How to compensate the effects of ageing and fading in PADC detectors

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2° interconfronto internazionale radon in campo per sistemi di misura passivi: ambienti lavorativi e abitativi
Motivation

On filed measurements:

- Several months of measurement duration
- Non controlled environmental parameters

The calibration factor measured in a reference facility
1) High concentration
2) Short duration

Must be exported

To an on field measurement.
1) low concentration
2) Long duration
Theory – Limit angle

\[ \theta_c \text{ Limit angle} \]

\[ \theta \]

\[ \beta \]

\[ V_B \cdot t \]

Pre-etching surface

Post-etching surface

\[ L(E,t) = \cos \theta \int V_T(E,t) dt - V_B \cdot t \]

\[ \int_0^t V_T(E,t') dt' \approx V_T \cdot t \]

\[ c \theta \int V_T(E,t') dt' - V_B \cdot t > 0 \quad \Rightarrow \quad \cos \theta \cdot V_T > V_B \]

\[ \cos \theta_c = \frac{V_B}{V_T} \]

\[ \cos \theta_c = \frac{1}{V} \]

\[ V = \frac{V_T}{V_B} \text{ Reduced track attack velocity} \]

Criterion for track etching

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Theory – Assessment of the intrinsic efficiency

Blind solid angle: integral between $\theta_c$ and $\pi/2$

$$\frac{1}{2\pi} \int_{\theta_c}^{\pi/2} 2\pi \cdot \sin\theta' d\theta' = \cos \theta_c$$

$$\epsilon = 1 - \cos \theta_c = 1 - \frac{1}{V}$$
In tracks formed by fission fragments from $^{252}\text{Cf}$, $V>>1$. Equation (1) can be approximated as:

$$d \approx 2 \cdot h$$
Fading and ageing test: Irradiations

Detectors: TASLtrack

Detectors coming from a single batch have been divided in groups and subgroups and irradiated in the reference radon chamber and with $^{252}$Cf at POLIMI.

Etching has been done at MI.AM

Reading has been done with the Politrack at POLIMI
Fading and ageing test: material and methods

2 irradiation groups **(A, B)** for fading analysis, each group is divided in subgroups. Irradiated both to Radon and $^{252}$Cf

Irradiation at time $T=0$

**Group A** Etching delay after irradiation (months). Storage: -18°C

**Group B** Etching delay after irradiation (months). Storage: Lab shelf
Fading and ageing test: material and methods

2 irradiation groups (C, D) for ageing analysis, each group is divided in subgroups

Batch reception at time T=0. Delayed irradiation followed by an immediate etching

Group C delay after reception
Storage: -18°C

- C1
- C2
- C3

Group D delay after reception. Storage: Lab shelf

- Radon only D1
- Radon only D2
- $^{252}$Cf Only D3

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Alpha particle tracks are affected by fading, while fission fragment ones aren’t.

$V_B$ remains constant
$V_T$ decreases
Impact of ageing and fading

<table>
<thead>
<tr>
<th>Group</th>
<th>Subgroup</th>
<th>Without correction</th>
<th>Reference exposure value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Measured exposure value (kBq h m^{-3})</td>
<td>Difference %</td>
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<tr>
<td>A</td>
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<td>D2</td>
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<td>-25.2</td>
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The impact on the sensitivity of fading, seems more severe than ageing
$^{252}$ Cf V and angle distributions

- Fridge 9 months ageing
- Shelf 9 months ageing
- Shelf 6 months fading
$^{252}$Cf minor axis distributions

6 months fading

3 months fading

No fading

X axis in µm
The normalized efficiency $\mathcal{E}$ is defined as the ratio between the efficiency measured for a specific group (B2 and B3) and the efficiency measured for the reference groups (A1 and B1).
Fading/ageing compensation

\[
\exp\left(\text{FP}_{\text{ref}}\right) = \frac{\exp(\text{FP})}{1 - \beta(\text{FP} - \text{FP}_{\text{ref}})}
\]

\[
\beta = \frac{m}{m \times \text{FP}_{\text{ref}} + q}
\]

\(\text{FP}_{\text{ref}}\) is the reference fading parameter, defined as the mean value of the fading parameters of the detectors (radon exposure) belonging to groups A1 and B1.
Fading/ageing compensation

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The reference exposure value is affected by uncertainty of 5% at a confidence level of 68%.
Conclusions

1) The fading/ageing is due to a reduction of $V$ deriving from a reduction of $V_T$. $V_B$ is not affected.
2) Fading and ageing can be handled in the same way.
3) The square root of the 90% percentile of the area distribution works very well as fading parameter.
4) The fading/ageing compensated exposure can be measured in a single scan of the plastic.

References

Thanks for your attention