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R&D on Plasma-Etched Gas Electron Multipliers for X-ray Polarimetry in Space

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Gas Electron Multipliers (GEMs) play a critical role in high-resolution X-ray polarimetry, enabling precise measurements for astrophysical missions such as IXPE, Polarlight, and the upcoming eXTP telescope. These detectors rely on the ability to amplify electron signals generated by incoming X-rays with high spatial resolution while maintaining optimal detection efficiency in the 2–8 keV range. The IXPE collaboration has successfully refined Gas Pixel Detector (GPD) technology using laser-drilled GEMs and collecting the amplification signals with a dedicated detector called XPOL. The polarization of the incoming X-ray is retrieved by tracking the secondary electrons emitted through photoelectric and Auger processes after the incoming particle interacts with the gas (dimethyl ether - DME) in the chamber. Regarding microstructural aspects, the overall sensor performance in detecting the polarization of the incoming radiation is affected by three main error contributors: local or global misalignments of the GEM pattern between the top and bottom layers, inconsistencies in GEM hole geometry, and inhomogeneity across the GEM effective area. These three factors introduce systematic errors in the measurement which are difficult to quantify and thus challenging to subtract from the actual measurement. For this reason, further optimization of the GEM hole patterning is essential to maximize detector performance. To address these challenges, we investigated a plasma-based Reactive Ion Etching (RIE) technique developed at Fondazione Bruno Kessler (FBK) for GEM fabrication, in contrast to the laser-drilling approach used for IXPE and the standard wet-etch process employed by traditional manufacturers. This method allows for the production of GEM foils with more vertical and uniform hole profiles, potentially improving polarization resolution. We introduce a novel plasma-etched GEM design featuring holes with a 30 µm diameter and a 50 µm pitch. These structures have been extensively characterized using Scanning Electron Microscopy (SEM) and Plasma-Focused Ion Beam (PFIB) analysis to assess their geometry and uniformity. In collaboration with INFN , we conducted comprehensive electrical testing and performance validation within GPDs, supported by detailed Garfield++ simulations. Initial experimental results indicate that plasma-etched GEMs exhibit gain vs. voltage behavior, tested with 55Fe in a 70/30 Ar/CO_2 mixture at 1 bar, comparable to the detectors currently deployed in IXPE. While still in the early stages of research and development, this plasma-etching technique holds significant promise for enhancing the sensitivity of future space-based X-ray polarimeters. By improving the uniformity of charge amplification, it has the potential to refine polarization measurements and advance detector technology for next-generation missions. A detailed explanation of the future steps of the project, focusing on evaluating performance in terms of polarimetry resolution and comparing it to IXPE detectors, will also be provided.

Eligibility for ”Best presentation for young researcher” or ”Best poster for young researcher” prize

Yes

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