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Editorial: Silicon radiation detectors: Status and perspectives

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Editorial on the Research Topic
Silicon radiation detectors: Status and perspectives

In the last 40 years, i.e. since the first detectors were fabricated using the planar process as we know it today, the field of silicon sensors has seen an impressive development with several families of detectors being invented, studied, and deployed for the detection of charged particles and photons in a huge energy range. In fact, scientific, medical, industrial, and consumer solutions heavily rely on such silicon sensors. The maturity of silicon technology, which leverages decades of scientific work devoted to R&D towards industrial mass fabrication coupled with the availability of large and excellent quality silicon crystals, allows and facilitates the conception and fabrication of sensors in a huge variety of types, shapes, dimensions, including single channel or monolithic multi-channel arrays.

Still, space for new devices and improved performance is possible. Both research institutions and private industry are very active in the research and production of novel detectors for a multitude of applications, both industrial and scientific. For example, in High Energy Physics (HEP), new sensor technologies are emerging to address the more and more demanding radiation tolerance levels found in the core of HEP colliders, so that their physics goals, which require higher luminosity, can be achieved. Two recent such advancements are 3D detectors and Low-Gain Avalanche Diodes (LGADs). The former are pixel sensors which, owing to their unique architecture of columnar electrodes etched into the silicon bulk which disentangles wafer thickness and n and p separation distance, provide a remarkable radiation hardness at relatively low bias voltage (and therefore low power dissipation). This makes them the most appealing solution for use in the innermost layers of tracking detectors. LGADs are avalanche diodes specifically designed for the detection of mips with exceptionally good timing resolution, allowing the separation of events originating from the same bunch crossing where a high multiplicity of events is expected.

The development of advanced semiconductor detectors such as these also requires novel, refined, or improved characterization methods, for example to measure localized

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properties in three coordinates inside the bulk. One of these advanced characterization techniques is IBIC, which utilizes focused, MeV energy range ions to probe charge transport, which extends the reach of other, even recently developed, characterization techniques such as Transient Current Technique, which uses a laser beam to scan and map an area.

Detectors are more than just the silicon sensor: refined integrated electronics are necessary to reap the most from the silicon sensor advancement. A well-designed read-out system can make the difference in terms of portability, power consumption, and applicability in the most disparate fields, but needs to be tailored for the specific application. In this collection, an example of a silicon sensor (microstrip detector) read out by sophisticated electronics for simultaneous XRF and XRD in portable analytical applications is shown. The topic of electronics deserves ample space on its own for all its applications and complexity and is outside the scope of the present collection.

Electronics, at least some of the front-end—the most crucial for noise properties—can be monolithically integrated in the sensor, with the obvious advantage of minimizing the capacitance and the complexity associated with the interconnections (wire-bonds or bump-bonds). One such detector is the DePFET, a sensor amplifier structure first proposed in 1987 but which in recent years has seen tremendous improvements, and it has been deployed for particle tracking, space missions, and real-time imaging for transmission electron microscopes. If properly tailored, these devices can reach sub-electron noise and single-electron resolution through repetitive readout or extended dynamic range, depending on the demands of the application.

Noise levels below the electron enable the detection of single photons, which is clearly an attractive feature of silicon sensors and may be seen as the ultimate Frontier for them. It is also becoming a key capability in an increasing number of fields. One such type of detector is the SPAD (single devices and arrays), that due to their ubiquitous design can be fabricated using standard Complementary Metal-Oxide Semiconductor (CMOS) processes for mass and unexpensive production, with the additional advantage of the possibility of integrating complex electronics in advanced technology nodes.

The underlying goal of this collection is to give an overview of the status of the silicon sensors, touching the topics mentioned above. Far from being comprehensive, it brings the hope of both introducing and updating such fascinating field to a broad audience.

Author contributions

The authors confirm being the sole contributors of this work and have approved it for publication.

Conflict of interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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