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A scalable gas pixel detector based on micro-Resistive-WELL technology for X-ray and neutron imaging

The micro-Resistive-WELL (μ-RWELL) is a compact, spark-protected, single amplification stage Micro-Pattern Gas Detectors (MPGD).
The new micro-structure based on the resistive technology concept of a very efficient spark quenching is a high reliable device. In addition, since the detector does not require any complex as well as time-consuming assembly procedures (neither stretching nor gluing), it becomes extremely simple to be assembled. These features allow an easy engineering of the detector that could result in industrial applications.
The new detector is composed by only two elements, i.e. the readout-PCB embedded with the amplification stage (the core of the detector named μ-RWELL_PCB), and the cathode.
The amplification stage of the detector realized by photolithography as a matrix of wells (with a pitch of 140 μm and a diameter of 60-70 μm) on a 50 μm thick polyimide substrate is embedded through a resistive layer combined by the readout board.
The resistive layer can be prepared by different technologies, such as, for instance, DLC (Diamond Like Carbon) dry sputtering or screen printing. The required surface resistivity, typically ranging from few units to hundreds MΩ/square, is clearly a crucial parameter that must be optimized as a function of detector performance. A cathode electrode defining the gas conversion-drift gap completes the detector mechanics.
The proposed technology, suitable for large area tracking devices and compact digital hadron calorimetry in HEP experiments (it has been proposed for the phase-2 upgrades of CMS and LHCb muon apparatus and for the neutrino detector of the SHIP experiment), can be exploited for fine X-ray and thermal neutron (using suitable lithium-fluoride or Boro-10 coated cathode) imaging in industrial applications.
Neutron science, acting in a complementary way with respect to X-ray, gives us knowledge that improves our everyday lives, our health and our environment.
As an example neutron imaging is suitable to investigate DNA molecules and proteins that control aging and cancer, opening the way towards the development of new techniques and more effective treatments and medicines. Further examples of neutron science applications in the environmentally friendly materials and processes are: fuel cells driven by hydrogen, solar power, climate technology, new generation materials and life science.
For both X-ray and neutron imaging applications the detector must be designed with a multi-pixel anode (pitch of the order of 1 mm) that coupled with a suitable front-end electronics with charge readout will allow fine 2D-track reconstruction by charge centroid (about 50 μm image resolution). In addition using Time to Digital Converters (TDCs) to extract the arrival time of the ionization clusters, a full 3D-reconstruction of the event would be available (μ-TPC mode).

The development of a dedicated ASIC solution for the read-out of the μ -RWELL, based on 130 nm process technology, is crucial in order to fully exploit the detector potentiality.
A typical read-out chain will consist of a high gain and low noise pre-amplifier stage, followed by a suitable shaping, tail-cancellation stage and a discriminator, to obtain a binary read-out. The discriminated signal is typically used for time measurements being the input to a Time to Digital Converter (TDC) circuit, having resolutions in the order of 1-2 ns (r.m.s.). The TDC can be integrated on the same circuit containing the amplifier, shaper and discriminator.
Thanks to new microelectronics technologies a very dense Front-End electronics characterized by low-power consumption, low-noise, selectable-gain and complying high rate and harsh radiation environments may be proposed satisfying charge and timing requirements.
Either a separate chain or a dedicated signal processing chain have to be foreseen for position and timing measurements together with an adequate digital pipeline length to account for trigger latency. Since the device is used in multi-disciplinary applications, where self-trigger capability is generally required, the architecture should be operated also in data-driven mode.

In conclusion the μ-RWELL detector with dedicated integrated electronics is a high performance, wide impact, scalable device suitable for both large area applications in HEP (as tracking device) and industrial and medical applications (as X-ray and neutron imaging gas pixel detector).

Summary

The project aims in developing a new scalable gas pixel detector based on the micro-Resistive-WELL (μ-RWELL) technology with a dedicated front end electronics for X-ray and neutron imaging purposes.
The novel architecture is a compact, spark-protected, single amplification stage Micro-Pattern Gas Detectors (MPGD). The micro-structure exploits several solutions and improvements achieved in the last years for MPGDs, in particular, for GEMs and Micromegas.

Primary author: BENCIVENNI, Giovanni (Istituto Nazionale Fisica Nucleare Frascati (IT))

Co-authors: RANIERI, Antonio (Universita e INFN, Bari (IT)); MORELLO, Gianfranco (Istituto Nazionale Fisica Nucleare Frascati (IT)); FELICI, Giulietto (Istituto Nazionale Fisica Nucleare (IT)); POLI LENER, Marco (Istituto Nazionale Fisica Nucleare Frascati (IT)); GATTA, Maurizio (Istituto Nazionale Fisica Nucleare Frascati (IT))

Presenter: BENCIVENNI, Giovanni (Istituto Nazionale Fisica Nucleare Frascati (IT))