Measurement results of IHEP-IMEv1 low gain avalanche devices and IHEP-IMEv2 sensor design for ATLAS HGTD

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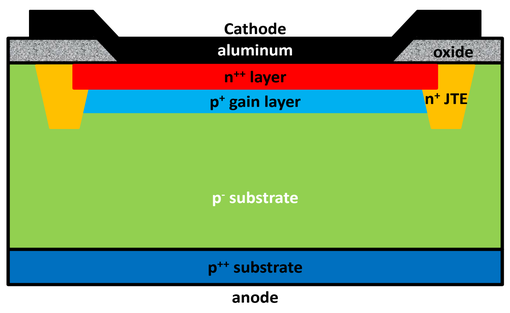
Abstracts

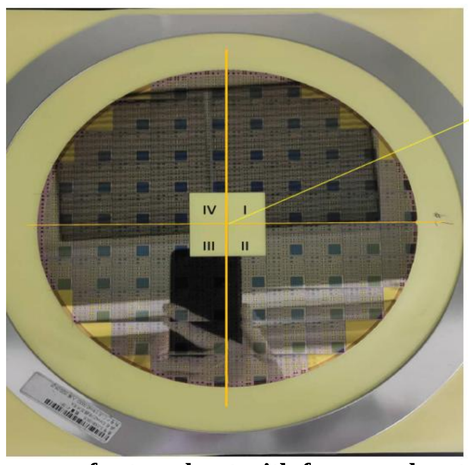
Low- Gain Avalanche Detector (LGAD) with time resolution better than 50ps has been choose as the sensors for HGTD project and have so far been developed by several institutes. This poster will show the measurement results about 50um thick IHEP-IMEv1 LGAD sensors designed by the Institute of High Energy Physics (IHEP) and fabricated by Institute of Micro Electronics (IME). Beta source measurement results show that the time resolution of IHEP-IMEv1 sensors are better than 40ps and the collected charges are larger than 20fC before irradiation. The properties of IHEP-IMEv1 sensors fulfill the required specifications of sensors before irradiation for ATLAS HGTD project. Performance of the sensors after irradiation will also be shown. Furthermore, this poster will show the second version of sensor design for 15×15 sensor arrays, especially simulation results of process parameters for gain layer implantation which will be optimized for the sensors to meet irradiation requirements of the project.

Devices physics Structure



◆The most important part of LGAD senor is the charge multiplication in the so called gain layer which is formed by a heavily doped 1–2μm thick *p*+ layer sandwiched between the *n*++ implant and the *p* substrate.
◆While other structures as JTE (Junction Termination Extension), is implanted to avoiding early breakdown at the edge.
◆The thickness of the p- substrate are as thin as ~50um for superior time resolution of around 35ps per detector layer.
◆The negative anode voltages are applied from backside electrode to make sure the sensor work at the voltage before breakdown and with Gain >10 for effectively charge collection, while the signals of each sensor be collected and analyzed form the top cathode electrode.

Devices Fabrication



one wafer taped out with four quadrants

◆Substrates:
8 inch boron doped (100)-oriented p-type silicon wafers with 50um thick EPI layer which has resistivity of 1kΩcm.

◆3 wafers with different process parameters were taped out.

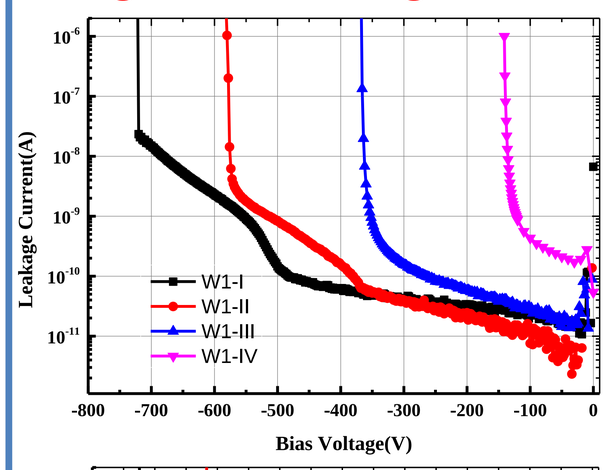
◆ for each wafer having four quadrants, four different doses for p+ layer were implanted into different quadrants of one wafer.

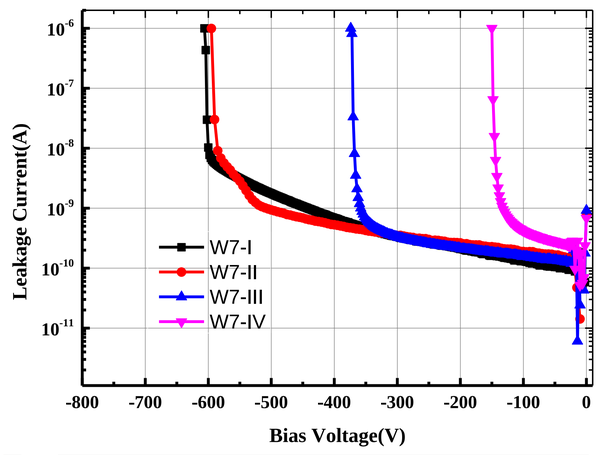
◆The implantation parameters of p+ layer and n++ layer for different wafers and quadrants are listed in the follow table .

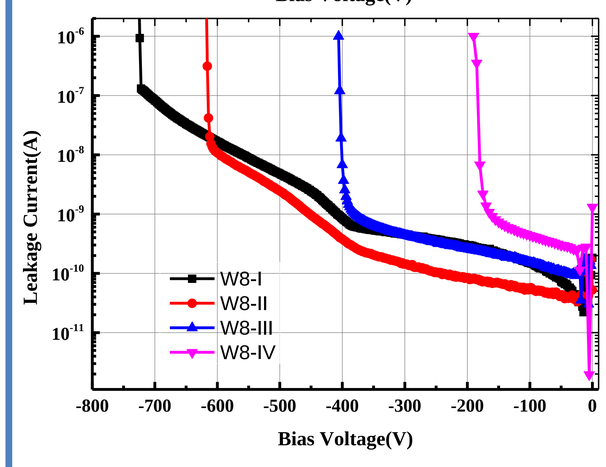
Process parameters of p+ layer and n++ layer for different wafers(W1\W7\W8) and quadrants(I\II\III\IV)

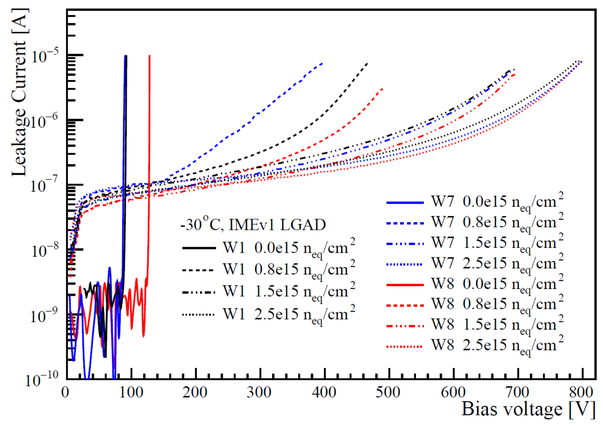
		W1				W7				W8			
Carbon injection		Yes				No				No			
n++ layer	Energy(KeV)	40				40				50			
	Dose(cm^{-2})	1e15				1e15				1e15			
p+ layer	Energy(KeV)	400				400				400			
	Dose(cm^{-2})	I	II	III	IV	I	II	III	IV	I	II	III	IV
		low	middle	high	extremely high	low	middle	high	extremely high	low	middle	high	extremely high

leakage current-voltage characteristics



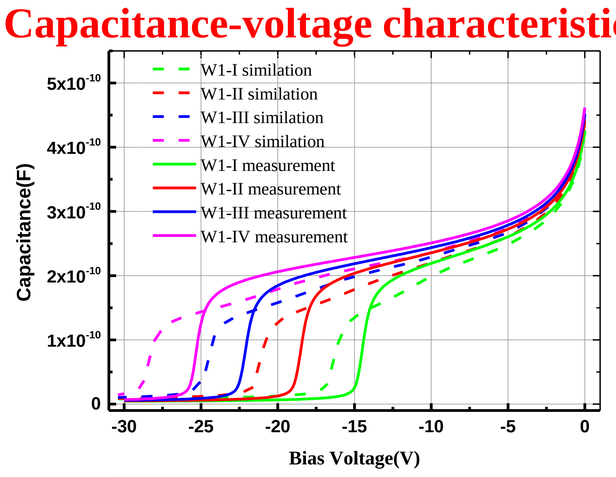


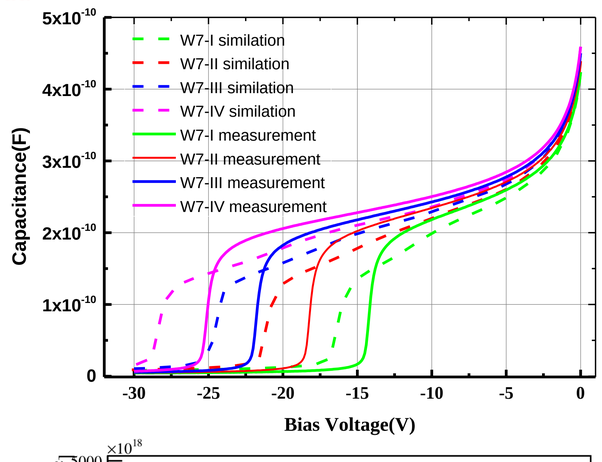


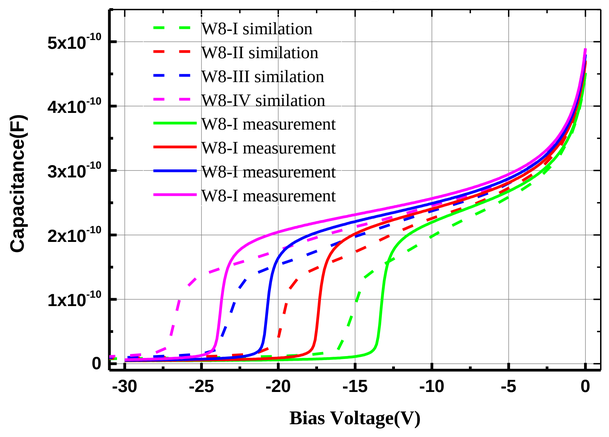


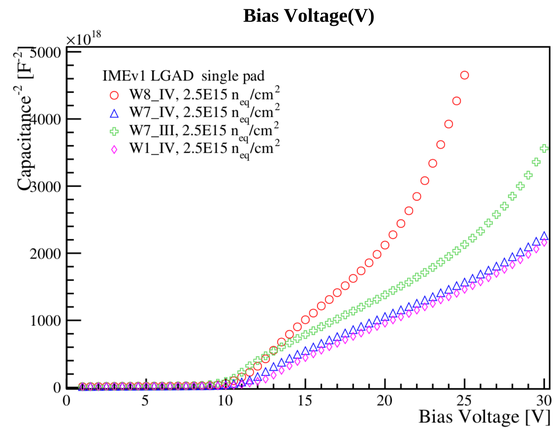
◆The leakage current for all the sensors with different injection parameters at room temperature before breakdown are less than 1nA.
◆The V_{BD} which is defined as the voltage where the leakage current is 500nA decrease as the dose of p+ layer up. And to be specific, the V_{BD} decrease about 140V as the dose of p+ layer increase about 0.2e12cm^{-2}.
◆ The results fit with TCAD simulation results, while the difference is about 2V between testing results and simulation results because of the process variation.
◆ Compared with sensors of the fourth quadrants of wafer 7, sensors form same quadrants of wafer 8 with higher n++ implantation energy shows higher breakdown voltage, about 50V higher.
◆After irradiation, the leakage current increase to 100nA for all the sensors (IV-quadrant)and the V_{BD} increases as increasing the irradiation dose.

Capacitance-voltage characteristics



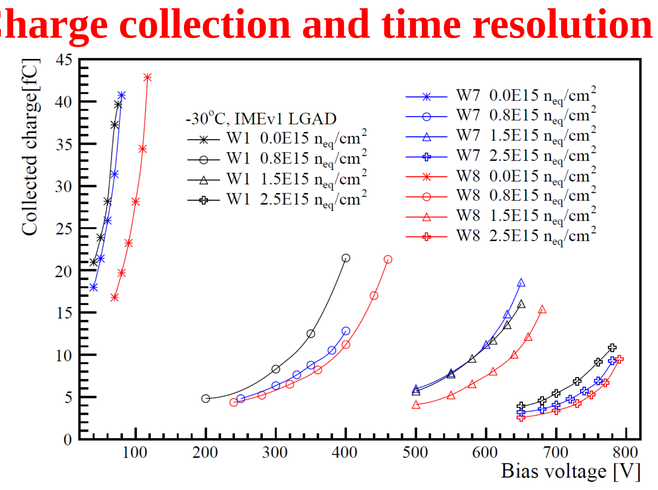


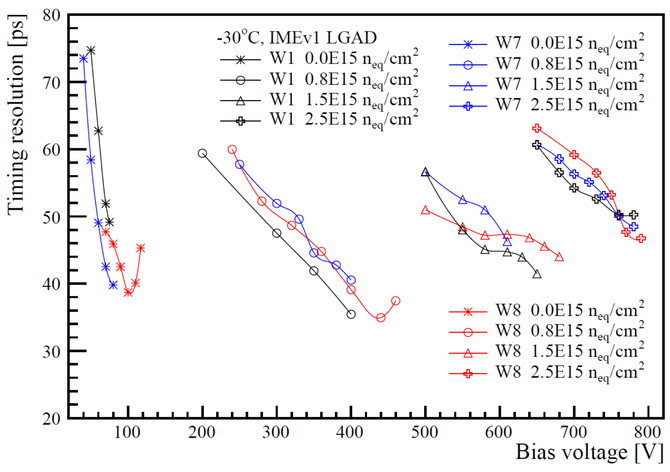




◆Gain layer depletion voltage (V_{GL}) increase with p+ layer dose up.
◆The trends of the capacitance properties also fit with TCAD simulation results, while V_{GL} from testing results are about 3-5V higher than simulation results.
◆Compared with wafer 7, sensors form wafer 8 with higher n++ implantation energy shows lower V_{GL}
◆Wafer 1 with carbon injection shows similar capacitance properties as comparing with wafer 7 with same gain layer implantation.

Charge collection and time resolution

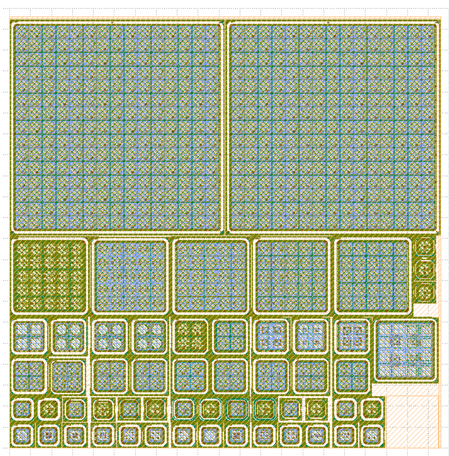


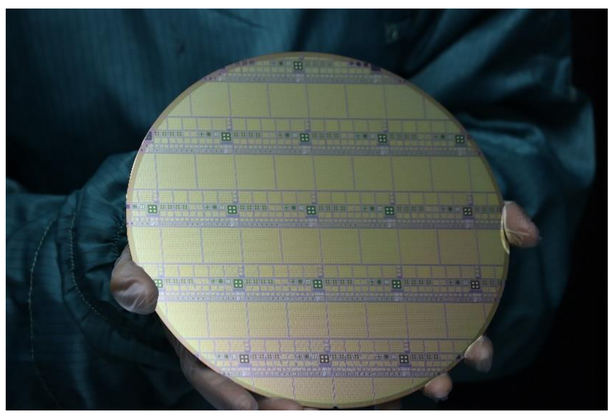


◆All IHEP-IMEv1 LGAD sensors have a collected charge larger than 15fC before irradiation, some of them can reach to 30fC, which satisfy the requirement of the ATLAS HGTD project (>15fC before irradiation).
◆After 2.5e15neq/cm^2 irradiation, sensors have a collected charge larger than 4fC at about 700V, which satisfy the requirement of the ATLAS HGTD project (>4fC after irradiation).

◆The time resolution of sensorsW1-IV, W7-IV, and W8-IV, which have p+ layer dose up to 2.5e12cm^{-2} can be lower than 40ps at -30℃.
◆After 2.5e15neq/cm^2 irradiation, the sensors can reach time resolution lower than 50ps
◆These three sensors have the potential to satisfy the ATLAS physics requirement in HGTD project (< 35 ps before irradiation, <70ps after irradiation).

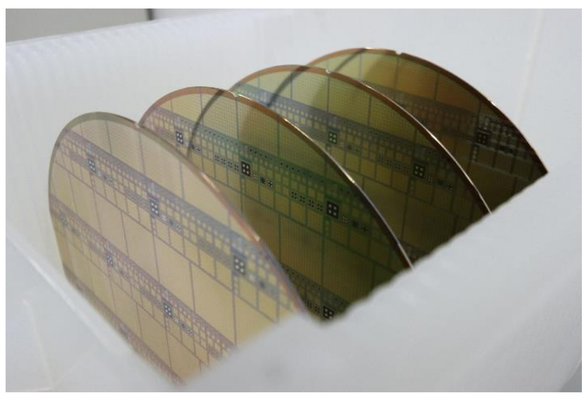
IHEP-IMEv2 design and fabrication





For IHEP-IMEv2 run, IHEP and IME will add large array sensors(15×15), optimizing the doping of gain layer and condition of carbon injection to improve the performance of charge collection after irradiation.

5 wafers have been taped out. Measurement will be done soon.



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