ELECTRONIC NEUTRON SENSOR BASED ON COINCIDENCE DETECTION

B. Barelaud, J.L. Decossas, F. Mokhtari, J.C. Vareille

C2M, University of Limoges, 123, Av. Albert Thomas
87060 Limoges Cedex - France

INTRODUCTION

The last Symposium on neutron dosimetry which took place in Paris in November 1995 have shown again that it doesn't exist any individual active neutron dosemeter. The state of art on electronic device (1), the needs of the nuclear power industry in individual neutron monitoring (2, 3) and the new trends of researchs (4) were presented. They confirm the relevance of our studies in progress in the C2M team of the University of Limoges. The aim of this work is to realize an individual electronic neutron dosemeter.

The device in the progress of being development will operate either as a dosemeter or as ratemeter giving $H_p(10)$ and $\dot{H}_p(10)$ either as a spectrometer permitting to caracterize the primary neutron beam.

PRINCIPLE OF THE ACTIVE MONITOR

The reactions used are given : - for Boron 10 there are two mechanism

a - ${}^{10}_{5}B + {}^{1}_{0}n \rightarrow {}^{7}_{3}Li + {}^{4}_{2}\alpha$ with Q-value = 2.79 MeV (6%) (E_{li} = 1.01 MeV, E_α = 1.78 MeV)

b - ${}^{10}_{5}B + {}^{1}_{0}n \rightarrow {}^{7}_{3}Li^{*} + {}^{4}_{2}\alpha$ with Q-value = 2.31 MeV (94%) (E_{li} = 0.84 MeV, E_α = 1.47 MeV)

$\downarrow$

$Li + \gamma + 0.478$ MeV

- for Lithium 6

a - ${}^{6}_{3}Li + {}^{1}_{0}n \rightarrow {}^{3}_{1}H + {}^{4}_{2}\alpha$ with Q-value = 4.78 MeV (100%) (E_H = 2.73 MeV, E_α = 2.05 MeV)

The monitor has two parts : the sensor and the electronic for the signal processing. The sensor (fig.1) is composed of two facing diodes which enclose a reactive layer of ^{10}B or ^{6}Li. These elements have a high cross section to low energy neutron. Several parameters influence the response of the device :

1 - The area of the reactive layer is limited by the area of usual wafers available for microelectronic chips. The increasing of layer thickness leads to an absorption of particles from the nuclear reaction that occurs inside the layer, and in order to use the device as a spectrometer that last-mentioned must be thin as possible. However, it's not compatible with the need for high sensitivity necessary in dosimetry.

2 - The thickness of the dead layer of the detecting diodes must be minimised since it always acts as an energy absorber for the recoils.

3 - The thickness of the depleted layer must be adapted to the range of the most energetic particles crossing the various layers.

4 - The bulk of the wafer should not have any influence on the response of the sensor.

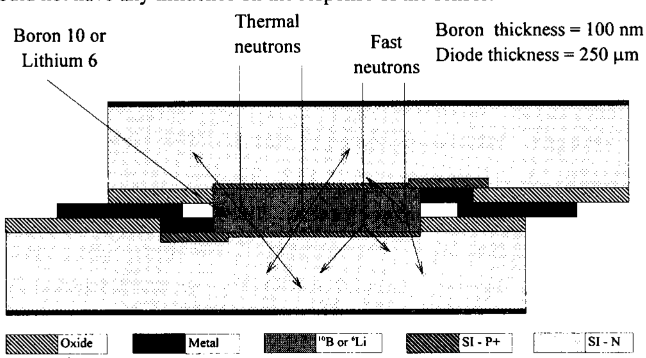

Fig.1 : Schematic view of the detector

Signal processing consists of an usual coïncidence system (5). Several possibilities have been used experimentally to measure the spectra of each detector or, by summing the pulses from both detectors, to get the distribution of the total energy of the nuclear reaction particles.

DESCRIPTION OF THE DETECTION SYSTEM

In order to obtain dose equivalent, we need to know characteristics of neutron beams with different energy ranges because quality factors are function of neutron energy. In these conditions the aim of this work is to realize a rough spectrometer. Next explanations are presented in the case of ^{6}Li reactive layer ; relation between energy is : $E_\alpha + E_{Li} = Q + E_n$ with E_α energy of α particle, E_{Li} energy of ^{6}Li ion, Q value of the energy reaction and E_n energy of the incident neutron.

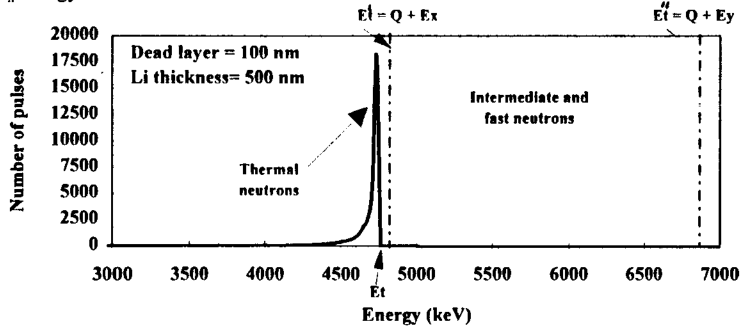

Fig.2 : Spectrum obtained by sommation of the two particles energy and thresholds

Working on spectra obtained by sommation of the two particles energies (fig.2), energy thresholds may be used so that we obtain :

1 - under the energy threshold, $E_T = Q$ (E_T = total energy = $E_\alpha + E_{Li}$) , pulses are due to thermal neutrons,

2 - between two energy thresholds $E_T' = Q + E_x$ and $E_T'' = Q + E_y$ ($E_T'' > E_T'$) lies spectrum of pulses due to neutrons with energy $E_x < E_n < E_y$. This method is interesting for intermediate neutrons and fast neutrons of low energy.

We have point out that it is necessary to satisfy two conditions :

- $E_x \geq \varepsilon$,where ε is the energy resolution of the device (sensor and electronic system). Electronic are in progress to optimize the resolution.
- $E_y \leq E_M$, where E_M is the maximal energy which allows to consider that in the nuclear reaction ^{6}Li (n, α) ^{3}H the value of angle θ (θ = angle between the two products of the reaction) leads to coïncidence detection.

Modelisation are in progress to define this value.

FIRST EXPERIMENTAL DEVICE AND PERSPECTIVE

In order to show the device feasibility, we used commercially available diodes (Hammamatsu) including a reactive layer (Boron 10) which was realized in the laboratory. The dead layer thickness is larger than 1 μm (which is too high), the depleted zone thickness is 100 μm and the boron 10 layer thickness is 100 nm. The device was tested thanks to an AmBe source with paraffin shielding. The registered spectrum is presented on figure 3. Two peaks appear for α particles and two other peaks for Li ions. This result is in agreement with the response obtained by simulation.

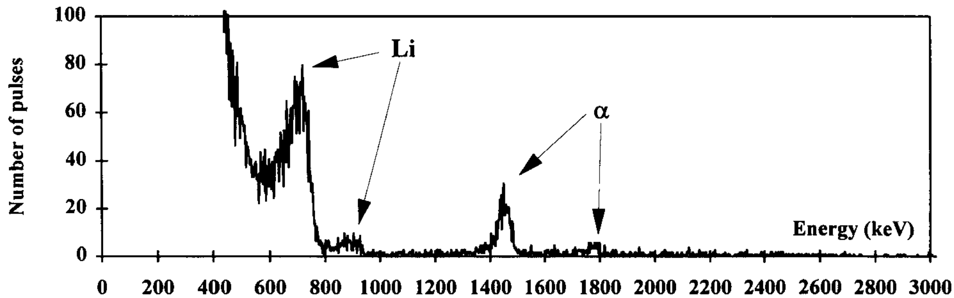

Fig.3 : Experimental spectrum obtained with commercially diodes

The sensor response has been modeled thanks to calculation codes developped in our laboratory and it appears that reaction with ^{6}Li reactive layer is more interesting because it doesn't present an excited state and the energy of particles is higher than in ^{10}B case. But a technological difficultie exits for Li which is able to diffuse inside silicium bulk of the diode. So, it is impossible to use a ^{6}Li reactive layer.

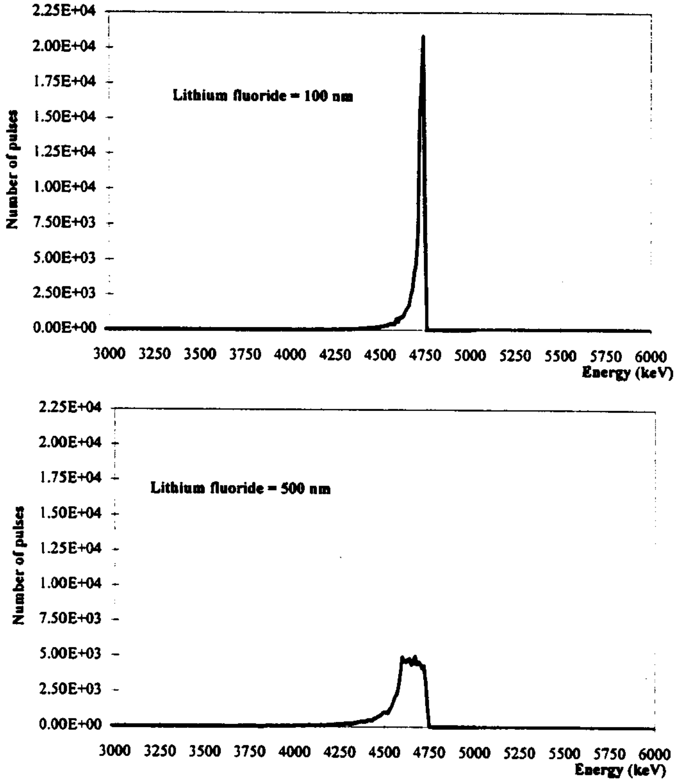

Fig.4 : Distribution of the total energy deposited in the sensor for 100 nm dead layer thickness and a LiF reactive layer

In these conditions, it is necessary to realize a reactive layer with a compound which contains ^{6}Li. We propose LiF. The modelization was made and the first results are given figure 4.

In conclusion, it appears that LiF will be used as reactive layer in the coïncidence device and technological realization of LiF layer is in progress.

ACKNOWLEDGEMENTS

This work was supported by the Commission of European Community (contract FI3PCT9 30072) and EDF - France (Comité de radioprotection). We are very grateful for these helps.

REFERENCES

1. J. Barthe, J.M. Bordy and T. Lahaye, Electronic Personal Neutron Dosemeters. *8th Symposium on Neutron Dosimetry, PARIS, 13 - 17 Nov. 1995.*
2. A. Rannou, A. Clech, A. Devita, R. DOLLO and G. Pescayre, Evaluation of Individual Neutron Dosimetry by a Working Group in the French nuclear Industry. *8th Symposium on Neutron Dosimetry, PARIS, 13 - 17 Nov. 1995.*
3. C. R. Hirning and A. J. Walker, Needs and Performances Requirements for Neutron Monitoring in the Nuclear Power Industry. *8th Symposium on Neutron Dosimetry, PARIS, 13 - 17 Nov. 1995.*
4. J. C. Vareille, B. Barelaud and al., Neutron Detectors for Individual Electronic Dosemeters. *8th Symposium on Neutron Dosimetry, PARIS, 13 - 17 Nov. 1995.*
5. B. Barelaud, F. Nexon-Moktari, C. Barrau, J.L. Decossas, J. C. Vareille and G. Sarrabayrouse. *Radiat. Prot. Dosim.,61,N° 1-3, pp. 153 - 158, (1995).*