§49. Development of Single-crystal CVD Diamond Radiation Detector for Neutron Burn History and Bang Time Monitor

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1. Introduction

To optimize fast ignition, obtaining information related to implosion instability, dynamics of imploded plasma, heating dynamics by high-energy electron, and neutron reaction dynamics are extremely important. However, no detector attained those capabilities because high-intensity X-rays accompanied fast electrons used for plasma heating[1]. To solve this problem, single-crystal CVD diamond was grown and fabricated into a radiation detector.

In this study, we aimed to obtain basic data i.e response function of X-rays, neutrons for burn history and bang time measurements. Last year, we succeeded to obtain fast response function less than 2ns[2], however, neutron signal was not obtained because of low S/N due to low neutron yield and electric noise. To improve S/N, saturation drift velocity and charge collection efficiency improvement are required In H26, charge trapping reduction for electrons and noise reduction at GXII experiment were conducted.

2. CVD growth and detector fabrication

A CVD growth was done as following conditions; the methane concentration, gas pressure, substrate temperature, and microwave power were 0.12%, 110 Torr, 850 °C and 1000 W, respectively. The self-standing layer's size was 5 × 5 × 0.05 mm. Aluminum Schottky contact and titanium carbide/gold ohmic contact were fabricated on each sides of the crystal by evaporation. The contacts were connected to a SMA receptacle using silver paste. I-V measurements and alpha-particle-induced charge distribution measurements were conducted. We used 5.486 MeV alpha particles from an ^{241}Am radioactive source. A silicon surface barrier detector was used as the standard for charge collection efficiency. Epsilon values of silicon and CVD diamond, i.e. 3.67 eV and 13.1 eV, were used for charge collection efficiency calculations.

Alpha-particle induced measurements of CVD diamond grown at 0.12% of methane concentration was shown in figure 1. The charge collection efficiency of 100.0 % and 100.4 % and energy resolution of 0.97 % and 0.38 % for electrons and holes were obtained. Enlarge view of peak shape was shown in inset. Compare to holes, 0.4% of charge trapping still remained for electrons. This trapping center was suspected to be due to ion implantation which is a part of lift off methods process. To reduce theses defects, we will plan to conduct annealing for the ion implanted substrate and self-standing plates.

3.Experimental at GXII

In fast ignition, intense electric noise accompanied with laser irradiation was extremely severe problem. We succeeded to reduce electric noise approximate σ p-p = 20mV, last year. This noise was suspicious to be caused by trigger signal from trigger box which was not shielded enough. Therefore, we conducted response function measurements with completely electrical floated system by using intense X-ray signal as trigger signal. Figure 2 shows response function of X-rays. Measurements were conducted using oscilloscope with 600MHz analog bandwidth. Noise level reduced to several mV which was equivalent to quantizing error of oscilloscope. We will fabricate shield box with time fiducial system using Si-Pin photo diode next year. Using this time fiducial system we will try to obtain fiducial trigger signal under complete electric floating.

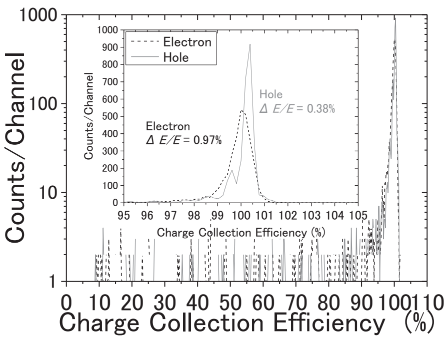

Fig. 1. Alpha particle induced charge measurements of single crystal CVD diamond radiation detector. The charge collection efficiency of 100.0 % and 100.4 % and energy resolution of 0.97 % and 0.38 % for electrons and holes were obtained.

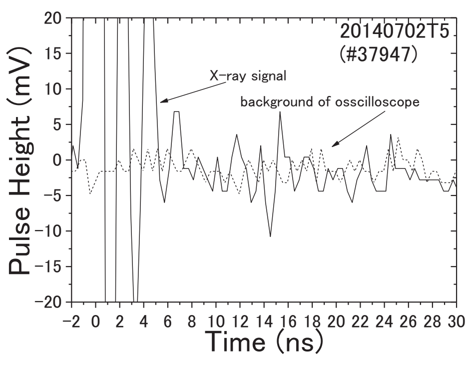

Fig. 2. response function of diamond radiation detector for X-rays. Signal noise reduced to several mV, which is comparable to quantizing error of oscilloscope.

1) Arikawa, Y.: Review of Scientific Instruments 83, (2012) 10D909
2) Shimaoka,T: Review of Scientific Instruments 86, (2015) 053503