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Retrspective accident dosimetry using trapped charges

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1. Introduction

Apprehensions about radiological accidents have been escalated more than ever before as nuclear facilities including power plants and industrial applications of radiation. Especially, the Fukushima accident has raised the apprehensions dramatically. In addition, after 9.11 terroristic attack worries about radiation terrorism have been considerably increased. In such radiological emergency cases, one of the most urgent actions is to start a procedure for rapid triage of the individuals or groups who need medical treatments due to exposure of radiation. In case large numbers of casualties are involved, it is more important because available medical facilities and staffs responsible for treatment for radiation injury are generally limited. It is often come to the fore that the main problem is the panic at the accident place in public rather than the actual health hazard caused to radiation exposure. Therefore, rapid and reliable dose measurements activity is essential to reassure those receiving insignificant level of exposures which need no immediate action.

Retrospective accident dosimetry refers to measurements of doses from exposures to radiation incurred during unforeseen events. Most popular retrospective dosimetry technique is biological dosimetry[1]. Dicentric chromosome aberrations technique scoring of aberrations in metaphases prepared from human lymphocytes is most commonly used. This is considered as a reliable technique because the sample is extracted from the individual human body itself. There are other techniques in biological dosimetry such as Fluorescence In Situ Hybridization (FISH) using translocations, premature chromosome condensation (PCC) and micronucleus assay. However the minimum detectable doses (MDD) are relatively high and sample preparation time is also relatively longer. Therefore, there is limitation in use of these techniques for the purpose of triage in a short time in case of emergency situation relating large number of persons. Electronic paramagnetic resonance (EPR) technique is based on the signal from unpaired electrons such as free radicals in irradiated materials especially tooth enamel, however it has also limitation for the purpose of triage because of difficulty of sample taking and its high MDD. Recently as physical methods, thermoluminescence (TL) and optically stimulated luminescence (OSL) technique have been attracted due to its lower MDD and simplicity of sample preparation. TL is a phenomenon of light emitting from a pre-irradiated material when it is heated. OSL is analogous to TL process just except that the stimulation is carried out optically. TL and OSL are originated from trapped charges which have been trapped in localized energy levels in a material during the exposure to ionizing radiation. Density of the trapped charges is generally proportional to the radiation dose absorbed and the intensity of emitting light is also proportional to the density of trapped charges, thus it can be applied to measure radiation dose retrospectively.

In this presentation, TL and OSL techniques are going to introduced and discussed as physical methods for retrospective accident dosimetry using trapped charges especially in electronic component materials.

2. Materials and Methods

TL and OSL from natural minerals (quartz and feldspar) extracted from the materials such as bricks, roof tiles and porcelain collected from in the accident area have been used for dose reconstruction in locations where radiation monitoring measurements were not carried out. Although OSL technique has several advantages over traditional TL technique, it was suggested later than TL technique because more complex equipment is needed for OSL measurements. A suitable light source for stimulation, and light filter package to discriminate the extremely deem emitting OSL light from the very strong stimulation light are essential to compose an OSL measurements system. In 1990s suitable light emitting diodes having enough light intensity were available and OSL technique was applied to dose reconstruction in the Chernobyl accident site.[2]

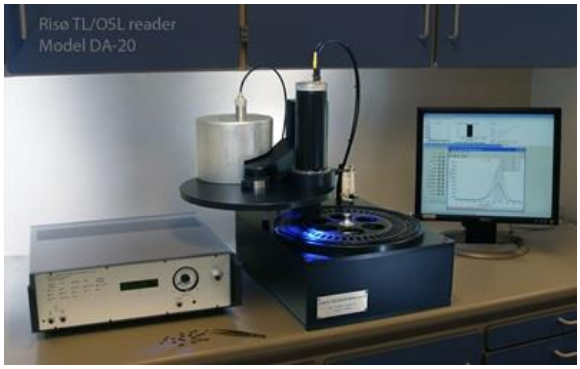

Fig. 1 An automated TL/OSL measurement system having reference irradiator (Risoe Model DA-20)

Recently, intensive researches have been carried out to find materials having appropriate radiation sensitivity that are carried close to human body. Most promising materials found are personal electronic devices such as mobile phone, USB flash memory chip. It has been

evaluated that OSL and TL properties of several electronic components of the devices which have become available for common use and can be found with almost each person most of the time. Mobile phones one of most attractive devices because the use of mobile phones has become so common that one may consider the availability of mobile phones with almost each person most of the time; as good as a part of the body of persons of all ages. The radiation sensitivity of the electronic components has been attributed to the ceramic content of the components mainly alumina and SiO_2. Fig. 2 show the electronic components in a mobile phone.

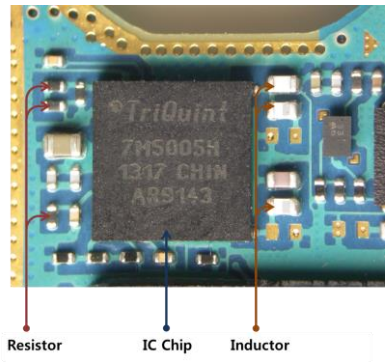

Fig. 2 Electronic components in a mobile phone

3. Dosimetric properties of electronic components

3.1 Dose response

In general, IC chips, inductors and resistors exhibited a fairly good linearity for doses up to about 9 Gy (Fig. 3). However, the sensitivity of ICs is much lower than resistors and inductors. It is because the origin of luminescence is the different from that of resistor and inductors and the lower contents ratio of luminescent material in IC sample.

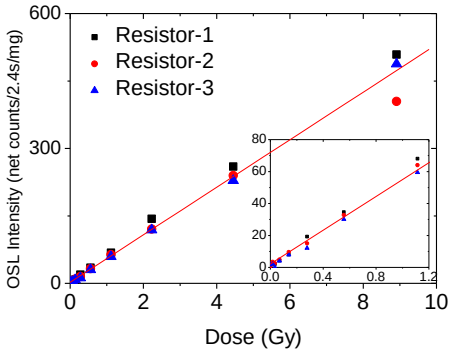

Fig. 3 Dose response curve of OSL from chip resistor

3.2 Fading

Fig.4 shows that OSL relative signal loss of the samples. One of the disadvantages of OSL technique is high fading of signal. Several methods are under way to overcome this disadvantage.

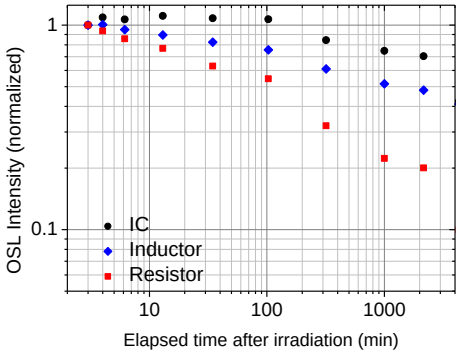

Fig. 4 Fading of OSL signals of IC, inductor and resistor

3.3 Sensitivity and minimum detectable dose

Table 1 shows the OSL sensitivity (OSL/mGy/g) and minimum detectable dose of the electronic components. It may be noted that the inductors exhibited OSL sensitivity about 5 times and 40 times higher than that of the resistors and the IC chips, respectively.

Table 1 Comparison of OSL sensitivity and minimum detectable dose (MDD) of IC chips, inductors and resistors of smart phones

Electronic component	Sensitivity (OSL/mGy/g)	MDD (mGy)
IC chip	8.9	13.7
Inductor	348.1	2.4
Resistor	65.8	6.6

4. Conclusions

As a tool for dose reconstruction for emergency situation, thermoluminescece and optically stimulated luminescence techniques which are based on trapped charges during exposure of material are introduced. These techniques have several advantages such as high sensitivity, fast evaluation and ease to sample collection over common biological dosimetry and EPR techniques. These advantages make trapped charge technique to apply to the purpose of rapid triage in large scale of radiological accident including terror case with radioactive materials. However, biological dosimetry and EPR mothods also have their own advantages; the sample is extracted from the individual human body itself, lower fading rate. Therefore, those techniques for retrospective dosimetry should be applied complementarily in a radiological accident.

REFERENCES

[1] Lloyd, D.C. et al. In Proceedings fo the EU Conference on the Radiological Consequences of the Chernobyl Accident (EUR. 16544EN), p. 965-974, 1996.
[2] Botter-Jensen, L., The Proceedings of the Nordic Society for Radiation Protection Seminar, p. 26-29, 1996.