Silicon Detectors in CMS

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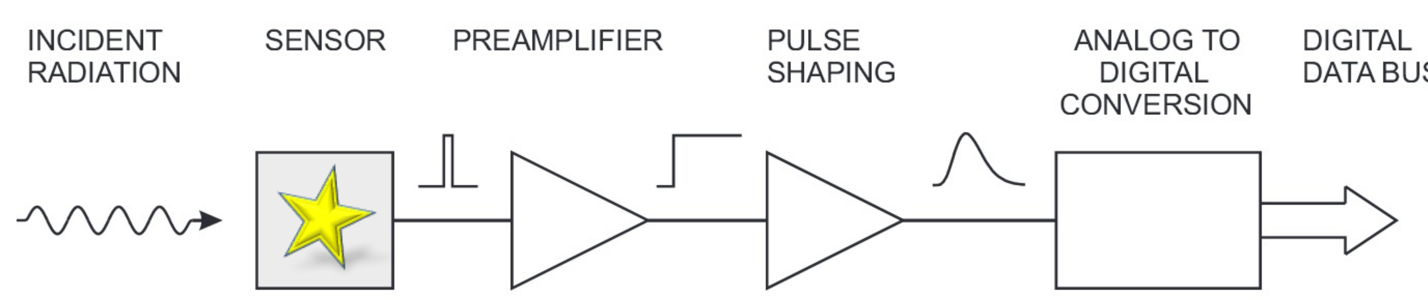
Silicon Detectors

In CMS, silicon detectors are used to detect high-energy particle collisions. When voltage is introduced to a diode in the silicon, an electric field is formed. When a particle passes through this field, the charge moves along the field lines to a sensor. The signal is then amplified since it is usually very small. The amplification causes electronic “noise” which is minimized by pulse shaping. The resulting signal is then converted to a digital format and collected as data.



Basic detector functions: Radiation is absorbed in the sensor and converted into an electrical signal (Spieler 2). Our focus is on the sensor itself.

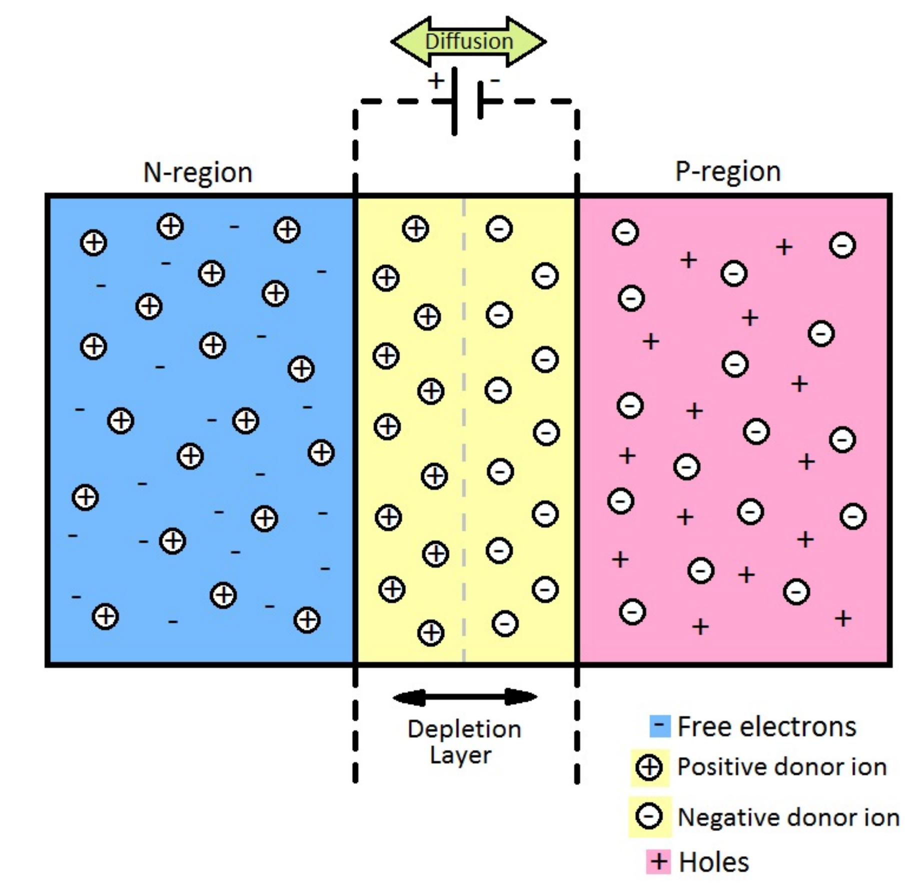
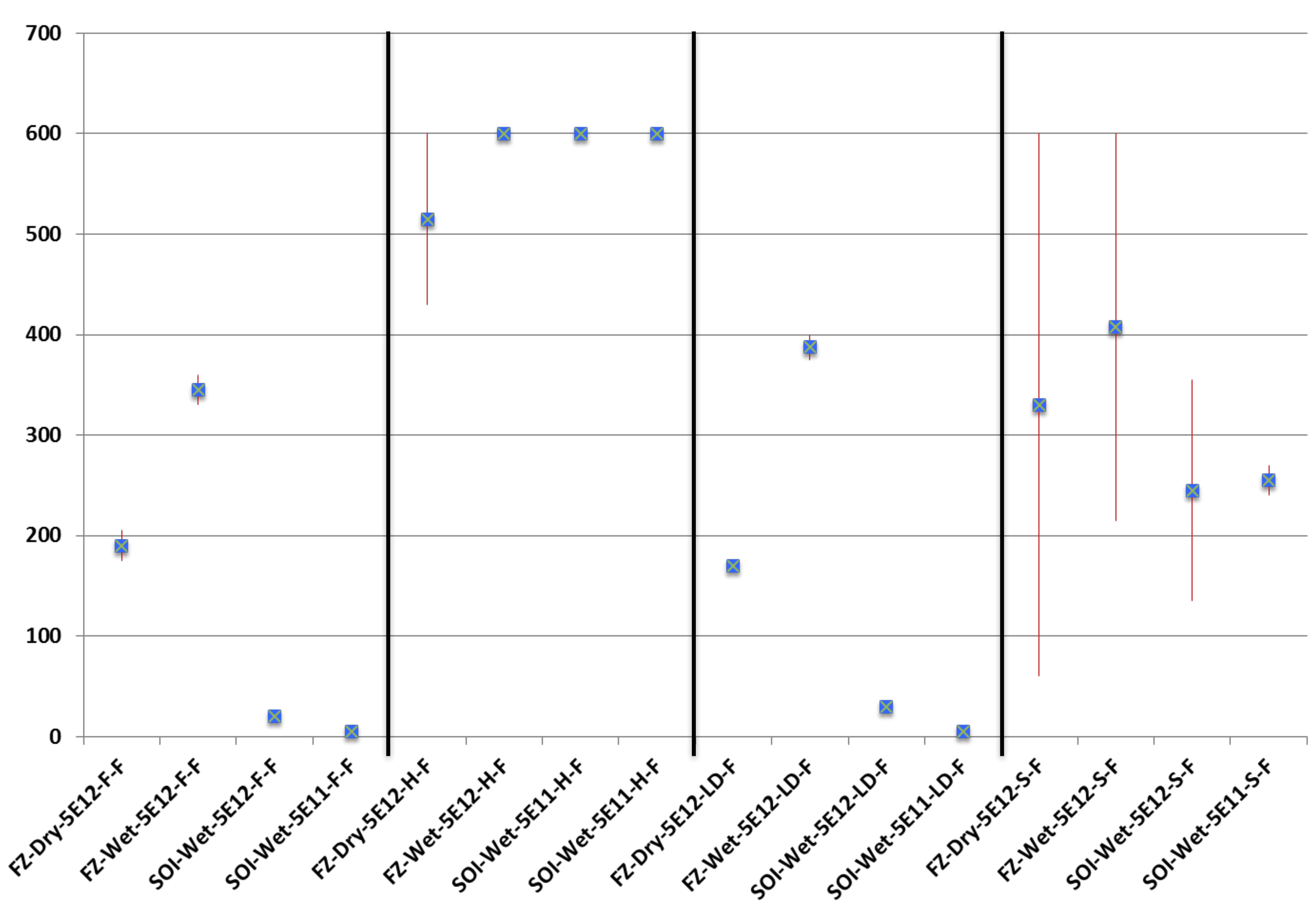


Illustration of depletion in the sensor.



Plot of breakdown voltages of various test structures and wafers.

Breakdown and Depletion

Breakdown occurs when there is an uneven buildup of current in the wafer that causes damage. From the data collected, it appears that float zone wafers with a wet oxide trend with the highest breakdown. It also seems that the HPK-style guard rings make for the highest breakdown.

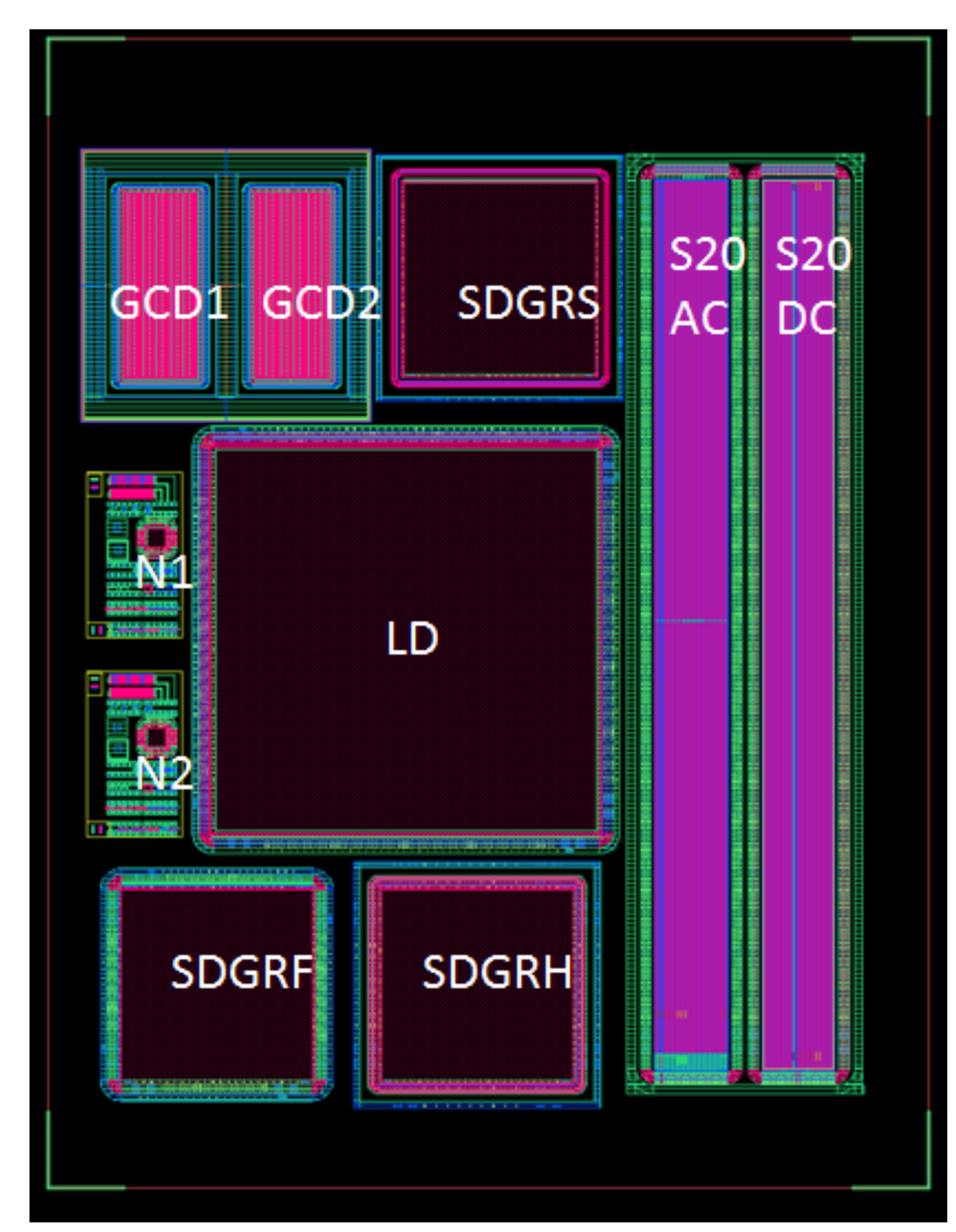
We want a high breakdown so that we are able to reach depletion voltage without fear that there may be damage done to the wafer.

Depletion occurs when an applied voltage causes electrons and electron holes to arrange themselves in such a way that creates an electric field.

As previously mentioned, this field is essential in the particle detection process. Because of this, we need to know at what voltage this field is fully generated.

Type	Oxide	Wafer	GR	BD Max	BD Min	Depleti
FZ	Dry	13	S	600	60	N/A
FZ	Dry	13	LD	170	170	N/A
FZ	Dry	13	F	205	175	N/A
FZ	Dry	13	H	600	430	175
FZ	Dry	13	S20	35	35	N/A
FZ	Wet	15	S	600	215	N/A
FZ	Wet	15	LD	400	375	N/A
FZ	Wet	15	F	360	330	N/A
FZ	Wet	15	H	600	600	N/A
FZ	Wet	15	S20	55	55	N/A
SOI	Wet	F5	S	355	135	65
SOI	Wet	F5	LD	30	30	70
SOI	Wet	F5	F	20	20	40
SOI	Wet	F5	H	600	600	60
SOI	Wet	F5	S20	55	50	N/A
SOI	Wet	G2	S	270	240	75
SOI	Wet	G2	LD	5	5	N/A
SOI	Wet	G2	F	5	5	N/A
SOI	Wet	G2	H	600	600	80
SOI	Wet	G2	S20	70	65	N/A

Final data summary of VI and CV tests on cut 18 of the Novati wafer.



Cut 18 of the wafer, tested at Fermilab.

Conclusions

The trick is then balancing the two measurements. The detector must be able to reach depletion without breaking down.

From the data collected at Fermilab, it appears that HPK-style guard rings have the highest breakdown and therefore are the most durable. Float zone wafers also appear to be very durable but break down sooner over time.

SOI wafers break down sooner but also have smaller depletion voltages, so they may be able to operate at lower voltages altogether.

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Acknowledgments

Special thanks to Ron Lipton for taking me on as his mentee and teaching me so many new things in my short time here.

References

Spieler, Helmuth. “Semiconductor Detector Systems.” Oxford: Oxford UP, 2005. Print.

August 2016

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