Preliminary Radiation Hardness Test of a Fabricated Charge Sensitive Amplifier for Feasibility of High Radiation Field Application

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1. Introduction

In radiation detectors, signals are essentially charges produced by radiation, thus it is naturally the best way to use a charge sensitive amplifier (CSA) system to extract those signals [1]. In most cases, A CSA is closely connected to a radiation sensor due to low current signals from sensors (usually below fA) and noise pickup from connection lines between a sensor and a CSA [2]. Thus, both a radiation detector and a CSA may be exposed to radiation damage in high radiation field. A hybrid-type CSA for a semiconductor radiation detector was fabricated to test feasibility to radiation damage. A CSA was evaluated in terms of an equivalent noise charges (ENC) and an energy resolution. In this study, ENCs are compared before and after irradiation by high gamma-ray and neutron fields as preliminary test.

2. Methods and Results

2.1 ENCs of a CSA

Noises of radiation detector system can be categorized by detector's noise and electronics' noise. Electronics' noise can be expressed by the ENC and as follows:

$$\sqrt{\mathrm{ENC}}^2 = \sqrt{\mathrm{ENC_s}}^2 + \sqrt{\mathrm{ENC_p}}^2 + \sqrt{\mathrm{ENC_{1/f}}}^2 \quad (1)$$

$$q_n^2 = (2eI_d + 4kT/R_b + i_{na}^2)F_i T_S + (4kTR_s + e_{na}^2)F_v C^2/T_S + F_{vf}A_f C^2 \quad (2)$$

Since radiation detectors typically convert the deposited energy into charge, the system's noise level is also expressed as equivalent noise charge Q_n, which is equal to the detector signal that yields a signal-to-noise ratio of one. ENC_s means the series noise, ENC_P the parallel noise, and $ENC_{1/f}$ the 1/f noise. C is the sum of all capacitances shunting the input, F_i, F_v, and F_{vf} depend on the shape of the pulse determined by the shaper and T_S is a characteristic time. More specific explanation can be found in reference 3.

A fabricated CSA was shown in figure 1. The CSA consists of a JFET and other filter components. An equivalent circuit of a fabricated CSA can be found in reference 3. An Ortec® 448 research pulser, a 572 shaping amplifier, and a Spectrum Master MCA were used throughout the experiments. 2 mV, 4 mV of pulses were fed through a 1pF capacitor. Standard deviation of an original pulse from a pulser was 0.214 mV at 4 mV.

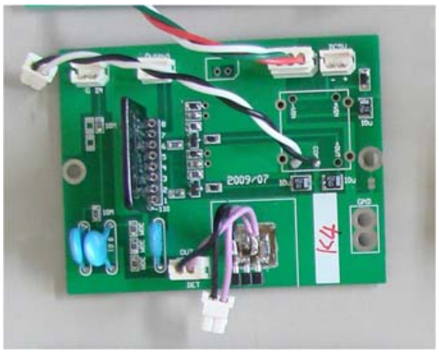

Fig. 1. The fabricated charge sensitive amplifier and the evaluation board for semiconductor radiation detector.

ENCs were measured with respect to calibration capacitors instead of detectors before irradiation. ENCs were also measured with respect to shaping times of a shaping amplifier. Energy spectra in case of feeding pulses directly to a shaping amplifier at 3 μs shaping time is shown in figure 2. FWHM (full-width half maximum) were 1.43 and 3.64 channel at 2 mV and 4 mV, respectively. This values presented noises of a pulser and a shaping amplifier.

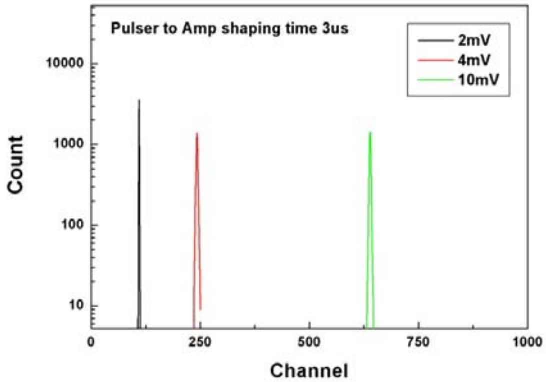

Fig. 2. Energy spectra in case of feeding pulses directly to a shaping amplifier at 3 μs shaping time. FWHM were 1.43 and 3.64 channels at 2 mV and 4 mV, respectively.

The measured ENCs of a fabricated CSA are shown in figure 3. These ENCs includes noises of a pulser and a shaping amplifier. As shown in figure 3, detector capacitance must be low from the results to achieve minimum electronics noise and to enhance energy resolution.

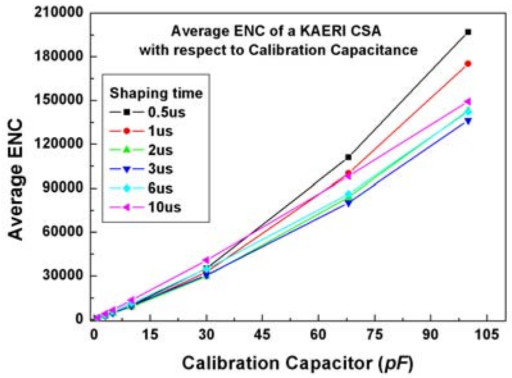

Fig. 3 The measured ENCs in case of a fabricated CSA with respect to calibration capacitances and shaping times.

2.2 ENCs of a CSA after irradiation

A fabricated CSA was firstly exposed by high dose gamma-ray. The total exposure dose was 3 X 10^2 Gy. And next, the CSA was exposed by thermal neutrons at ENF (Ex-core Neutron Facility) in KAERI. The total exposure dose was 1.6X 10^5 n/cm·s for approximately 2 hours.

After exposure to radiation, ENCs were measured with respect to calibration capacitors. The measured ENCs of a fabricated CSA after exposure are shown in figure 4. The comparison of ENCs are also shown in figure 5.

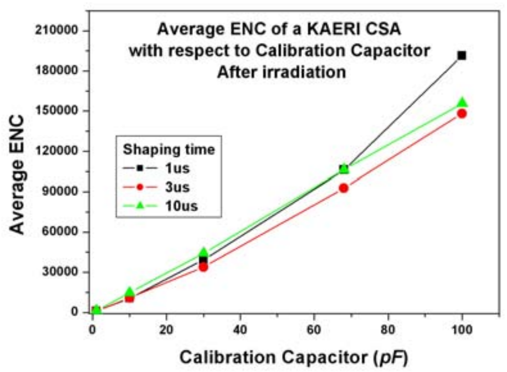

Fig. 4 The measured ENCs with respect to calibration capacitances and shaping times after exposure to radiation.

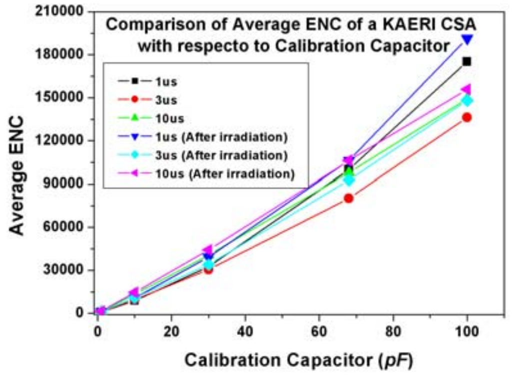

Fig. 5 Comparison of ENCs before and after exposure

After exposure to radiation, electronic noises of a fabricated CSA were increased. Approximately 15% worse ENC values are shown with respect to the calibration capacitance.

3. Conclusions

A hybrid-type CSA was fabricated with general electronic components. To measure life time of the CSA, this was exposed by high dose gamma-ray and neutron and compared with ENC value. In future work, the CSA will be exposed to high dose gamma-ray with time period to measure life time against exposure dose.

REFERENCES

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