



(51) International Patent Classification:
H01L 27/24 (2006.01) *H01L 45/00* (2006.01)

(21) International Application Number:
PCT/US2011/024162

(22) International Filing Date:
9 February 2011 (09.02.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
12/711,810 24 February 2010 (24.02.2010) US

(71) Applicant (for all designated States except US): **SAN-DISK 3D, LLC** [US/US]; 601 McCarthy Boulevard, Milpitas, California 95035 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **KREUPL, Franz** [DE/US]; 900 High School Way 2227, Mountain View, California 94041 (US). **ZHANG, Jingyan** [US/US]; 3003 Monroe Street, Santa Clara, California 95051 (US). **XU, Huiwen** [CN/US]; 1461 Mallard Way, Sunnyvale, California 94087 (US).

(74) Agents: **DUGAN, Brian M.** et al.; Dugan & Dugan, P.C., 245 Saw Mill River Road, Suite 309, Hawthorne, New York 10532 (US).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

[Continued on next page]

(54) Title: MEMORY CELL WITH SILICON-CONTAINING CARBON SWITCHING LAYER AND METHODS FOR FORMING THE SAME

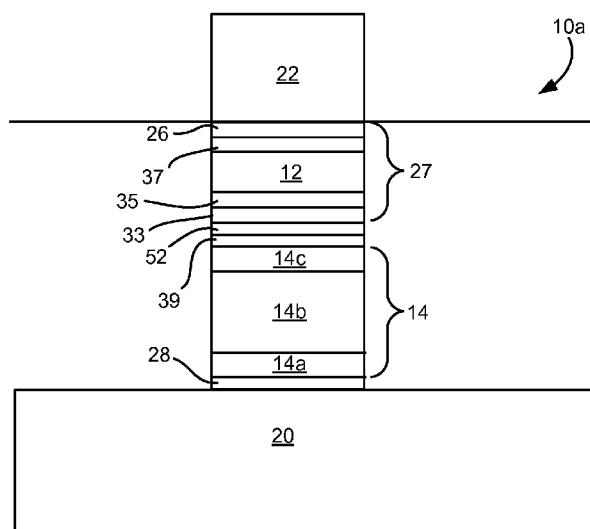


Fig. 3A

(57) Abstract: A method of forming a memory cell is provided that includes forming a metal - insulator-metal (MIM) stack (27), the MIM stack including (a) a first conductive carbon layer (35); (b) a low-hydrogen, silicon - containing carbon layer (12) above the first conductive carbon layer; and (c) a second conductive carbon layer (37) above the low-hydrogen, silicon - containing carbon layer; and forming a steering element (14) coupled to the MIM stack.



— *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

(88) Date of publication of the international search report:
3 November 2011

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2011/024162

A. CLASSIFICATION OF SUBJECT MATTER

INV. H01L27/24 H01L45/00
ADD.

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)

H01L G11C

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, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2010/017428 A1 (SANDISK 3D LLC [US]) 11 February 2010 (2010-02-11)	1-10, 12, 15-19, 21, 24-26, 30-45, 47, 50, 51, 53-55
A	page 5, line 3 - page 6, line 17 page 9, lines 21-29 page 20, lines 30-34 figure 2A ----- -/--	11, 20, 27-29, 46, 52



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

12 May 2011

Date of mailing of the international search report

22/08/2011

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Meul, Hans

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2011/024162

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	FRANZ KREUPL ET AL: "Carbon-based resistive memory", TECHNICAL DIGEST IEDM 2008, IEEE INTERNATIONAL ELECTRON DEVICES MEETING, PISCATAWAY, NJ, USA, 15 December 2008 (2008-12-15), pages 1-4, XP031434495, ISBN: 978-1-4244-2377-4 page 4, column 2, paragraph 1-2; figures 5,6A -----	1-10,12, 15-19, 21, 24-26, 30-45, 47,50, 51,53-55
Y	US 2009/201715 A1 (KREUPL FRANZ [DE] ET AL) 13 August 2009 (2009-08-13) paragraphs [0053], [0068], [0097], [0098]; figures 4,5,11A-11D -----	1-10,12, 15-19, 21, 24-26, 30-45, 47,50, 51,53-55
Y	US 2010/012914 A1 (XU HUIWEN [US] ET AL) 21 January 2010 (2010-01-21) paragraph [0077] -----	5,35,42, 55
Y	EP 0 028 707 A1 (IBM [US]) 20 May 1981 (1981-05-20) page 3, line 31 - page 4, line 35 -----	8,9,38, 39
Y	US 6 100 193 A (SUEHIRO SHINTARO [JP] ET AL) 8 August 2000 (2000-08-08) column 22, lines 1-16 -----	12,21,47
Y	EP 1 892 722 A1 (INFINEON TECHNOLOGIES AG [DE]) 27 February 2008 (2008-02-27) paragraphs [0009] - [0011] -----	43,44, 50,51

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/024162

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-12, 15-21, 24-47, 50-55

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-12, 15-21, 24-47, 50-55

Method of forming a memory cell comprising a MIM stack including a low-hydrogen, silicon-containing carbon switching layer between two conductive carbon layers, wherein the MIM stack is formed by depositing a single low-hydrogen carbon layer with subsequent silicon implantation or by depositing a tri-layer structure of different carbon-containing layers.

1.1. claims: 1-11, 15-20, 24-46, 50, 51, 53-55

Method of forming a memory cell comprising a MIM stack including a low-hydrogen, silicon-containing carbon switching layer between two conductive carbon layers, wherein the MIM stack is formed by sputtering a carbon layer and implanting silicon into the carbon layer.

1.2. claims: 12, 21, 47, 52

Method of forming a memory cell comprising a MIM stack including a low-hydrogen, silicon-containing carbon switching layer between two conductive carbon layers, wherein the carbon switching layer is formed by sputtering a silicon carbide target

2. claims: 13, 14, 22, 23, 48, 49

Method of forming a memory cell comprising a MIM stack including a low-hydrogen, silicon-containing carbon switching layer between two conductive carbon layers, wherein at least one of the conductive carbon layers is formed by depositing amorphous carbon and annealing the aC to form primarily sp² bonded carbon or by sputtering a carbide target.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2011/024162

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2010017428 A1	11-02-2010	US 2010032638 A1	11-02-2010
		US 2010032639 A1	11-02-2010
		US 2010032643 A1	11-02-2010
		US 2010032640 A1	11-02-2010
		WO 2010017425 A1	11-02-2010
		WO 2010017426 A1	11-02-2010
		WO 2010017427 A1	11-02-2010

US 2009201715 A1	13-08-2009	NONE	

US 2010012914 A1	21-01-2010	WO 2010009364 A1	21-01-2010

EP 0028707 A1	20-05-1981	CA 1148101 A1	14-06-1983
		DE 3065180 D1	10-11-1983
		IT 1151096 B	17-12-1986

US 6100193 A	08-08-2000	NONE	

EP 1892722 A1	27-02-2008	CN 101132052 A	27-02-2008
