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Topmetal-CEE: a pixel sensor for the readout of GEM detectors for high-rate particle tracking

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In this talk, we report the R\&D program underway at CCNU to develop a pixel chip for the readout of GEM detectors appropriate for use in the CSR external-target experiment (CEE) at HIRFL for beam monitoring. The chip offers simultaneous time-over-threshold (TOT) and time-of-arrival (TOA) measurements, and a data-driven readout scheme with a rate of 40 MPixels/s. Two generations of the chips were produced, with the second generation offering much-improved performance over the first one. The design and characterization of the chips are presented, including the tests using injected pulses, α particles, laser beams, and heavy-ion beams.

Summary (500 words)

Within the project of building a beam monitor for the CSR external-target experiment (CEE) at HIRFL, pixel sensors used as the anode for the readout of GEM-equipped TPC-type detectors, are being developed. The Topmetal-CEE chip features a row of 180 pixels, each occupying an area of about 1 mm $\times$ 100 μm. Each pixel includes a top metal layer as the charge-collection electrode (CCE), a charge-sensitive amplifier, a discriminator, a time-to-amplitude converter, and a logic circuit. The chip offers simultaneous time-over-threshold (TOT) and time-of-arrival (TOA) measurements, and a data-driven readout scheme with a rate of 40 MPixels/s.

The first-generation chips (Topmetal-CEEv1) were fabricated in GSMC 130 nm CMOS process. The second-generation chips include two versions, named Topmetal-CEEv2 and Topmetal-CEEv3, which were fabricated in GSMC 130 nm and TSMC 180 nm CMOS processes, respectively. The test results show that the second-generation chips yield much-improved performance. In particular, the minimum operating threshold decreases from about 20k e^- to 2.5k e^-, thanks to a careful optimization of the chip design.

Basic electronic tests were performed to study the noise, threshold variation, minimum operating threshold, resolution of TOT and TOA, power consumption, etc. The responses to α particles, laser beams, and heavy-ion beams were also studied. The laser test of Topmetal-CEEv1 shows that the time resolution varies from 9 to 13 ns, for different drift distances. The test of Topmetal-CEEv1 with 350 MeV/u Kr-ion beam demonstrates a spatial resolution of better than 50 μm.

More results are foreseen by the time of the conference, including a heavy-ion beam test with second-generation chips, planned in the middle of May.

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