PERFORMANCE OF A DIRECT ION STORAGE (DIS) DOSEMETER FOR INDIVIDUAL MONITORING

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INTRODUCTION

The development of the Direct Ion Storage dosemeter was triggered by the need to find an electronic successor for the aging Film- and TLD-dosemeters. As the basis of any passive dosemeter, there must always be a reliable means of storing information, such as the electron traps in TL materials. The new development was based on the same principle for information storage as is used in almost all microelectronic devices today; a nonvolatile FAMOS (Floating Gate Avalanche-injected MOS) memory cell. In electronics these devices are known as EPROMS, EEPROMS and Flash-Memories. In order for a memory cell to act as a dosemeter, it must be sufficiently sensitive to ionizing radiation to the extend that the small dose levels down to a few μGy encountered in radiation protection applications can be reliably detected.

In a nonvolatile solid-state memory cell the information is stored in the form of electronic charge being trapped on the floating gate of a MOSFET transistor. Original memory designs were only used to store digital information which meant that in each memory cell there was either a low amount or a high amount of charge stored to represent one of the two binary digits 0 or 1. In the recent years new types of nonvolatile memories have been developed and made commercially available to be used for storing analog information. This means that the amount of charge in each memory cell can be made fully variable and therefore, these memory cells can be used to store analog information directly. Analog-EEPROM memories are used today in speech recording applications for example in electronic telephone answering systems.

The radiation sensitivity of normal solid-state memory cells is inherently too low for use as detectors in radiation protection applications. The main reason for this is that these devices are specifically designed to be as insensitive as possible to ionizing radiation so that they could be used in space, military and nuclear industry applications without damage.

In an Analog-EEPROM memory cell, the charge on the floating gate can be set to a predetermined level by injecting electrons through the oxide layer. The charge is then permanently stored on the gate because in the normal operating temperature range the electrons have a very low probability to exceed the energy barriers in the metal-oxide and oxide-silicon interfaces. These types of memory cells are known to retain the stored charge for hundreds of years.

In order for ionizing radiation to have an effect on the stored charge, either new charge has to be brought to the gate or some existing charge removed. Ionizing radiation incident on the oxide layer does produce electron-ion pairs but due to the relatively poor mobility of charge carriers in the oxide, recombination occurrs and most of the free charge is neutralized before it has a chance to cross the metal-oxide interface. MOS dosemeters that are based on this principle are not sensitive enough for most radiation protection applications. The Direct Ion Storage (DIS) principle is based on allowing the surface of the floating gate to be in direct contact with the surrounding air. Ionizing radiation incident in the air space produces electron-ion pairs with extremely high mobility and if there is an electric field surrounding the floating gate, these charge carriers can very efficiently be transferred to the gate before recombination occurrs. The electric field around the gate is generated by injecting an initial charge on the gate. By surrounding the whole memory structure with a conductive wall, effectively an ion chamber is formed between the wall and the floating gate (Figure 1). For photon radiation, the interactions take place mainly in the wall and the secondary electrons ionize the air between the wall and the floating gate. For other charged particle radiation, if the wall is sufficiently thin, the charged particles are allowed to transfer their energy directly into the air space. The dosimetric characteristics can therefore be adjusted by altering the properties of the wall material and other fill-gases instead of air could also be used[1].

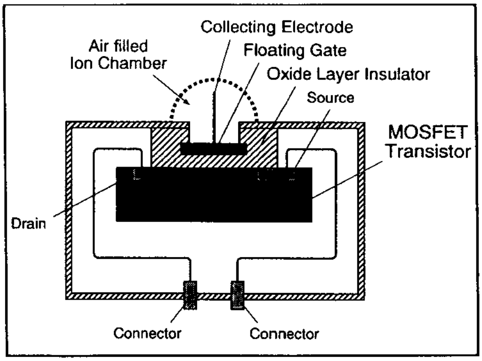

Figure 1. Schematic of a dosemeter based on DIS

Figure 2. The complete electronic Dosemeter

IONIZATION CHAMBER DESIGN

The operating voltage of an ionization chamber based on DIS is 25 to 30 Volt. To obtain an electric field strength in the order 10 kVm^{-1}, necessary for linearity up to high dose rates, the distance between electrodes has to be 2 to 3 mm. The extremely high sensitivity of the DIS methods allows for the use of chamber volumes of 1 cm^3 and less with a resulting detection limit well below 10 mSv. The size of a detector containing two sets of chambers, one to determine $H_p(10)$ and one to determine $H_p(0.07)$ is 35 mm x 50 mm x 7 mm. This detector may be used as a passive dosemeter or it can be combined with an on line readout device to build an electronic dosemeter[2] (Figure 2).

PRELIMINARY DATA ON DETECTOR CHARACTERISTICS

Photon energy dependence

The photon energy dependence of a prototype ionization chamber was tested on the ISO water slab phantom (30 cm x 30 cm x 15 cm, PMMA walls, water filling) using ISO narrow series (N) photon radiation qualities and the most recent conversion coefficients $h_{pK}(0.07)$ and $h_{pK}(10)$ proposed by ISO. The results show that after further optimization of the detector construction an excellent photon energy dependence down to 15 keV for $H_p(10)$ detectors and to at least 6-8 keV for $H_p(0.07)$ detectors can be expected (Figure 3).

Sensitivity to beta radiation

Tests to determine the sensitivity for beta radiation have been performed with ^{204}Tl irradiations of a NPL beta secondary standard ($E_{\beta_{max}}$ = 0.8 MeV). The response for $H_p(0.07)$ varied between 0.47 and 0.75 for different entrance window designs.

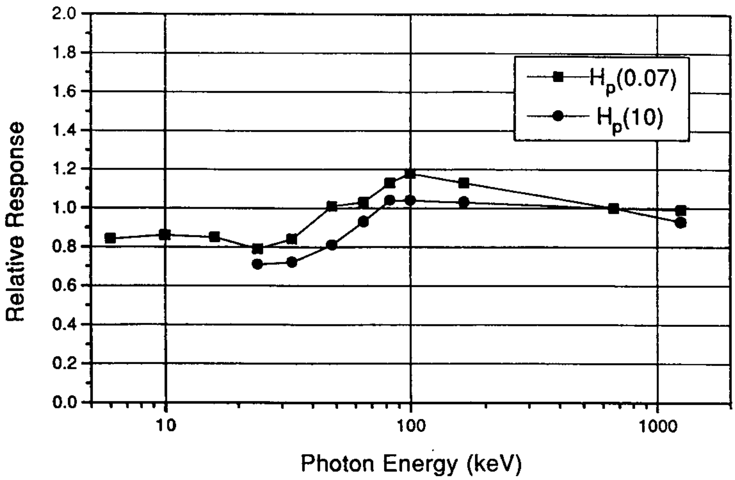

Figure 3. Photon energy dependence of a prototype DIS-dosemeter for $H_p(10)$ and $H_p(0.07)$.

Dose and dose rate range

Linearity of the dose rate has been tested up to 10 Sv/h with deviations of less than 10 %. The dose range can only be fully tested with a complete unit with a final design of the electronics. The intention is to reach a resolution for low dose values of 1 μSv and an upper range of 5 Sv.

CONCLUSIONS

The DIS based dosimetry system is quite simple but highly sensitive. It covers a wide range of photon and beta radiation energies and can be applied as a passive or an electronic device to measure $H_p(10)$ and $H_p(0.07)$. The system seems not to be sensitive to electromagnetic fields.

The tests were performed on prototype instruments, therefore, all test results obtained so far are preliminary. Further optimization of the detector design is possible. The system has a potential to fulfil the requirements of a legal electronic dosemeter. Applications in neutron and radon dosimetry as well as in other fields will be studied.

REFERENCES

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