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Graphene and 2D Materials for Radiation Detection Devices

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Pixels detectors are widely used detection devices in high-energy physics experiments. For more precise and accurate measurements one would like to have faster, less noisy and smaller pixels, but current technology imposes several limits on these characteristics.

The aim of this study is to explore the applications of bi-dimensional materials such as graphene or transition metal dichalcogenide monolayers (TMDs) to address these problems. In particular, one wants to determine whether nanoelectronic devices based on 2D materials could be used to obtain built-in amplification of the pixel signal. In this work some prototype pixel sensors (50x50μm^2) based on graphene and MoS_2 transistors are investigated by means of numerical simulations, to evaluate the expected performance. The working principle is the field-effect modulation of the channel conductivity of a 2D material-based transistor, due to the presence of ionization charges in a silicon absorber placed beneath. Several architectures were tested, and a final device of choice is presented, with a sketch of a realistic readout system and its noise figure. The conductance modulation due to incoming particles is found to be more than 30% (on a baseline of $\sim 10\mu$A), resulting in a strong current signal.

According to simulation results, 2D materials-based pixels show promising built-in pre-amplification and good signal quality, with $\mathrm{SNR} \sim 290$ for a MIP crossing the device. Moreover, their fabrication would be in principle simple, if 2D materials fabrication technology continues to improve. More specifically, these devices would be less complex than other proposed systems such as SOI or DEPFET pixels. These aspects allow to conclude that it would be highly desirable to further study the subject, to perfect the device design, as well as to build some prototype devices to be tested with a radiation source.

Authors: CIARROCCHI, Alberto (Università di Pisa); FORTI, Francesco (Universita di Pisa & INFN (IT)); IANNACCONE, Giuseppe (Dipartimento di Ingegneria dell'Informazione, Università di Pisa)

Presenters: CIARROCCHI, Alberto (Università di Pisa); FORTI, Francesco (Universita di Pisa & INFN (IT))

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