On-Line High Dose-Rate Gamma Ray Irradiation Test of the CCD/CMOS Cameras

Jai Wan Cho and Kyung Min Jeong
Korea Atomic Energy Research Institute, (150-1 Dukjin-Dong), 1045 Daedeokdaero, Yuseong, Daejeon, Korea
Email: jwcho@kaeri.re.kr

1. Introduction

In this paper, test results of gamma ray irradiation to CCD/CMOS cameras are described. From the CAMS (containment atmospheric monitoring system) data of Fukushima Dai-ichi nuclear power plant station, we found out that the gamma ray dose-rate when the hydrogen explosion occurred in nuclear reactors 1~3 is about 160 Gy/h[1]. If assumed that the emergency response robot for the management of severe accident of the nuclear power plant has been sent into the reactor area to grasp the inside situation of reactor building and to take precautionary measures against releasing radioactive materials, the CCD/CMOS cameras, which are loaded with the robot, serve as eye of the emergency response robot. In the case of the Japanese Quince robot system, which was sent to carry out investigating the unit 2 reactor building refueling floor situation, 7 CCD/CMOS cameras are used. 2 CCD cameras of Quince robot are used for the forward and backward monitoring of the surroundings during navigation. And 2 CCD (or CMOS) cameras are used for monitoring the status of front-end & back-end motion mechanics such as flippers and crawlers. A CCD camera with wide field of view optics is used for monitoring the status of the communication (VDSL) cable reel. And another 2 CCD cameras are assigned for reading the indication value of the radiation dosimeter and the instrument. In the preceding assumptions, a major problem which arises when dealing with CCD/CMOS cameras in the severe accident situations of the nuclear power plant is the presence of high dose-rate gamma irradiation fields. In the case of the DBA (design basis accident) situations of the nuclear power plant, in order to use a CCD/CMOS camera as an ad-hoc monitoring unit in the vicinity of high radioactivity structures and components of the nuclear reactor area, a robust survivability of this camera in such intense gamma-radiation fields therefore should be verified. The CCD/CMOS cameras of various types were gamma irradiated at a dose rate of about 150 Gy/h till these cameras failed. A high dose-rate gamma ray radiation induced speckles in the camera image were heavily observed. In this paper we describe the evolution of their basic characteristics with high dose-rate gamma irradiation and shortly explain the observed phenomena.

2. Experiments

A block diagram of a typical gamma irradiation set ups for the CCD/CMOS cameras are shown in Fig. 1 and Fig. 2.

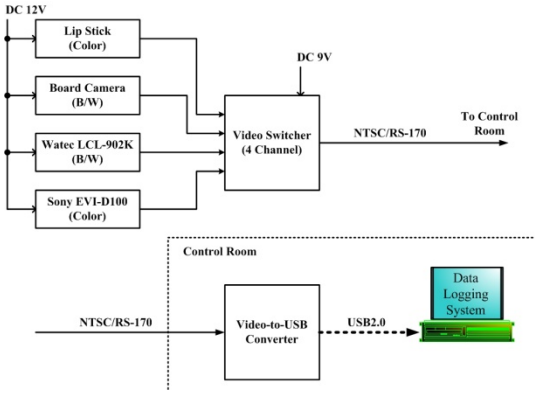

Fig. 1. A schematic diagram of the gamma irradiation test

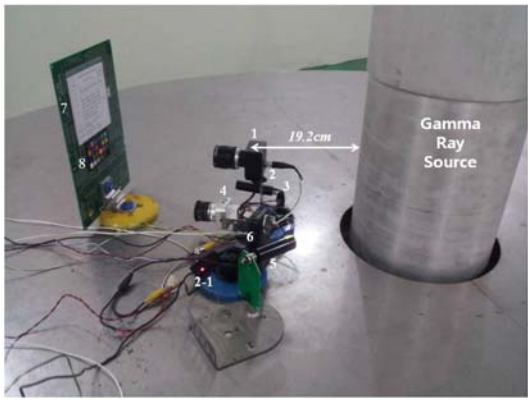

Fig. 2. Various typed CCD/CMOS cameras placed in the gamma irradiation facility (150 Gy/h dose rate).

Table 1. CCD/CMOS cameras used for gamma irradiation

No	Camera	Type	Note
1	CCD, B/W	Board	
2	CCD, Color	Pin Hole	Sensor Head and Signal Processing Unit are separated each other.
3	CCD, Color	Lip Stick	20mm diameter.
4	CCD, B/W	Board	
5	CCD, Color	Lip Stick	Off-Line / Power Off
6	CMOS, Color	Black Box for Car	Images are stored in SD Memory Device
7	Resolution Target	Character	VT-1 & VT-2 Class
8	Resolution Target	Color	Munsell 24 Color Checker Board

As shown in Table 1, the low cost and general purpose CCD/CMOS cameras are selected for the gamma irradiation test, based on the assumptions that expensive high

performance cameras will not be needed when simply monitoring the status of flipper, crawlers and communication wire reel as Quince robot. In order to evaluate on-line performance of various cameras simultaneously as shown in Fig. 2, 4 channel video switching module is used. The switching time among the video channels is setup to 10 seconds. As shown in Fig. 1, high performance CCD camera (EVI-D100, pan/tilt/zoom integrated module), used as the monitoring unit of RaBOT (nuclear emergency robot system developed after JCO criticality accident at 1999 year[2]) was on-line gamma ray irradiation tested on another time. The gamma ray dose rate is 150 Gy/h same as Fig. 2.

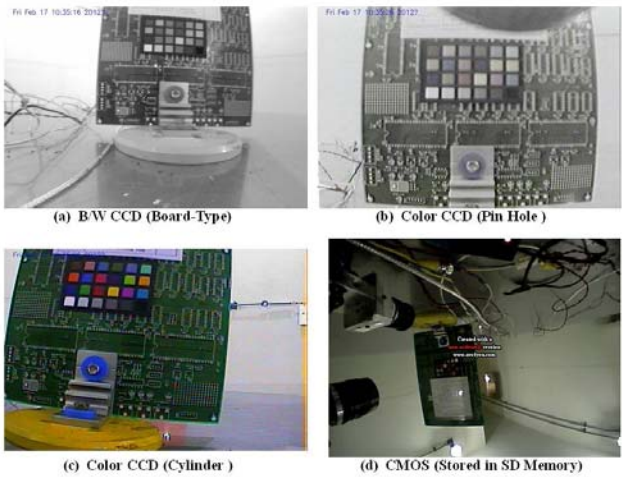

Fig. 3. Images of CCD/CMOS cameras before gamma ray irradiation

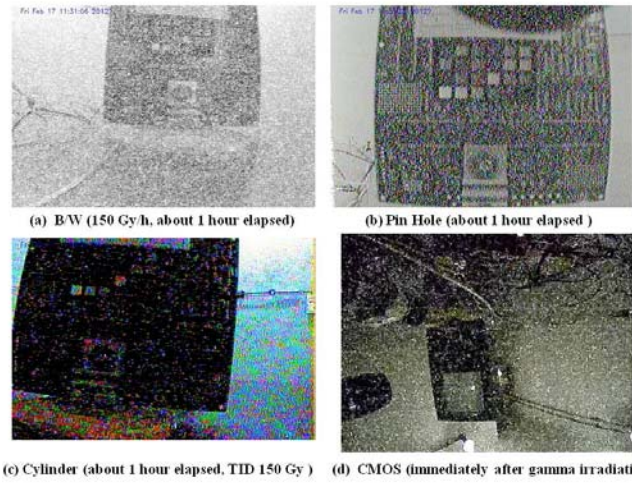

Fig. 4. Images of CCD/CMOS cameras during gamma ray irradiation (150 Gy/h doserate)

Fig. 4 shows gamma ray irradiation results of the CCD/CMOS cameras. The low-cost color CCD/CMOS cameras lose the color rendering function under high dose gamma ray irradiation (150 Gy/h, similar dose rate at the time of hydrogen explosion of Fukushima Dai-ichi nuclear power plant) as shown in Fig. 4. Fig. 5 shows gamma ray irradiation results of the high performance CCD camera (Sony EVI-D100, pan/tilt/zoom integrated module) under the same dose rate as the low-cost CCD/CMOS cameras. From the above experimental results, heavily generated speckles due to the high dose-rate gamma ray irradiation disturb detailed observation of the VT-1 & VT-2 resolution target. And the low-cost CCD/CMOS cameras are not appropriate to monitor the status of motion mechanics of the nuclear emergency robot under the high dose rate gamma ray (nuclear accident level) environments.

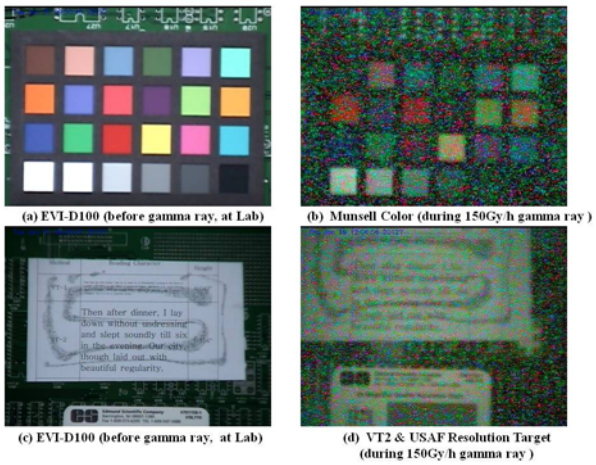

Fig. 5. Images of high performance CCD camera before and during gamma ray irradiation (150 Gy/h dose rate)

The gamma ray irradiation test results of the CCD/CMOS cameras are summarized in Table 2.

Table 2. Gamma ray irradiation test results of CCD/CMOS cameras

Camera Type	Purchase Year	Note (Dose Rate : 150Gy/h)
B/W CCD x 2 (Board)	2004	Survived after 225 Gy TID.
Color CCD (Pin Hole)	2012	Survived after 225 Gy TID.
Color CCD x 2 (Lip Stick)	2006	Failed all after 150 Gy TID
Color CMOS (Car Black Box)	2009	Survived after 225 Gy TID, Lost color rendering function partially
SD Memory for Car Black Box	2009	Read stored image after 225 Gy TID
EVI-D100 Pan/Tilt/Zoom Integrated	2002	Failed after 150 Gy TID

3. Conclusions

We have conducted high dose-rate (150 Gy/h) gamma ray irradiation experiments on CCD/CMOS cameras, estimated to being used as the eye of the nuclear emergency response robot. The heavily generated speckles due to the high dose-rate gamma ray irradiation are estimated to disturb the eyesight of the robot. From the above experimental results, radiation-hardened design or radiation-tolerant design using shielding technique should be applied to CCD/CMOS cameras for carrying out the eyesight function of the nuclear emergency robot, assumed that this robot system is sent into the nuclear reactor area for the management of severe accident of the nuclear power plant.

[1] http://www.tepco.co.jp/nu/fukushima-np/
[2] http://roboticstaskforce.wordpress.com /