padles
Passive Dosimeter for Lifescience Experiments in Space
Development of a Passive Dosimeter for Life Science Experiments in Space (PADLES) in NASDA
Participants of NASDA group

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- Hiroshi Yasuda, Nakahiro Yasuda, NIRS
Plan of Presentation

- Objective
- Methodology (TLD&CR-39)
- Ground performance test
- Applications
- Summary
- Future Work
PADLES for biological samples to confirm biological damage in space

Investigating biological effects due to space radiation and microgravity requires precise measurements of space radiation.

(a) The absorbed dose
(b) The dose equivalent
(c) LET distributions of heavy-charged particles in the LET region above 10 keV/μm
(d) Tracking of heavy charged particles for biological samples
■ PADLES is located close to biological samples in JEM

PADLES with biological samples

BEU  MELFI  CBEF
Constituent Elements

**TLD-MSO-S** (thermoluminescent dosimeters)

Mg$_2$SiO$_4$: Tb powder enclosed in a pyrex glass with Ar gas
(Kasei Optonics industry)

**CR-39** (plastic nuclear track detectors)

HARZLAS TD-1 are doped with 0.1%wt NAUGARD 445
(Fukuvi Chemical industry)
(a) The absorbed dose : $D_{TLD}$

\[ D_{TLD} = f M K_{\text{proton}} \]

(Gy-water)

$f$ : correction factor (fading effects, temperature dependence)

$M$ : TLD reader output,

$K_{\text{proton}}$ : the conversion factor for water equivalent absorbed dose
(b) The differential LET distribution: $dN/dL (>10\text{keV/mm})$

$$\frac{dN}{dL} = \frac{\Delta N}{\Delta L} \frac{1}{TS \Omega}$$

(particles s$^{-1}$cm$^{-2}$sr$^{-1}$ (keV/µm)$^{-1}$)

$\Delta L$ : range of LET bin (keV/µm),

$T$ : observation time (sec),

$S$ : scan area (cm$^2$),

$\Omega$ : solid angle–$2\pi$
(continued)

**The absorbed dose for > 10 keV/µm**

\[ D_{\text{CR-39}} = 1.602 \times 10^{-6} 4\pi T \sum_{>10\text{keV/µm-water}} (dN/dL L_e \Delta L) \]

(mGy-water)

**The dose equivalent for > 10 keV/µm**

\[ H_{\text{CR-39}} = 1.602 \times 10^{-6} 4\pi T \sum_{>10\text{keV/µm-water}} (Q(L_e) dN/dL L_e \Delta L) \]

(mSv-water)

\[ Q : \text{quality factor. *Q-L relation } \]

ICRP Pub.60(1990)

(c) –1 **The total absorbed dose :** $D_{\text{TOTAL}}$

\[
D_{\text{TOTAL}} = D_{\leq 10\text{keV/\mu m-water}} + D_{>10\text{keV/\mu m-water}} = (D_{\text{TLD}} - \kappa D_{\text{CR-39}}) + D_{\text{CR-39}}
\]

\[
= D_{\text{TLD}} + (1 - \kappa) D_{\text{CR-39}}
\]

(mGy)

(c) –2 **Total dose equivalent :** $H_{\text{TOTAL}}$

\[
H_{\text{TOTAL}} = D_{\leq 10\text{keV/\mu m-water}} + H_{>10\text{keV/\mu m-water}} = (D_{\text{TLD}} - \kappa D_{\text{CR-39}}) + H_{\text{CR-39}}
\]

(mSv)

$\kappa$ : mean TL efficiency for high-LET particles from TLD
The mean TL efficiency for high-LET particles of TLD-MSO: $\kappa$

$\kappa = \sum_{LET > 10 \text{keV/\mu m}} \left( \frac{f(LET) \Delta D(LET)}{D_{\text{CR-39}}} \right)$

Where,

$\Delta D(L_c) = 1.602 \times 10^{-6} \left( \frac{\Delta N(L_c)}{\Delta L_c \Delta L} \right)$ (mGy-water).
CR-39
Measurement of etch pit aperture
D, d: major and minor axes
V: track formation sensitivity

CR-39 Calibration curves

LET distributions
>10keV/μm

QL relation
ICRP 1990

Dose equivalent
>10keV/μm

Absorbed dose
>10keV/μm

Mean TL efficiency
>10keV/μm

TLD-MSO
Dose Calibration for protons

TLD-MSO
Fading correction etc.

TLD-MSO
LET response function

Absorbed dose
<10keV/μm

Total absorbed dose
Total dose equivalent
Effective quality factor

TLD-MSO
TL readout
<table>
<thead>
<tr>
<th><strong>Ground</strong></th>
<th><strong>SPACE</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1997 : Introduction of dosimetric techniques from WASEDA univ.</td>
<td>STS-95 flight experiments (Genetic change induced in human cells in space shuttle experiment)</td>
</tr>
<tr>
<td>1999 :</td>
<td>Analysis of STS-95 dosimeter packages</td>
</tr>
<tr>
<td>~ 2000 : Preparation of TLD reader and CR-39 auto scanning system</td>
<td></td>
</tr>
<tr>
<td><strong>2001~2002</strong></td>
<td><strong>2002~2005</strong></td>
</tr>
<tr>
<td>: Performance tests of TLD and CR-39 with heavy ion beams from HIMAC in NIRS</td>
<td>: Improvement of the automatic CR-39 analysis system</td>
</tr>
<tr>
<td></td>
<td>: Loading to ISS KIBO with biological samples</td>
</tr>
<tr>
<td><strong>2006 ~</strong> : Preparation and test of FM of PADLES</td>
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</tr>
</tbody>
</table>

*Research project with Heavy Ions at NIRS-HIMAC*
**TLD-MSO: Dose and LET response function**

### Absorbed Dose in water (mGy) vs. Relative TL yield (a.u.)

- **Fe ion 204 keV/µm**
- **Ar ion 94.4 keV/µm**
- **Si ion 57.9 keV/µm**
- **C ion 13.5 keV/µm**
- **proton 0.54 keV/µm**

### Relative TL Response vs. LET (keV/µm-water)

- **Co-60**
- **Gamma rays**
- **Heavy ions**
- **Heavy ions (RUN2)**
- **LET = a + b \cdot \log(LET)**

LET (keV/µm-water) range: $10^{-1}$ to $10^4$
**TLD-MSO**: Fading effects

160 MeV/n proton exposure  
storage time: up to 3 months

- **Exposure/storage at –80°C**
- **Exposure/storage at R.T.**
- **Exposure/storage at 37°C**
Sample aboard ISS Russia SM
2001/8/21-12/10 (71 days)
TD-1 6N-NaOH 65h-etching, x100

Calibration curves at various incident angles

TD-1 : 13.5-h etch; 70°C; 7N-NaOH
Automatic scanning

REL_{\theta=200eV,Cr-39} (MeVg^{-1}cm^{2})
Space radiation damage test of the High-Definition TeleVison (HDTV) camera aboard ISS Russian module ZEVEZDA

To investigate white effects in HDTV CCD elements due to HZE particles, test stacks of CCDs sandwiched between CR-39 sheets are used in the ISS Russian SM.
PADLES for ZVEZDA Russia

CCD
C-MOS

CR-39 TNF-1
CR-39 TD-1
TLD-MSO
CR-39 TD-1

TLB-UD807
Altitude: 400km
An angle of inclination: 51.6°
Preriminaly results from TLD

Launch Schedule

<table>
<thead>
<tr>
<th>TLD annealing</th>
<th>2001/6/7</th>
<th>Contol: Ground storage days</th>
<th>186</th>
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</thead>
<tbody>
<tr>
<td>Launch</td>
<td>2001/8/21</td>
<td>Flight sample: Ground storage days</td>
<td>115</td>
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<tr>
<td>Returan</td>
<td>2001/10/31</td>
<td>Flight sample: exposure days</td>
<td>71</td>
</tr>
<tr>
<td>TLD measurement of 10 TLD</td>
<td>2001/12/10</td>
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</tbody>
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- PADLES: 0.215 ± 0.015 mGy/day
- Russian I.C.: 0.242 mGy/day
Summary

■ Objectives
Space radiation dosimetry for biological experiments

■ Methodology (TLD&CR-39)
We determine the absorbed dose and dose equivalent for space radiation in the entire LET region by a combination of the CR-39 and TLD-MSO data.

■ Ground performance tests
We obtained the calibration data using high-energy heavy-ion beams from HIMAC in NIRS.

■ Applications
PADLES can be applied for personal dosimetry and radiation damage research on electronic devices.
PADLES with biological samples:

- **Manual measurement** → *several month to year required*

  (1 sheet of CR-39: $252 \times 189.42 \mu m/field$, 2.5cm square samples → 約5400 fields/sample)

  ↓

  1 life science space experiments need up to 100 sheets of CR-39

  ↓

- **Auto and high-speed scanning system measurement**

  → *within two weeks after return*

We aim to offer the datas to researchers quickly using the automatic CR-39 analysis system, which in cooperation partnership researchers **NIRS**
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