III. 2. Proton Irradiation to Commercial Back-Thinned TDI-CCD for ASNARO Project

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Introduction

It is the time when quick space utilization is expected worldwide now. Under the background, USEF initiated ASNARO Project to realize small size and high performance earth observation satellite whose cost and manufacturing time will be drastically less than the current conventional satellite development methodologies. The expected performance of the mission is better than 0.5 m of GSD from 504 km altitude which is the same level as the high performance spacecraft in the world. The total mass of the spacecraft is 450 kg. The development of the spacecraft will be completed by the end of JFY2010, and expected to be launched in the year of 2012.

In order to use commercial parts for space , it is necessary to confirm the tolerance of radioation to meet with in orbit to use . We have completed the proton irradiated test for commercial Back-Thinned TDI-CCD which will be used for ASNARO spacecraft at Cyclotron and Radioisotope Center, Tohoku University.

Explanations of ASNARO spacecraft performance and USEF are shown at the end.

General

The major radiation damage for space use CCD and Optocouplers is generally displacement damage by proton (non-ionizing effect), rather than total ionizing dose (ionizing effect). Therefore, we irradiated proton to commercial Back-Thinned TDI-CCD (Time Delay integration-CCD: which is made in Japan, and manufactured by the same process as ASNARO project's CCD) in order to evaluate the shift and degradation of dark output level and signal output level after irradiation and annealing(after irradiation).

Ater the evaluation, we confirmed that same process's CCD is possible to use for ASNARO Project in the proton space environment.

Evaluation Sample and Test Method & Condition

Evaluation sample

The evaluation sample is commercial Back-Thinned TDI-CCD which is made in Japan.

Test Facility

We used 3rd target room of Cyclotron and Radioisotope Center, Tohoku University.

Test Method

The test configuration is shown in Fig. 1. The drive board is shown in Fig. 2, which drives CCD and measures function, electrical & electro-optical characteristics of CCD before & after irradiation or annealing(after irradiation) . We shielded the devices placed around CCD on the drive board from irradiated proton by the shield block, which is lead plate and aluminum block(50 mm thickness). The shield block is shown in Fig. 3. For the functional check of the CCD during proton irradiation, we monitored CCD's output pictures (dark output level). CCD S/N 6 was biased during proton irradiation, the others were not biased.

Test Condition

(1) Irradiated proton condition

The test conditions and sample assignment are shown in Table 1. The applied maximum irradiated proton fluence (3E+10 p/cm^2: Step-4 @70 MeV) is equivalent to two times of ASNARO project's proton space environment (Integral Fluence at 10 MeV). During ASNARO project's application, CCD is used with no bias condition for most of the time, so we selected "not-applied bias" as primary condition .

(2) Annealing (after irradiation) condition

In order to evaluate the drift and degradation of electrical & electro-optical characteristics of CCD by annealing (after irradiation), we performed annealing (room temp, non-bias) during 60 days, and measured electrical & electro-optical characteristics at suitable phase of intermediate periods.

(3) Measured function, electrical & electro-optical characteristics

We measured dark output level and signal output level (including function, used light source colors were blue, red, green and white) at each irradiated step of Table 1 and suitable intermediate phase of anneal periods, using light sources.

Test Results and Consideration

Test Results

The trend of dark output level and signal output level by irradiation and annealing are shown in Figs. 4~6. Those trends are increased in almost proportion to fluence at irradiation phase. At annealing phase, those trends are not indicated complete saturation in 60 days annealing, and a little increases are observed.

Consideration

The test results were approximately within a supposition , except the dependence on proton energy. In our supposition, shift & degradation of electrical & electro-optical characteristics were larger by 30 MeV-proton than 70 MeV-proton, because NIEL (Non-Ionizing Energy Loss)was larger at 30 MeV-proton than 70 MeV-proton, therefore displacement damage was larger by 30MeV-proton than 70 MeV-proton. However test results showed smaller shift & degradation by 30 MeV-proton than 70 MeV-proton. If it is possible, we will evaluate the dependence on proton energy again by more samples.

Explanations of ASNARO Spacecraft Performance and USEF

ASNARO Spacecraft Performance

ASNARO spacecraft performance and characteristics is shown in Table 2, and on-orbit configuration is shown in Fig 8.

USEF

USEF（Institute for Unmanned Space Experiment Free Flyer）was established on May 16, 1986 by 13 major aerospace companies under the supervision of former MITI (now METI: Ministry of Economy, Trade and Industry) to promote industrialization , commercialization and utilization of the space, and has been developing and operated spacecraft system with missions those are related to the articles of the USEF.

Acknowledgments

ASNARO Project has been implemented by USEF and NEC under the entrustment of the NEDO (New Energy and Industrial Technology Development Organization), and under the direction of the METI (Ministry of Economy, Trade and Industry). The project is supervised by the engineering committee consisted of expert members from various organizations such as ISAS, universities and government institutions. The appreciation for the fruitful support from all members mentioned above are expressed here as the acknowledgement.

Table 1. Proton Irradiated Condition.

S/No. (CCD)	Bias (During Irradiation)	Proton Energy	Accumulated Fluence (p/cm2)	
S/No.1	Not Applied	70MeV	Step-1	1E+9
			Step-2	3E+9
			Step-3	1E+10
			Step-4	3E+10
S/No.2	Not Applied	70MeV	Step-1	1E+9
			Step-2	3E+9
			Step-3	1E+10
			Step-4	3E+10
S/No.6	Applied	70MeV	Step-1	1E+9
			Step-2	3E+9
			Step-3	1E+10
			Step-4	3E+10
S/No.5	Not Applied	30MeV	Step-1	Not Performed
			Step-2	
			Step-3	1E+10
			Step-4	3E+10

Flux rage: 1E+7～ 5E+7 p/cm2･sec

Table 2. ASNARO spacecraft performance and characteristics.

Mission - Optical Sensor - Data Transmission	Pan/Multi GSD: < 0.5m/2m (Pan/Multi, from504km) Swath: 10km X Band 16QAM, App. 800Mbps
Launch Orbit	JFY2012 (Expected) ISAS/JAXA New Solid (Assumed) (Compatible with H-IIA, Dnepr, etc.) Sun Synchronous Polar Orbit(504km) Inclination:97.4 deg. LST. of Descending Node: AM 11:00
Ground Tracking Network	S Band: TBD X Band Data: new station
Design Life Expected Operation	3 Years 3 Years
Spacecraft Mass Size	Bus 250kg Mission 150 kg Propellant 50kg <Total> App. 450 kg App. 2.5m X 3.5m X 3.2m (On orbit)
Electrical Power	SAP Power: App. 1300 W (EOL) (For Mission: 400 W)

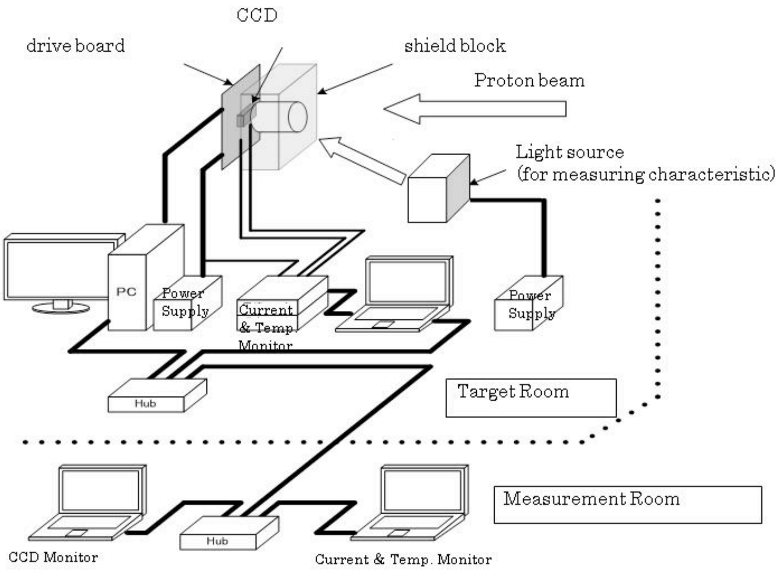

Figure 1.　Test configuration.

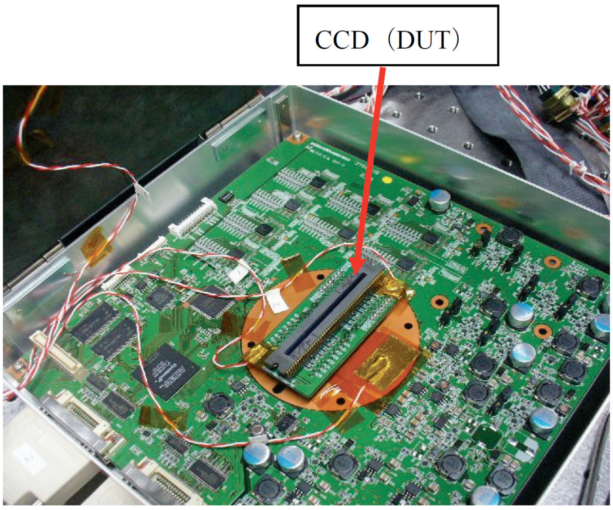

Figure 2.　Drive Board

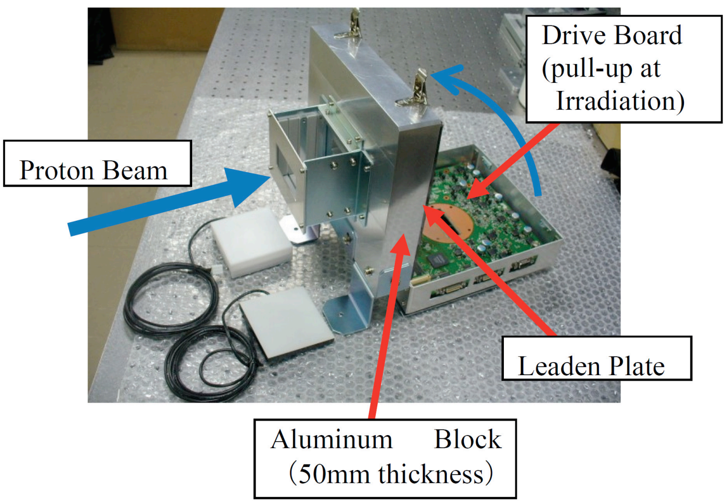

Figure 3.　Shield Block

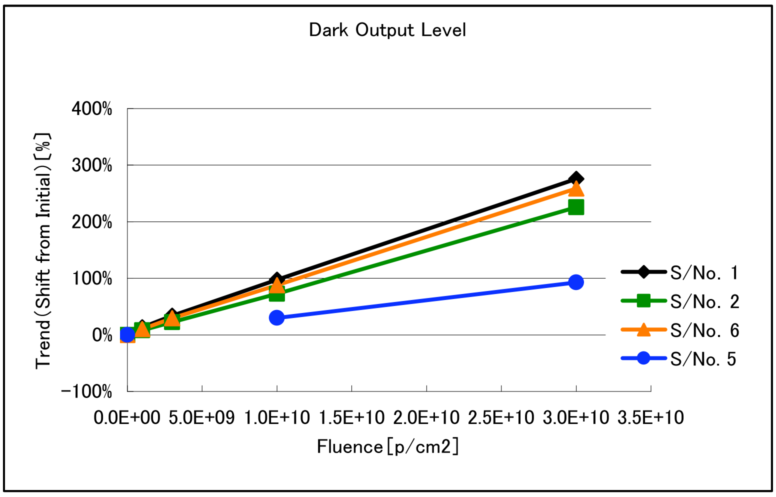

Figure 4. Dark Output Level (Irradiation Phase).

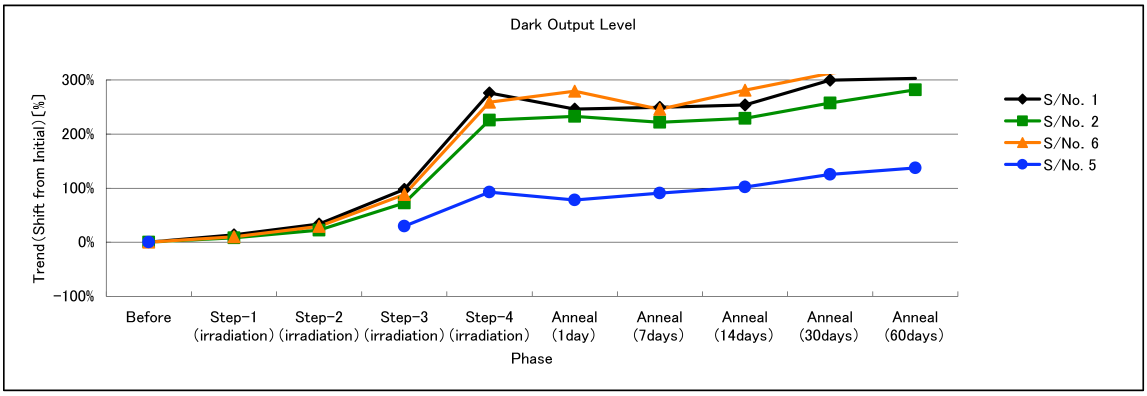

Figure 5. Dark Output Level (Irradiation ~ Annealing Phase).

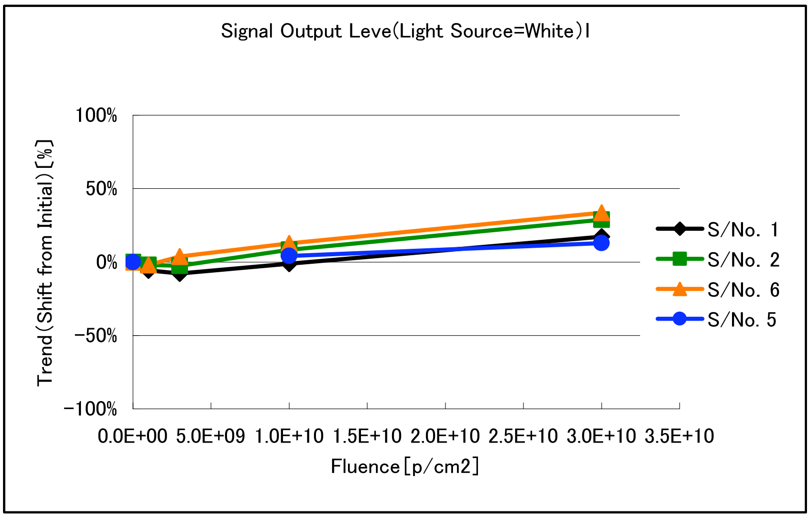

Figure 6. Signal Output Level (Irradiation Phase).

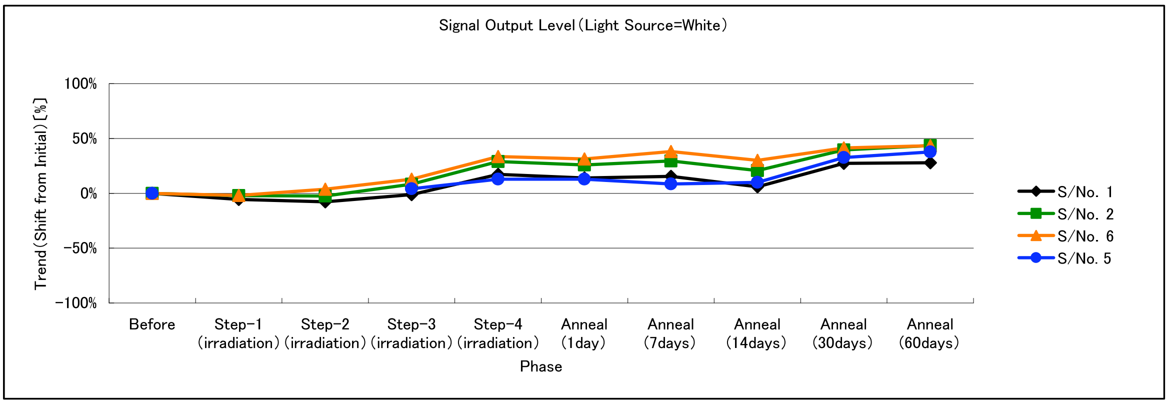

Figure 7. Signal Output Level (Irradiation ~ Annealing Phase).

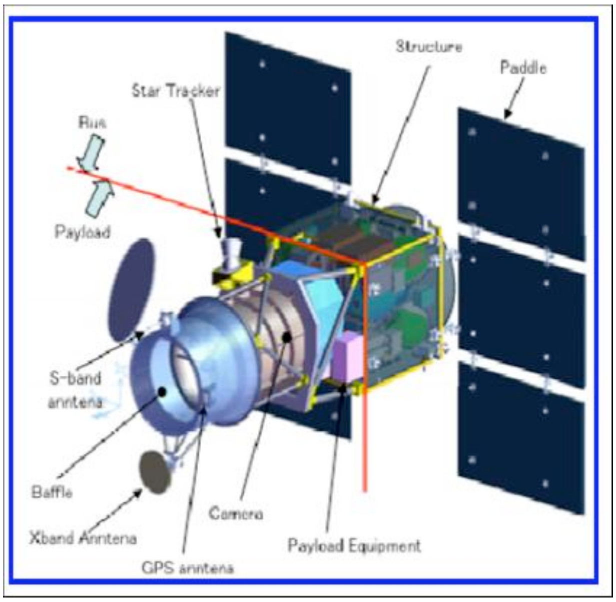

Figure 8. On-orbit configuration.