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Development of silicon interposer: towards an ultralow radioactivity background photodetector system

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It is of great importance to develop a photodetector system with an ultralow radioactivity background in rare event searches. Silicon photomultipliers (SiPMs) and application-specific integrated circuits (ASICs) are two ideal candidates for low background photosensors and readout electronics, respectively, because they are mainly composed of silicon, which can achieve good radio-purity without considerable extra effort. However, interposers, used to provide mechanical support and signal routes between the photosensor and the electronics, are a bottleneck in building ultralow background photodetectors. Silicon and quartz are two candidates to construct the low background interposer because of their good radio-purity; nevertheless, it is non-trivial to produce through silicon vias (TSV) or through quartz vias (TQV) on the large area silicon or quartz wafer. In this work, based on double-sided TSV interconnect technology, we developed the first prototype of a silicon interposer with a size of 10 cm$\times$10 cm and a thickness of 320 μm. The electrical properties of the interposer are carefully evaluated at room temperature, and its performance is also examined at -110 $^{\circ}$C with an integrated SiPM on the interposer. The testing results reveal quite promising performance of the prototype, and the single photoelectron signals can be clearly observed from the SiPM. The features of the observed signals are comparable with those from the SiPM mounted on a normal FR4-based PCB. Based on the success of the silicon interposer prototype, we started the follow-up studies that aimed to further improve the performance and yield of the silicon interposer, and eventually to provide a solution for building an ultralow background photodetector system.

Primary author: Prof. CAO, Guofu (IHEP)

Co-authors: Dr YANG, Haibo (IME); Prof. WANG, Qidong (IME)

Presenters: Prof. CAO, Guofu (IHEP); Dr YANG, Haibo (IME)

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