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(54) Title: MONOLITHIC SILICON PIXEL DETECTOR, AND SYSTEMS AND METHODS FOR PARTICLE DETECTION

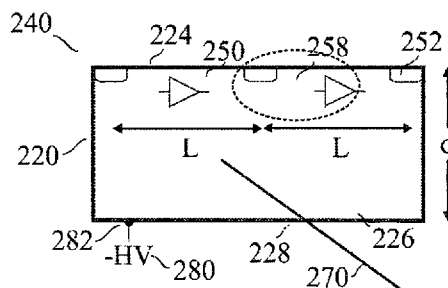


FIG. 2B

(57) Abstract: Monolithic silicon pixel detectors, systems and methods for the detection and imaging of radiation in the form of charged particles or X-ray photons comprise a Si wafer with a CMOS processed readout communicating via implants for charge collection with an absorber forming a monolithic unit with the Si wafer to collect and process the electrical signals generated by radiation incident on the absorber. In particular, a monolithic CMOS integrated pixel detector includes several components. Such components include a p-doped silicon wafer with a resistivity of at least 1kΩ cm (220, 310, 310') having a front- side (224, 314, 314') comprising a CMOS processed readout electronics (250, 350) comprising pixel electronics (258, 358) and a backside (228, 318) opposite the front side. In addition, the pixel detector includes charge collectors (252, 352) communicating with the pixel electronics (258, 358) and defining the pixel size. Still further, high voltage contacts (282, 382) are provided. The region of silicon wafer (220, 310, 310') below the charge collectors (252, 352) forms the absorber layer (226, 316) of pixel detector (240, 340). When the pixel detector (240, 340) is in operation, the charge collectors (252, 352) are disposed to receive electrical charges drifting across the absorber layer (226, 316) when generated by charged particles or X-ray photons (270, 370) incident on the absorber layer (226, 316). The readout electronics is disposed to convert said electrical charges into digital signals which can be stored, processed and displayed as images on a computer screen.

Declarations under Rule 4.17:

- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))*
- *of inventorship (Rule 4.17(iv))*

Published:

- *with international search report (Art. 21(3))*
- *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))*

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INTERNATIONAL SEARCH REPORT

International application No
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A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L27/146
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

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 practicable, 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.
X	SEGAL J D ET AL: "Second generation monolithic full-depletion radiation sensor with integrated CMOS circuitry", NUCLEAR SCIENCE SYMPOSIUM CONFERENCE RECORD (NSS/MIC), 2010 IEEE, IEEE, 30 October 2010 (2010-10-30), pages 1896-1900, XP032054379, DOI: 10.1109/NSSMIC.2010.5874104 ISBN: 978-1-4244-9106-3 page 1896 - page 1898; figures 1,3-5 ----- -/--	1-5, 9-11, 14-22



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 application or patent 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

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Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

International application No

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	MATTIAZZO S ET AL: "LePIX: First results from a novel monolithic pixel sensor", NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH. SECTION A: ACCELERATORS, SPECTROMETERS, DETECTORS, AND ASSOCIATED EQUIPMENT, vol. 718, 1 August 2013 (2013-08-01), - 1 August 2013 (2013-08-01), pages 288-291, XP028875085, ISSN: 0168-9002, DOI: 10.1016/J.NIMA.2012.10.098 pages 288-289; figures 1-2 -----	1-5, 9-11, 14-22
X	WULF E A ET AL: "Wafer-Bonded Silicon Gamma-Ray Detectors", IEEE TRANSACTIONS ON NUCLEAR SCIENCE, IEEE SERVICE CENTER, NEW YORK, NY, US, vol. 55, no. 2, 1 April 2008 (2008-04-01), - 1 April 2008 (2008-04-01), pages 790-796, XP011207284, ISSN: 0018-9499 pages 790-795; figure 1 -----	1-13
A	US 2006/118728 A1 (PHILIPS BERNARD [US] ET AL) 8 June 2006 (2006-06-08) paragraphs [0028] - [0051]; figures 1A-1B, 2A, 2B, 8 -----	1-22
A	WO 2009/071587 A2 (TEKNOFLOW OY [FI]; CONSEJO SUPERIOR INVESTIGACION [ES]; GARCIA FRANCIS) 11 June 2009 (2009-06-11) figures 1-3 -----	1-22
X	US 5 897 362 A (WALLACE STEVEN W [US]) 27 April 1999 (1999-04-27) column 1, line 64 - column 3, line 21; figures 3-6 -----	23-27
A	US 2011/042576 A1 (WILSON ROBIN [GB] ET AL) 24 February 2011 (2011-02-24) paragraphs [0003], [0016]; figures 3,5,7,9 -----	23-27
A	US 2014/203386 A1 (BUI PETER STEVEN [US]) 24 July 2014 (2014-07-24) figures 1-15,23 -----	1-27

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2017/000562

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.:

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: 1-22

A monolithic CMOS integrated pixel detector for the detection of charged particles or X-ray photons, its method of manufacturing and systems having said pixel detector, wherein the monolithic CMOS integrated pixel detector comprises a p-doped silicon wafer with a resistivity of at least 1K Ω cm.

2. claims: 23-27

A method for gettering impurities in a monolithic CMOS integrated pixel detector for the detection of charged particles or X-ray photons, the method comprising steps of: a providing a p-doped silicon wafer with a resistivity of at least 1 k Ω cm and providing a covalent wafer bond between said high resistivity wafer and a low resistivity p-doped wafer.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/IB2017/000562

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
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