Improved micro-pixel detector element for neutron measurement under high pressure

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Introduction

Some neutron scattering experiments performed at high-intensity pulsed neutron facilities require advanced two-dimensional neutron detectors that have features. To this end, we are currently developing a two-dimensional position-sensitive neutron detection system consisting of a two-dimensional detector element and capable of individual signal line readout.

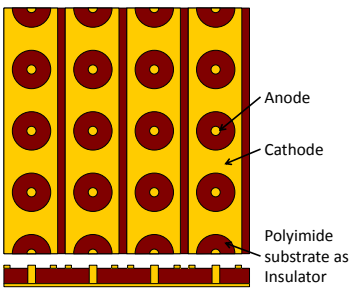
Superior spatial resolution and detection efficiency in a two-dimensional gas-based neutron detector can be typically obtained by increasing the gas pressure; however, this action decreases the output signal strength. To measure output signals under higher gas pressures, the supply voltage must be increased to boost the gas gain of the detector element. Therefore, we are developing a two-dimensional detector element to ensure that the detector system can be operated safely even under high voltages. In the present study, we have developed a micro-pixel detector element with a high-voltage resistance and then performed neutron irradiation experiments using this detector element.

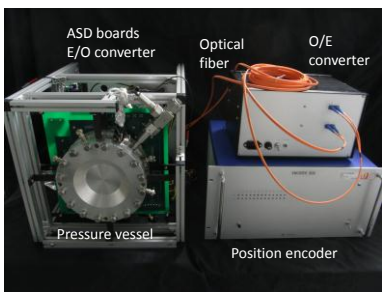
Experiments

MPGC detector element
Detection area: 51.2 × 51.2 mm²
Pitch of each axis: 0.4 mm

Fabricated by printing circuit board technologies. Additional etching is performed to improve the insulation between electrodes

Diameters of
anode pin: 60 μm
cathode hole: 255 μm





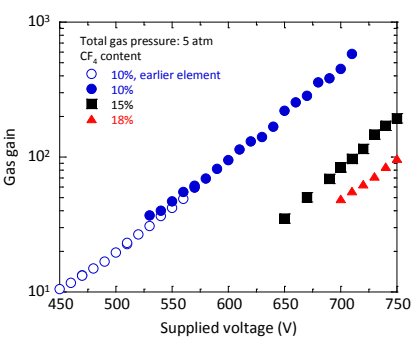
High pressure vessel
Inner size: 154 mmϕ x 30 mm^t
Pressure: < 11 atm
Helium leakage: < 10^{-7} Pa·m³/s
Conversion gap: 2 cm

Fill gas
He + CF_4

Neutron irradiation
Source: Cf-252
Intensity: 100MBq
Neutron flux: 10^7 n/m²·s

Our detection system comprises a detector head, a gas chamber, amplifier-shaper-discriminator boards, optical signal transmission device, position encoders with field programmable gate arrays, and a fast data acquisition device.

Gas gain



Voltage tolerance is improved and that the element works well at higher gas conditions.

5 atm 10% CF_4
voltage resistance (gas gain)
560V (50) → 670V (280)

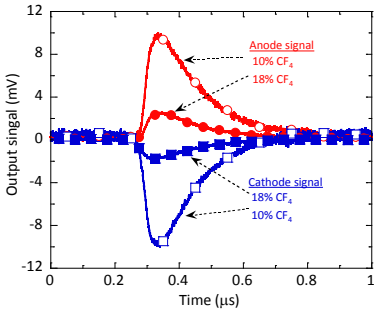
Developed element could work at 5 atm 15% CF_4 and 5 atm 18% CF_4 at a voltage of 750 V.

Gas conditions

	Gas pressure (atm)		Calculated detection efficiency (%)
	Total	CF_4	
5atm10%	5	0.5	72.4
5atm15%	5	0.75	70.4
5atm18%	5	0.9	69.0

Performances of the system

Output pulse shape

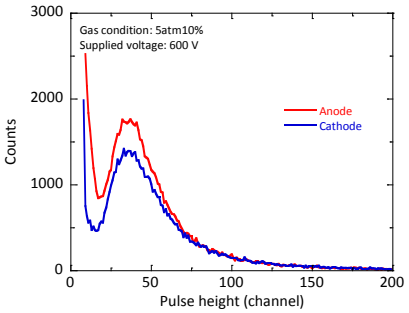


Response time
160 ns FWHM

A difference in signal duration was not observed by varying the gas condition and supplied voltage.

This signal was observed to be sufficiently fast to achieve a response time of less than 1 μs.

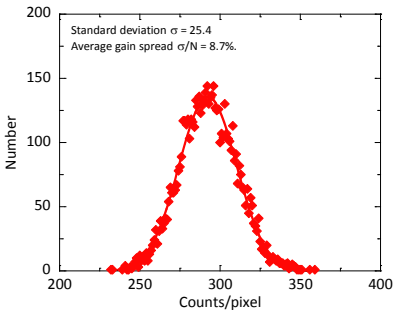
Pulse height distribution



A signal-pulse peak of neutrons can be clearly observed.

A majority of the spurious events generated in the lower channels as a result of electronic noise and gamma events can be easily suppressed using a discriminator.

Uniformity of 2D image



Average gain spread
8.7%

The image showed good homogeneity.

The average pixel count was 290 with a standard deviation of σ = 25.4

Conclusions

An improved micro-pixel detector element was developed and an irradiation test was performed using neutrons. The voltage resistance of the developed element was improved, and the element was capable of operating at voltages of up to 750 V at a gas pressure of 5 atm; when 15% and 18% CF4 gases were used, the measured gas gain was found to be approximately 200 and 100, respectively. The neutron detection system using the detector element was capable of individual signal line readout and exhibited a short pulse duration of 160 ns FWHM.