High density 3D integration of LGAD sensors through wafer to wafer bonding.

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The recent development of silicon diode Low Gain Avalanche Detectors (LGADs) [1, 2]. has enabled the design of granular ($\sim$1x1 mm^2) fast-timing layers for the ATLAS and CMS tracking systems at the HL-LHC. These systems will allow the determination of the time-of-passage of minimum ionizing particles to a precision of better than 50 ps [3].

The essential design aspects of the LGAD can be described as: a region "p++" with a dopant concentration significantly greater than that of the bulk "p" region. This leads, after depletion, to an electric field large enough to provide amplification (by as much as a factor of 70) through multiplication of the signal. Because of this amplification, the "p" region can be made very thin (50 μm or less), leading to a fast signal and, in turn, precise timing. Several new technologies are being studied to overcome the LGAD granularity limitation as outlined in these references [4, 5, 6]. These technologies, when refined, will allow to produce finely segmented LGADs down to less than 50 μm scale maintaining the exceptional time resolution.

However once a very high granularity is achieved on the sensor it is necessary to develop a high density interconnect technology with the readout Electronics. The flip chip bump bonding procedure of sensor and ASIC has been proven to work down to the 50um scale but with issue of yield arising at lower scale. To overcome this limitation a 3D integration technology based on wafer to wafer bonding is proposed to connect the LGAD sensor to signal processing layers integrated within the readout wafer. The 3D integration technology is common in communication, computing and medical industries, however the option of 3D integration is currently not available in the international HEP community.

This 3D integration technology for high density interconnect would be of extreme interest for future HEP experiments. It will allow for finer pitch detectors that are crucial for particle detection very close to interaction points. This technology will allow a high density interconnect between sensor and electronics with a readout pitch that can be as low as 10um. The ultimate goal is to provide readout to LGAD sensors with the ability to reach 10um of position resolution and 10ps of time resolution.

Furthermore it would allow to build low mass trackers with thin layers of detectors/readout, after thinning is foreseeable to have a 50um sensor plus a 10um of electronics per layer. This technology would make possible to build stacks of 3D interconnected sensors/readout that can be used for pattern recognition tracking [7] and for X-ray detection applications with thin sensors.

References

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