Dosimetry for space radiation in ISS lifescience experiments using PADLES system

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Plan of Presentation

1. Introduction

2. PADLES system
   - Ground-based experiments
   - Programs developments
   - PADLES demonstration

3. Dosimetric results in ISS ZVEZDA using AUTO PADLES

4. A support for life science experiments on ISS JEM
Constituent Elements

PADLES
(Passive Dosimeter for Lifescience Experiment in Space)

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)
Flight experiments

- **STS-95 flight experiment**
  - Genetic change induced in human cells in space shuttle experiment

- **ISS Russian segment flight experiment**
  - Space radiation damage test of HDTV CCD device for HTDV images

- **The MATROSHKA project.**
  - 29/1/2004 – (1 year)
  - Simulation as exact as possible an astronaut while he leaves the 'protective' area of the spaceship to carry out work in space
1. The first KIBO utilization solicitation (Dr. M. Majima Kagoshima univ.)

   Title : Biological effects of space radiation and microgravity on mammalian cells
   Biological sample : Human neuron progenitor cells
   Conditions : Experimental unit 37°C, 1-3 months

2. The international announcements of opportunity (Dr. Y. Furusawa Kyoto institute)

   Title : Biological Response of the Silkworm, *Bombyx mori*, in Space
   Biological sample : The egg of the Silkworm
   Conditions : MELFI 4°C & CBEF 6°C, 6 months

3. The international announcements of opportunity (Dr. T. Onishi Nara Medical univ.)

   Title : Gene expression of p53-regulated Genes in Mammalian Cultured Cell after Exposure to Space Environment
   Biological sample : human glioma cell lines, mouse lymphoma cell line
   Conditions : CBEF 37°C, 2 weeks

4. The international announcements of opportunity (Dr. F. Yatagai RIKEN)

   Title : Detection of Changes in LOH Profile of TK mutants of Human Cultures Cells
   Biological sample : human glioma cell lines
   Conditions : not yet decided
2. PADLES system

PADLES is located close to biological samples in ISS KIBO

<table>
<thead>
<tr>
<th>Irradiation temperature</th>
<th>Storage temperature</th>
<th>Sample Condition</th>
<th>Storage on ISS KIBO</th>
<th>Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>-60°C</td>
<td>-80°C</td>
<td>freezing</td>
<td>freezers</td>
<td>MELFI</td>
</tr>
<tr>
<td>-20°C</td>
<td>-20°C</td>
<td>freezing</td>
<td>freezers</td>
<td>MELFI</td>
</tr>
<tr>
<td>+4°C</td>
<td>+4°C</td>
<td>cold</td>
<td>refrigerators</td>
<td>MELFI</td>
</tr>
<tr>
<td>+25°C (RT)</td>
<td>+25°C (RT)</td>
<td>culture</td>
<td>incubator</td>
<td>CBEF</td>
</tr>
<tr>
<td>+37°C</td>
<td>+37°C</td>
<td>culture</td>
<td>incubator</td>
<td>CBEF</td>
</tr>
</tbody>
</table>

Cell Biology Experiment Facility (CBEF)

PADLE package for ISS (under manufacturing)

Japanese experiment module ‘kibo’

The Minus Eightys Degree Celsius Laboratory Freezer for the ISS (MELFI)

Load period: 3〜6 months

temperature: -80 〜 37
Ground-based experiments in HIMAC

- **TLD-MSO** : The dose response between load period of months

![Graph depicting dose response vs absorbed dose]

Absorbed doses on a space shuttle
(An altitude and an angle of inclination are equivalent to ISS, STS-89, -91)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>mGy/day</td>
<td>0.34</td>
</tr>
<tr>
<td>mGy/month</td>
<td>10.08</td>
</tr>
<tr>
<td>mGy</td>
<td>60.48</td>
</tr>
<tr>
<td>(0.064Gy)</td>
<td>/6 month</td>
</tr>
</tbody>
</table>
Ground-based experiments in HIMAC

- **TLD-MSO**

  - Fading effects for heavy ions

  **H** 0.54keV/μm, 10mGy
  **He** 2.3keV/μm, 50mGy
  **Fe** 200keV/μm, 50mGy

**Graphs:**

- Relative TL yield (a.u.)

**Table:**

<table>
<thead>
<tr>
<th></th>
<th>0.0</th>
<th>0.5</th>
<th>1.0</th>
<th>1.5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>H</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>He</strong></td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td><strong>Fe</strong></td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
</tbody>
</table>
Programs – PADLES analysis procedure –

Sample return

Flight Experiments

TLD-MSO

Chemical Etching

Microscope Image scanning

CR-39

8 μm short etching for SRP
23 μm long etching for LRP
7N NaOH

TLD PADLES

Data-base for TLD individual data

AUTO PADLES

A dose equivalent <10 keV/μm

An absorbed dose ≥10 keV/μm

A dose equivalent ≥10 keV/μm

LET distribution

Total absorbed dose

Total dose equivalent

Data offering to biological researchers
Programs - an improvement of the precisions-

- A calibration curve
- Calibration curves at various incident angles

TLD-PADLES

- Data-base for TLD individual data

AUTO PADLES

- LET distribution
- An absorbed dose $\geq 10 \text{ keV/\mu m}$
- A dose equivalent $\geq 10 \text{ keV/\mu m}$

TLD-MSO data base

- The calibration factors (Co-60, Cs-137, Proton)
- LET response functions
- Fading effects

CR-39 data-base

- A calibration curve
- Calibration curves at various incident angles
Materialization of high speed analysis by JAXA

Chemical etching,
Washing, drying : 5 days

TL reader measurement : 1 min

30 min / 1 cm²

The maximum analysis and data offering time to about 2 weeks for each experiment

Manual measurement : month
Auto PADLES : several minutes

Data input, file output : 1 min

Manual calculation : several days
Auto PADLES : within 30 sec
Handy for reference and selecting automatically

- The serial number, Lot
- Response rate for gamma-rays, High-energy protons
- The history of use
- Available/Non Available
- Under use/ Preservation
Managing the individual data of TLD elements and make the output files for AUTO PADLES

- Serial number, Lot
- The calibration factors obtained for gamma-rays, High-energy protons
- The history of use
- TL readouts on past flight experiments
PADLES demonstration

- The Experiment data-base section
- The CR-39 processing section
- The dose estimation section

The TLD PADLES TL readout output files

A large amount of microscope images

The CR-39 processing

An ellipse-fitting

Measurements of the major and minor axis

The Experimental data files

CR-39 response database for heavy ions from ground-based study

TLD-MSO response database for heavy ions from ground-based study

output
The CR-39 processing section - microscope image scan -

Focus: Auto-focus with an infrared marker

File form: BMP

(4000 images)
A high-speed and semi-automatic analysis system for track detectors with an ellipse fitting algorithm developed by NIRS, SEIKO precision inc.
3. Dosimetric results in ISS ZVEZDA using AUTO PADLES

- Differences of LET distribution caused by measurement methods

1. Manual measurement

2. Pit analysis measurement (automatic)
3. Dosimetric results in ISS ZVEZDA using AUTO PADLES

Differences of LET distribution caused by measurement methods

<table>
<thead>
<tr>
<th></th>
<th>71 days</th>
<th>257 days</th>
<th>446 days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorbed Dose</td>
<td>2.0%</td>
<td>1.2%</td>
<td>2.4%</td>
</tr>
<tr>
<td>Dose Equivalent [mSv]</td>
<td>6.6%</td>
<td>5.6%</td>
<td>10.4%</td>
</tr>
</tbody>
</table>

Contributions of total absorbed dose [400 keV/µm]
4. A support for life science experiments on ISS JEM

ISS biological research experiments proposed in the first KIBO utilization solicitation (PADLES for experimental unit M type)

1 PADLES / 1 unit  □  total 8 PADLES will be needed. (Without ground control)

1 PADLES:
- CR-39 16 sheets
- TLD-MSO 160

(minimum analysis area 1cm²)

Analysis time required: 26 days (208 h 8h/day work time)
4. A support for life science experiments on ISS JEM

- The comparison with scan speed

1 life science experiment need up to 10~100 sheets of CR

- 1 sheet of CR-39 : 178 mm x 132 mm /field, 1cm²
- 4800 fields/sample
- Plural life science experiments will be conducted on board

We will reduce the maximum analysis and data offering time for each experiment

We need more and more speedup of analysis time !!

<table>
<thead>
<tr>
<th>Microscope type</th>
<th>Focus</th>
<th>Size of sensor (pixl)</th>
<th>resolution (um/pixl)</th>
<th>Scan method</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leica</td>
<td>Contrast of image processing</td>
<td>764 x 574</td>
<td>0.33</td>
<td>Step scan</td>
<td>7h 1min</td>
</tr>
<tr>
<td>Luzex</td>
<td>Auto-focus with an infrared marker</td>
<td>768 x 493</td>
<td>0.38</td>
<td>Step scan</td>
<td>32min</td>
</tr>
<tr>
<td>HSP-1000</td>
<td>Cylindrical</td>
<td>$2^3 \times 1^5$ (0.7 x 35mm)</td>
<td>0.35</td>
<td>Line scan</td>
<td>30sec or less</td>
</tr>
</tbody>
</table>