Characterization of Novel Lightweight Radiation Shielding Materials for Space Applications

Michael Steffens[1], Felicitas Hepp[2], Stefan K. Höffgen[1], Phillip Krzikalla[2], Stefan Metzger[1], Frank Pellowski[3], Giovanni Santin[4], Lars Tiedemann[2], Adrian Tighe[4], Udo Weinand[1]

1 Fraunhofer INT, Euskirchen, Germany
2 HPS GmbH, München , Germany
3 OHB-System AG, München, Germany
4 ESA-ESTEC , Noordwijk, Netherlands

Abstract: Novel materials or multilayers can help reduce the mass requirement for radiation shielding of electronic components significantly. In this study, potential alternatives to the standard aluminium shielding approach are assessed by Monte Carlo simulations and promising candidates are manufactured and characterized by radiation tests including proton and electron tests.

Objectives

- Implement multi-layered shielding or High-Z / Low-Z compounds for realistic mission scenarios and potential application areas
- Consider practical aspects e.g. structural stability and reliability, compatibility with other processes.
- Compatibility with existing designs of spacecraft enclosures for instrumentation (especially important in upcoming project phases)

→ Have a ready-to-use end product ,which can be space qualified
→ Current status: Evaluate slabs of suitable candidate solutions

Material selection

- Environmental shielding performance analysis for various mission scenarios of commercial or scientific interest using MULASSIS (Geant4) on SPENVIS
- Trade-off with crucial material properties (e.g. CTE) , commercial feasibility and sustainability

→Test candidates: **Ta-enhanced CFRP** (Mat. A), **W-enhanced PE** (Mat. B), **W-enhanced polyamide (PA)** (Mat. C) and **adhesive with High-Z-content** (Mat. D).

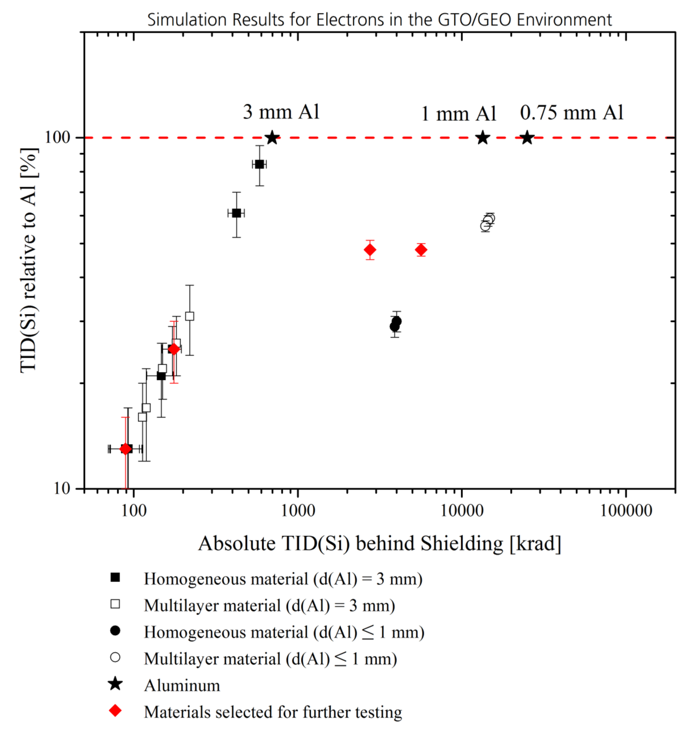

Fig. 1. Shielding performance analysis for several candidate materials. MULASSIS simulations with the materials exposed to electron environment during a GEO mission with extended GTO.

Test campaigns

- Transmission of 45 MeV protons degraded to variable energies through shielding (JULIC cyclotron at Forschungszentrum Jülich) (Fig. 2)
- Dose deposition by electrons in RADFETs (TY1004) and Alanine dosimeters behind shielding by 1.5 MeV – 12 MeV electrons (“Elekta Precise Treatment System” at PTB, Braunschweig and ELV-2 facility at IPF, Dresden)
- Further tests include outgassing, thermal conductivity and cycling, adhesion measurements, tensile and bending tests etc. Some tests performed on samples irradiated with Co-60 to 5 Mrad.

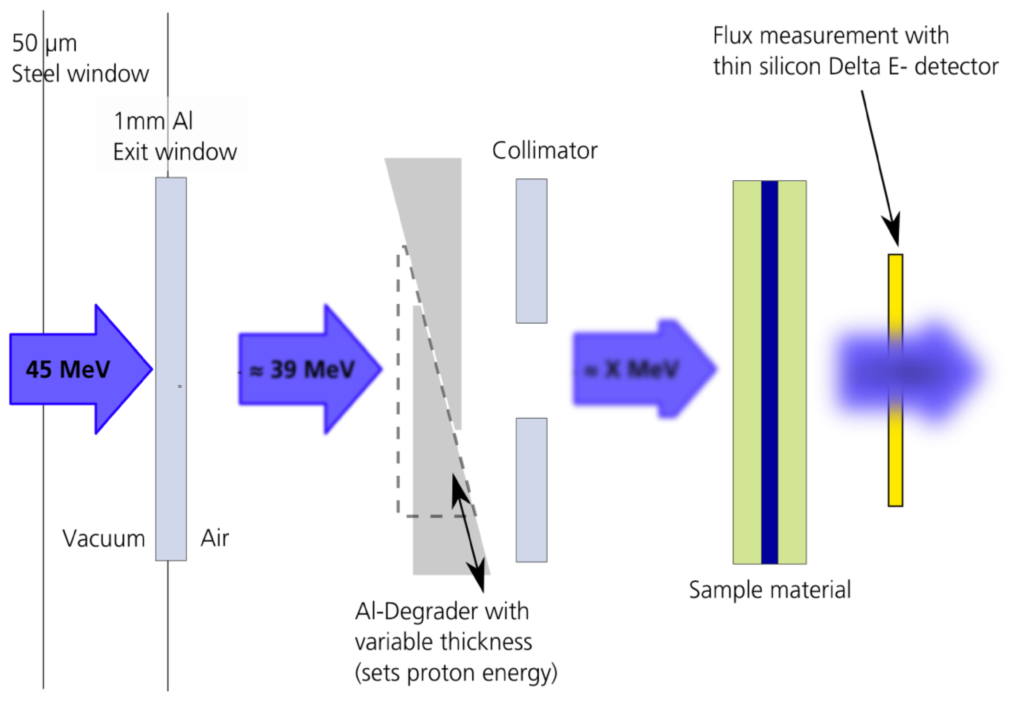

Fig. 2. Proton transmission measurements with a variable energy degrader and Si-PIPS detector

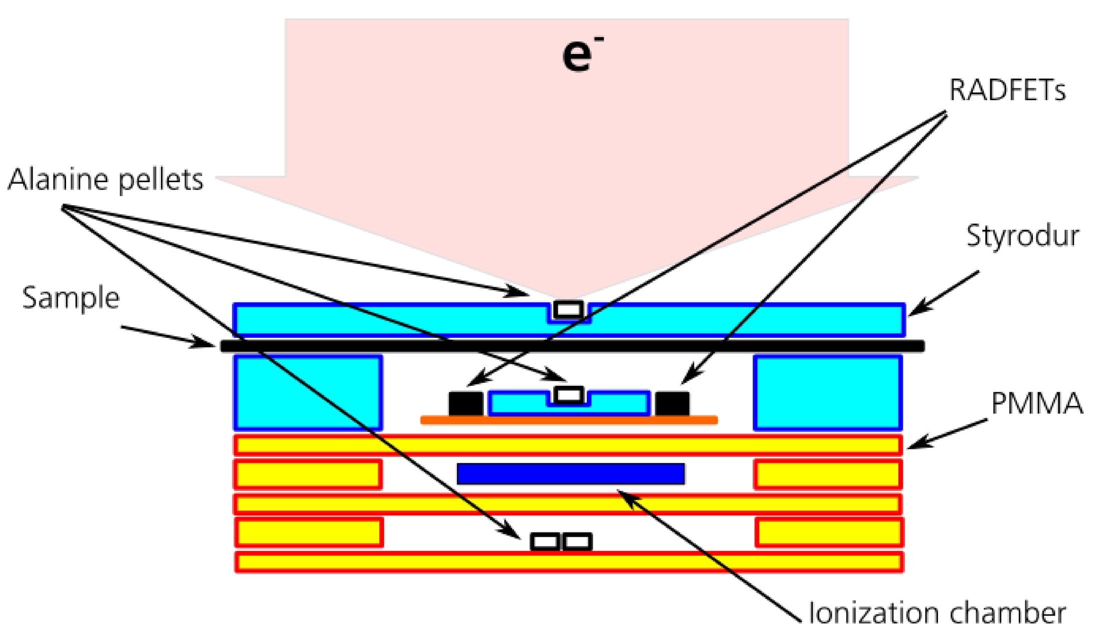

Fig. 3. Setup of the Electron Shielding Tests with RADFETs, Alanine, and ionization chamber

Results

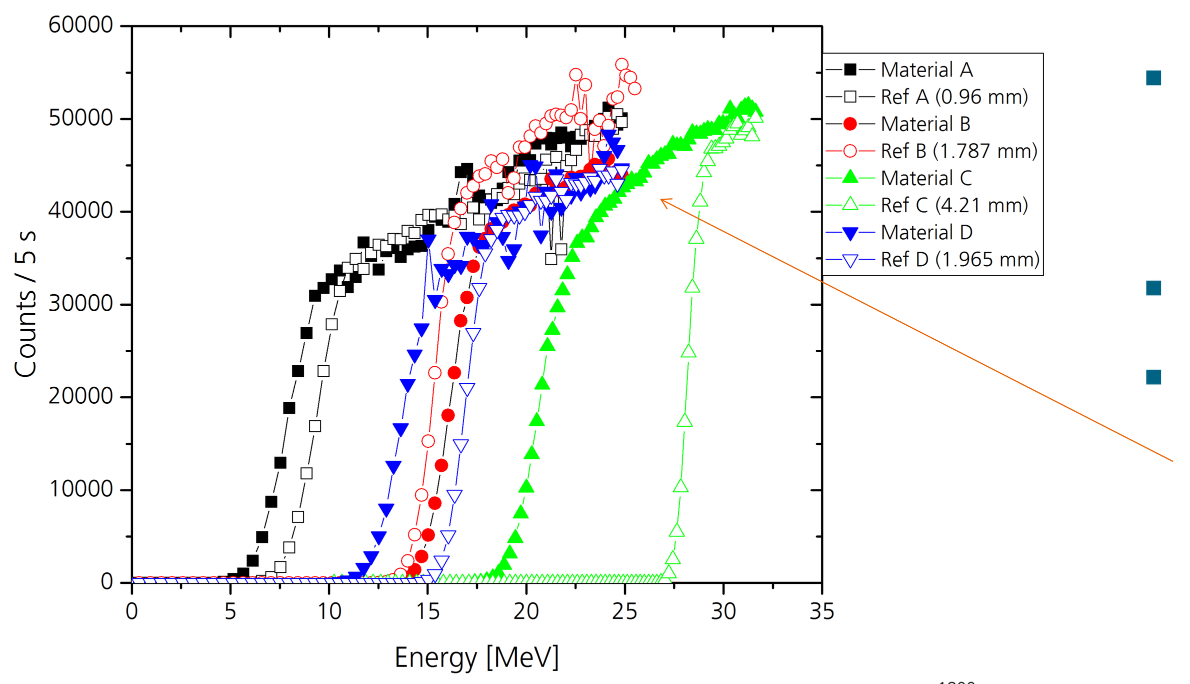

Fig. 3: Proton transmission through various shielding solutions including mass-equivalent Aluminum slabs

- **W-enhanced PE** (Mat. B) shows higher transmission energy than mass-equivalent aluminium
- Other materials are less efficient than Al
- Transmission not constant at larger degrader thickness (lower energies) due to enhanced proton scattering away from collimator axis

- The data from RADFETs and alanine behind shielding are scaled to the dose level of the respective upper alanine pellet
- Complementary MULASSIS simulations (10^{10} electrons)
- Good to reasonable match of alanine data (filled symbols) with MULASSIS simulations (dashed line)
- RADFET data inconsistent

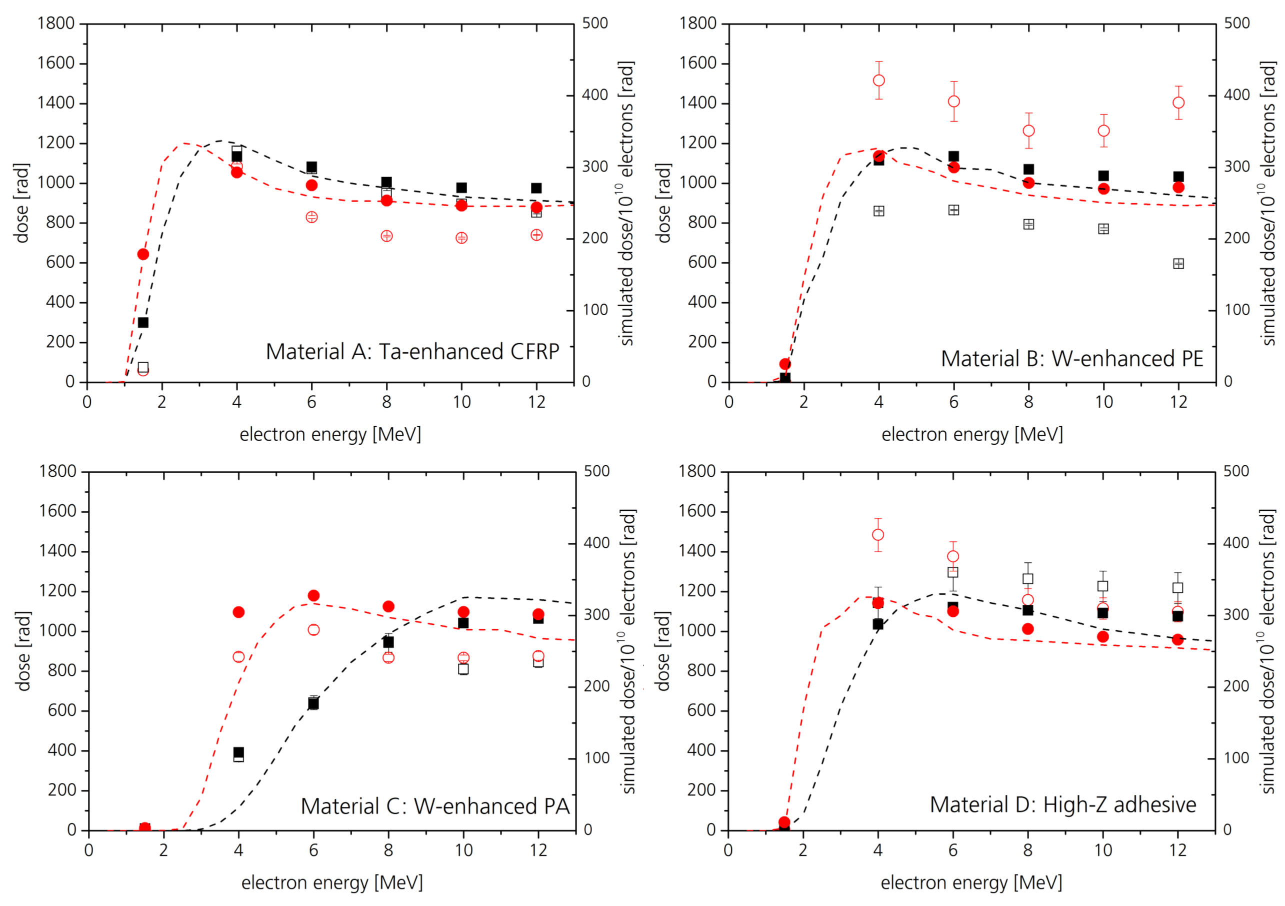

Fig. 4: Dose deposition behind various shielding solutions compared to mass-equivalent Aluminium slabs. Data taken with alanine dosimeters and RADFETs. Scaled to a reference alanine pellet in front of shielding

Material data:
RADFET
Alanine
MULASSIS simulation

Aluminum data:
RADFET
Alanine
MULASSIS simulation

- **W-enhanced PE** (Mat. B) suited for **electronic boxes** providing some structural stability. Especially suitable for **proton** rich environments. Currently shows some delamination issues. Work ongoing.
- **W-enhanced polyamide (PA)** (Mat. C) especially suitable for **electron**-dominated environments. High specific mass → use-case as **spot shield**.
- Outlook: tests on realistic implementations

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Contact:

Dr. Michael Steffens
Fraunhofer INT
Appelsgarten 2
53879 Euskirchen, Germany
Phone +49 2251 18-187
michael.steffensr@int.fraunhofer.de