Performance Evaluation of Silicon Photomultiplier Sensor for Thickness Gauge

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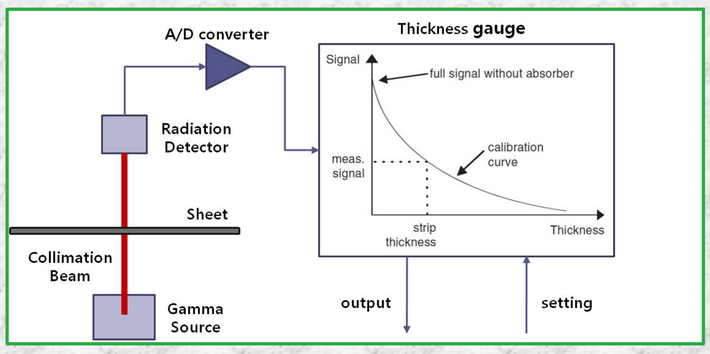
Background

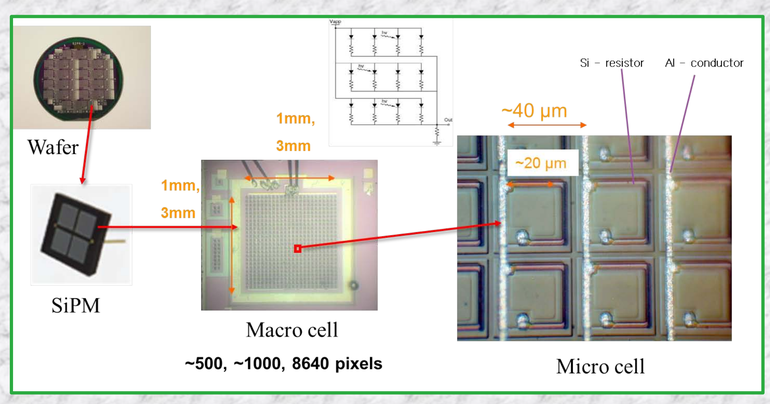
❖ Thickness Measuring Applications Using Gamma-rays

- Electrical, optical, and radiographic characteristics of silicon photomultiplier sensor
- Photo-multiplier tube and silicon photomultiplier sensor thickness gauge reduced in size for use in research labs



❖ Silicon Photomultiplier Sensor

	PMT	SiPM
Photon detection efficiency	20%	15~20%
Gain	10^6-10^7	10^6
High voltage	1-2kV	25V
Magnetic Field effect	Yes	No
Threshold sensitivity	1 ph.e.	1 ph.e.
Timing/10ph.e.	~100 ps	30 ps
Complexity	High	Low



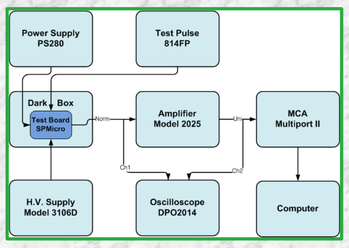
Objectives

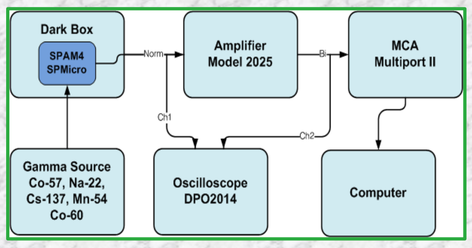
- To assess characteristics of silicon photomultiplier sensor for a radiation detector module and applicability of the sensor as a thickness gauge
- To characterize electrical, optical and radiographic properties of the silicon photomultiplier sensor
- A detector module was set with optimal scintillator combination and tested as a thickness gauge.

Material and Methods

❖ SiPM Characteristics Test

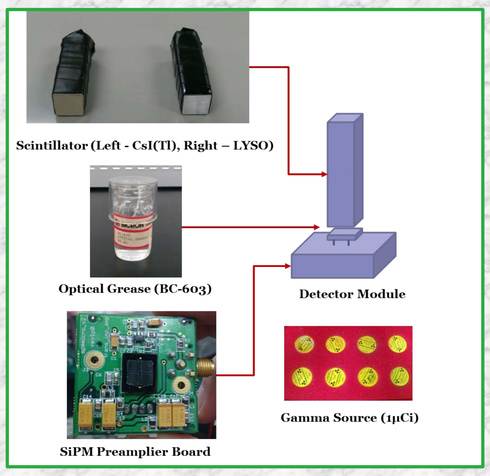
- The noise equivalent quantum measurement system. Test board was constructed for the experiment. Charge Sensitive Amp was used EV-product's ev5093. In the test board, SiPM could be applied to the changeable reverse bias.
- SiPM had more large internal capacitance than other semi-conductors. Measured values were shown that NEQ increased after a breakdown voltage about 28 V by scan type
- The dark count rate measurement system. SiPM could distinguish a single photon. Therefore, the experiment was processed in darkroom.
- The dark count rate did not change much compared to the neutron irradiation time.

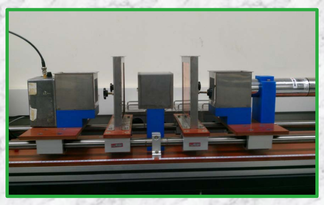


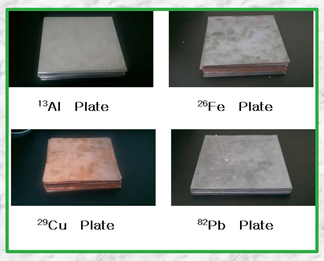


❖ Thickness Gauge Performance Test

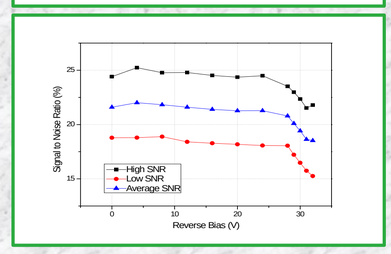
- Among transmissive thickness measuring technology application fields, a thickness gauge for steel rolling process was presumed to have been reduced to the size for use in research labs.
- Based on this, a commercial level conventional NaI(Tl) scintillator combined photomultiplier tube detector module and a CsI(Tl) scintillator combined silicon photomultiplier sensor detector module that displayed the highest efficiency in the test

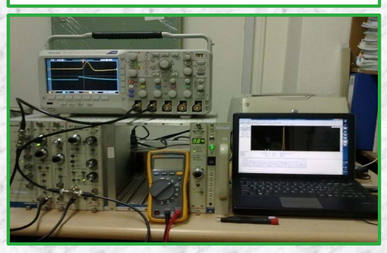






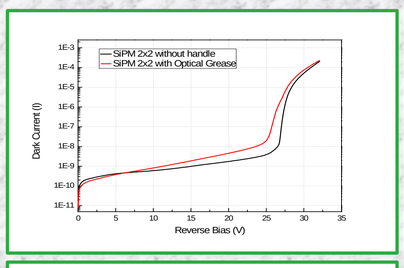
Results and Discussion

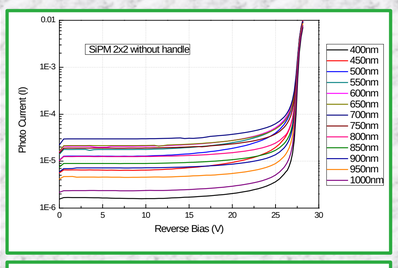


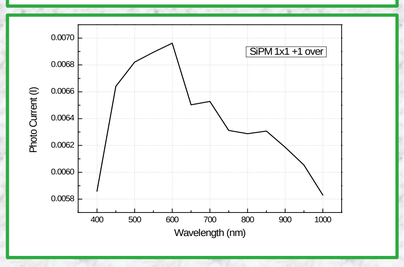


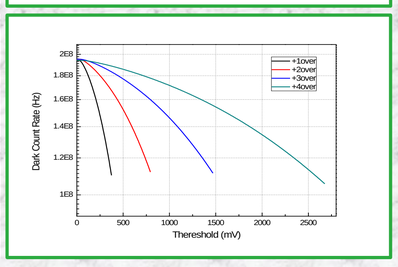
❖ Electrical Characteristics

- **Noise equivalence charge**
  Displayed high values of 10,000 or higher after driving voltage application and was matched to a large-area sensor of 100 pF or higher in internal electrostatic capacity.
- **Signal to noise ratio**
  Indicated an increase in noise level at 27 V or higher. However, it was an operable level considering that the equipment was driven at room temperature.
- **Dynamic Range**
  Display a significant drop in performance either, as it was measured to be between 68 and 72 dB.



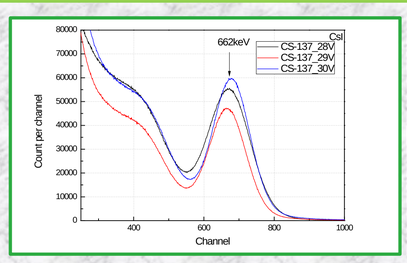


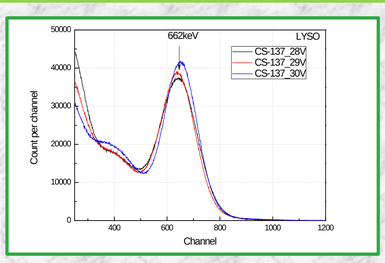


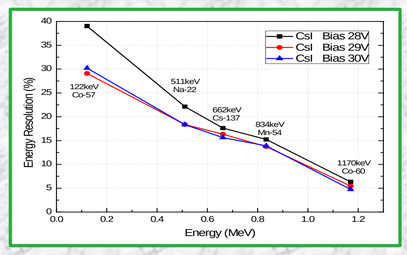


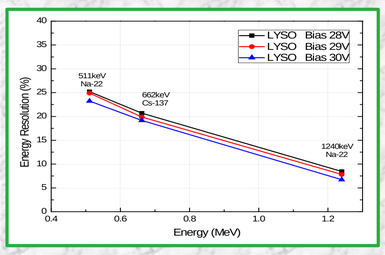
❖ Optical Characteristics

- **Dark current**
  displayed a typical current-voltage characteristic curve. Dark current increased due to the effect of optical adhesive.
- **Photon current**
  produced the maximum current output at the section of 550 - 600 nm.
- **Dark count rate**
  the high counting rate in dark was considered the biggest weakness of silicon photomultiplier sensor.









❖ Gamma-Ray Characteristics

- **Energy resolution**
  Using this silicon detector module, energy resolutions of gamma rays (^{60}Co, ^{137}Cs, ^{57}Co, ^{22}Na, ^{54}Mn) were measured. Resolutions according to CsI(Tl) and LYSO scintillator were ±3%.

❖ Energy Resolution

	Aluminum		Copper		Iron		Lead	
(%)	PMT	SiPM	PMT	SiPM	PMT	SiPM	PMT	SiPM
0mm	23.0	16.6	22.4	17.7	23.0	17.7	23.0	16.0
2mm	23.3	18.5	22.0	17.5	23.3	18.6	22.7	18.0
4mm	23.2	19.1	23.4	18.2	22.1	18.9	22.3	17.8
6mm	23.3	18.5	22.6	18.8	22.8	18.9	22.1	18.4
8mm	22.9	18.2	22.3	18.8	22.9	18.9	21.6	17.8
10mm	22.9	19.0	23.0	18.8	22.2	19.1	22.0	17.9

Conclusion

- Using this system, four types of ^{26}Al, ^{29}Cu, ^{55}Fe and ^{82}Pb metal plate thickness were measured.
- Applicability of silicon photomultiplier sensor based detector in industrial fields was examined.
- Thickness gauge using silicon photomultiplier sensor module, as a whole, displayed mean deviation lower by 5% than thickness gauge using general photomultiplier module.
- The coefficient of determination for both detector modules was 0.97 - 1.00 indicating a high level of correlation.
- Mean deviation was within 0.67 - 5.55%.
- As a result of comparing performance of both detectors tested under the same conditions, it was found that the silicon photomultiplier detector was more sensitive than general photomultiplier tube detector.

Acknowledgement

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