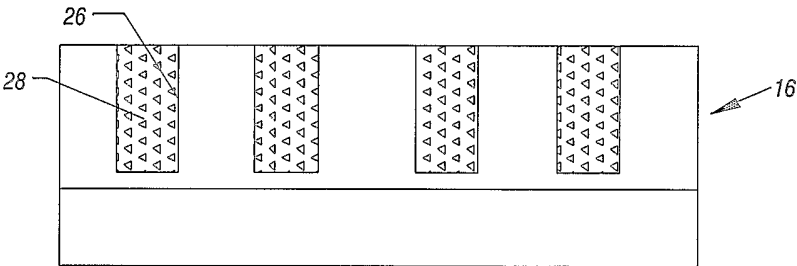


FIG. 3

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H01L21/768 H01L21/285

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 520 784 A (WARD MICHAEL G) 28 May 1996 (1996-05-28)	1-11, 13-20
Y	the whole document	12
X	US 6 159 853 A (LAI HAN-CHUNG) 12 December 2000 (2000-12-12)	1,2,5-8, 11, 13-15, 17-19
	column 4, line 10 - column 5, line 55	
Y	PATENT ABSTRACTS OF JAPAN vol. 0124, no. 21 (C-541), 8 November 1988 (1988-11-08) & JP 63 153265 A (NEC CORP), 25 June 1988 (1988-06-25) abstract	12

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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