US008536660B2

(12) **United States Patent**
Hsu et al.

(10) **Patent No.: US 8,536,660 B2**
(45) **Date of Patent: Sep. 17, 2013**

(54) **HYBRID PROCESS FOR FORMING METAL GATES OF MOS DEVICES**

(75) Inventors: **Peng-Fu Hsu**, Hsin-Chu (TW); **Yong-Tian Hou**, Singapore (SG); **Ssu-Yi Li**, Jhubei (TW); **Kuo-Tai Huang**, Hsin-Chu (TW); **Mong Song Liang**, Hsin-Chu (TW)

(73) Assignee: **Taiwan Semiconductor Manufacturing Company, Ltd.**, Hsin-Chu (TW)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 844 days.

(21) Appl. No.: **12/047,113**

(22) Filed: **Mar. 12, 2008**

(65) **Prior Publication Data**

US 2009/0230479 A1 Sep. 17, 2009

(51) **Int. Cl.**
H01L 21/02 (2006.01)

(52) **U.S. Cl.**
USPC **257/410**; 257/E29.137

(58) **Field of Classification Search**
USPC 257/369, 371, 374, 410, 411, 412, 257/E27.064, E27.067, E27.108, E29.128, 257/E29.137
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,974,056	A *	11/1990	Brodsky et al.	257/751
6,089,695	A	7/2000	Takagi et al.	
6,323,115	B1	11/2001	Tanabe et al.	
6,373,111	B1 *	4/2002	Zheng et al.	257/407
6,696,345	B2	2/2004	Chau et al.	
6,727,129	B1	4/2004	Nakajima	
6,794,234	B2	9/2004	Polishchuk et al.	
6,831,310	B1	12/2004	Mathew et al.	
6,855,641	B2	2/2005	Ryu et al.	
6,936,508	B2	8/2005	Visokay et al.	
6,998,686	B2	2/2006	Chau et al.	
7,157,378	B2	1/2007	Brask et al.	
7,160,767	B2	1/2007	Brask et al.	

(Continued)

FOREIGN PATENT DOCUMENTS

CN	1667808	A	9/2005
CN	1274018	C	9/2006
CN	1992273	A	7/2007

OTHER PUBLICATIONS

Chudzik, M., et al., "High-Performance High-k/Metal Gates for 45nm CMOS and Beyond with Gate-First Processing," Symposium on VLSI Technology Digest of Technical Papers, 2007, pp. 194-195.

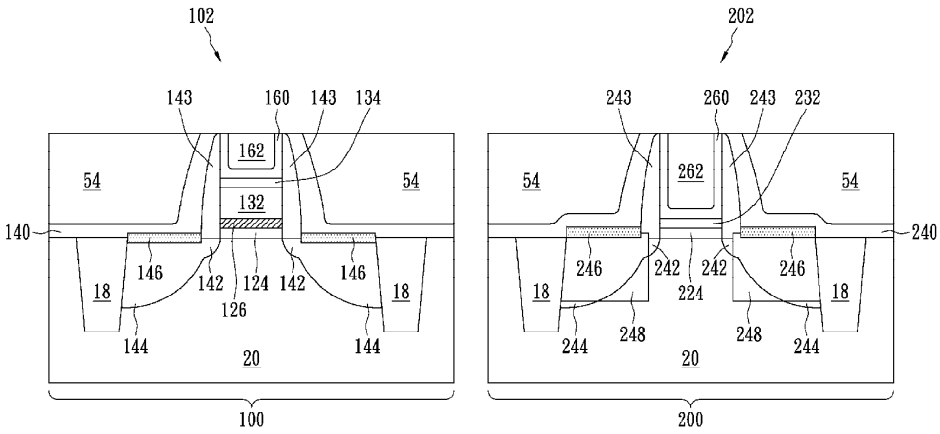
(Continued)

Primary Examiner — Vongsavanh Sengdara
(74) *Attorney, Agent, or Firm* — Slater & Matsil, L.L.P.

(57) **ABSTRACT**

A semiconductor structure includes a first MOS device including a first gate, and a second MOS device including a second gate. The first gate includes a first high-k dielectric over a semiconductor substrate; a second high-k dielectric over the first high-k dielectric; a first metal layer over the second high-k dielectric, wherein the first metal layer dominates a work-function of the first MOS device; and a second metal layer over the first metal layer. The second gate includes a third high-k dielectric over the semiconductor substrate, wherein the first and the third high-k dielectrics are formed of same materials, and have substantially a same thickness; a third metal layer over the third high-k dielectric, wherein the third metal layer and the second metal layer are formed of same materials, and have substantially a same thickness; and a fourth metal layer over the third metal layer.

17 Claims, 11 Drawing Sheets



(56) **References Cited**

U.S. PATENT DOCUMENTS

7,253,053	B2 *	8/2007	Eppich et al.	438/244
7,432,567	B2	10/2008	Doris et al.	
2002/0079548	A1 *	6/2002	Hu	257/412
2003/0057499	A1	3/2003	Yamamoto	
2003/0128384	A1	7/2003	Nelson et al.	
2004/0066535	A1	4/2004	Oyumi	
2004/0245578	A1	12/2004	Park et al.	
2004/0256679	A1	12/2004	Hu	
2005/0082605	A1	4/2005	Akasaka	
2005/0112875	A1	5/2005	Lander et al.	
2005/0157138	A1	7/2005	Silverbrook et al.	
2005/0260806	A1	11/2005	Chang et al.	
2006/0121678	A1	6/2006	Brask et al.	
2006/0166424	A1	7/2006	Schaeffer, III et al.	
2007/0018244	A1 *	1/2007	Hung et al.	257/337
2007/0075351	A1	4/2007	Schulz et al.	
2007/0105317	A1	5/2007	Nakajima	
2007/0138559	A1	6/2007	Bohr	
2007/0272975	A1 *	11/2007	Schaeffer et al.	257/327
2008/0099851	A1 *	5/2008	Hsu et al.	257/369
2008/0173947	A1	7/2008	Hou et al.	
2008/0188044	A1	8/2008	Hsu et al.	
2009/0039433	A1	2/2009	Yang et al.	
2009/0152636	A1 *	6/2009	Chudzik et al.	257/369

OTHER PUBLICATIONS

Tateshita, Y., et al., "High-Performance and Low-Power CMOS Device Technologies Featuring Metal/High-k Gate Stacks with Uniaxial Strained Silicon Channels on (100) and (110) Substrates," IEEE International Electron Devices Meeting, 2006, 4 pages, IEEE.

Hou, Y. T., et al., "High Performance Tantalum Carbide Metal Gate Stacks for nMOSFET Application," IEEE International Electron Devices Meeting, IEDM Technical Digest, Dec. 2005, pp. 31-34, Washington, D.C., United States.

Hsu, P. F., et al., "Advanced Dual Metal Gate MOSFETs with High-*k* Dielectric for CMOS Application," Symposium in VLSI Technology, Digest of Technical Papers, 2006, pp. 11-12, IEEE, Honolulu, Hawaii, United States.

* cited by examiner

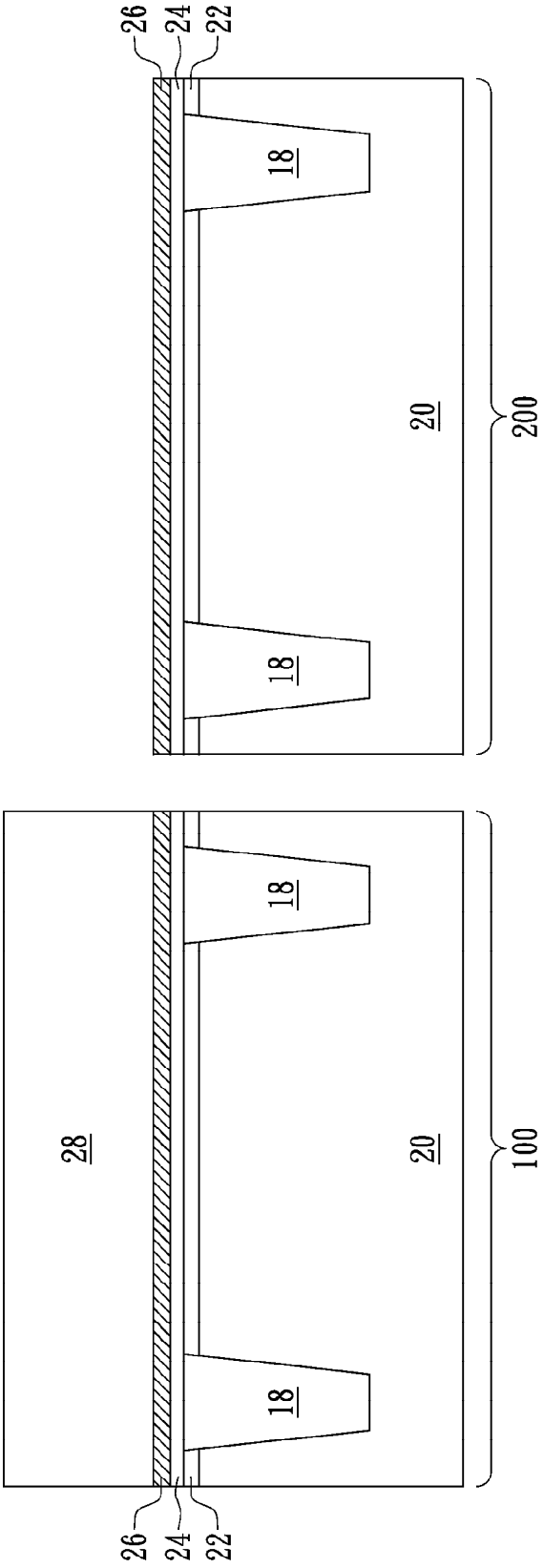


FIG. 1

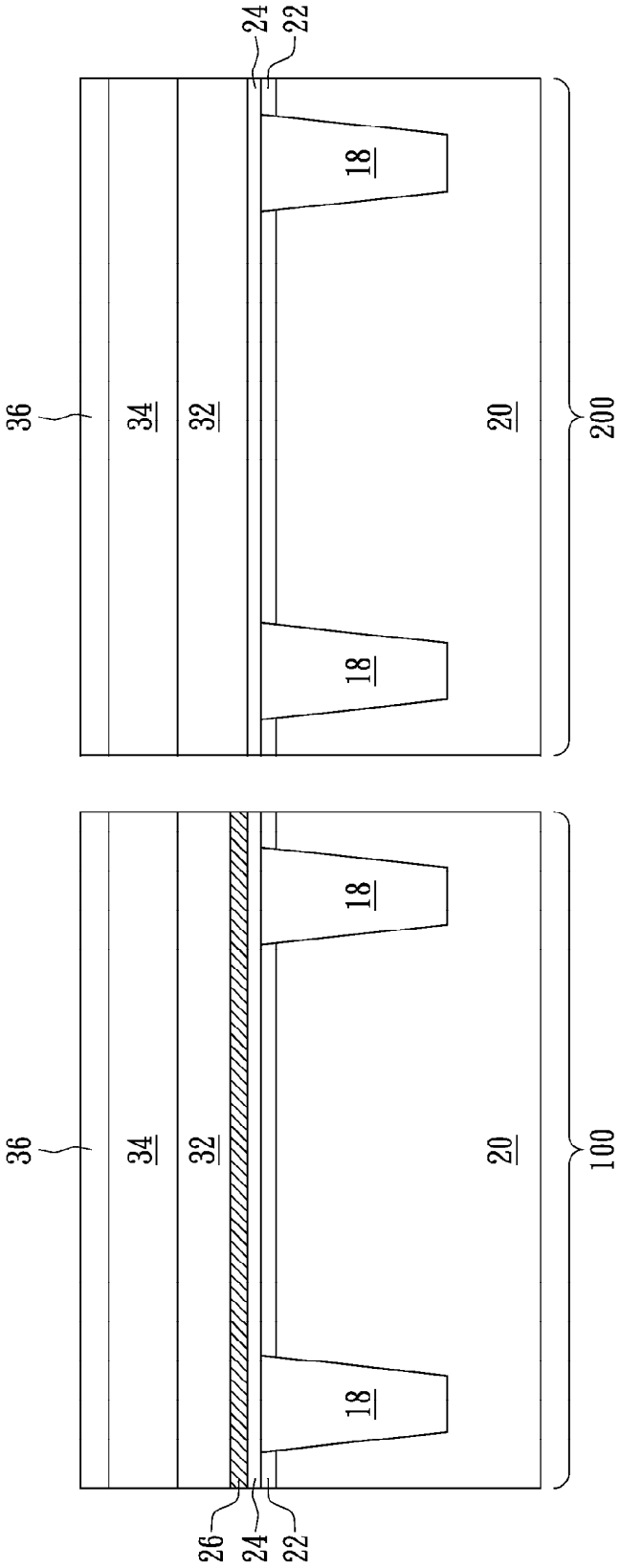


FIG. 2

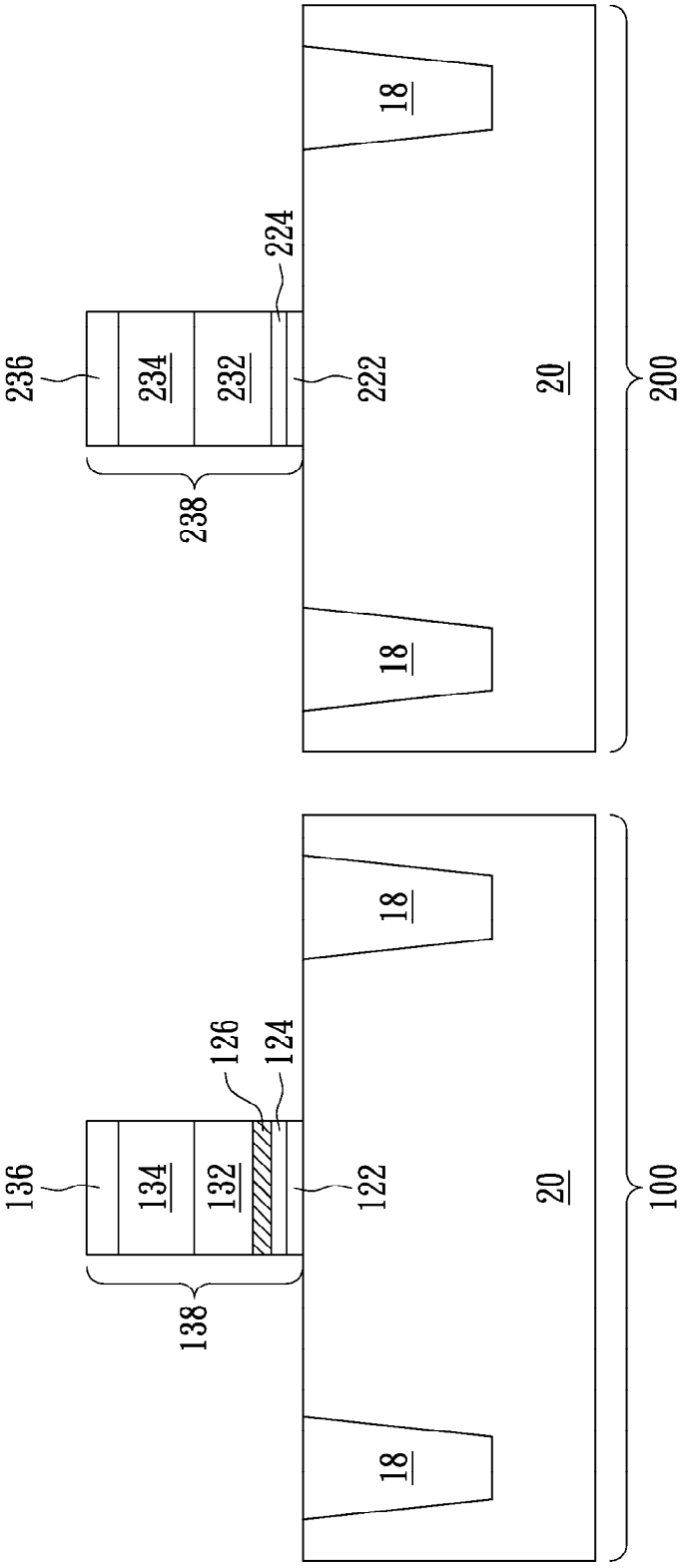


FIG. 3

DOCKET ALARM

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts

Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research

With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips

Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS
Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS
Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS
Sync your system to PACER to automate legal marketing.