

SIMULATION AND EXPERIMENTAL ASSESSMENT OF GAMMA RAY SHIELDING EFFECTIVENESS IN EPOXY AND FIBER CLOTH COMPOSITE LAYERS

**PhD research title: Radiation-Driven Astrochemical Processes In Ice Phases:
Applications
For Space Environments**

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Supervisor: **Mgr. Zuzana Kaňuchová PhD** , Astronomický ústav SAV, v. v. i



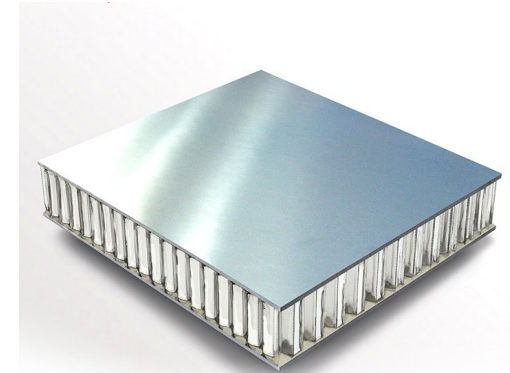
“Development of lightweight sandwich pannels for radiation shielding solution in upper space application”

SPENVIS Project: BARIUM
Model packages
Planet: Earth

Coordinate generators
Radiation sources and effects
Spacecraft charging
Atmosphere and ionosphere
Magnetic field
Meteoroids and debris
Miscellaneous
Geant4 Tools
General models
Multi-Layered Shielding Simulation (MULASSIS)
Geant4 Radiation Analysis for Space (GRAS)
Geant4-based Microdosimetry Analysis Tool (GEMAT)
Sector Shielding Analysis Tool (SSAT)
Planet specific models
Magnetocosmics
Planetocosmics
Common settings
Definition of source particles
User defined materials
Geometry definition tool
ECSS Space Environment Standard

Source particle type and spectrum	
Environment: <input type="button" value="Mission based"/>	<input type="button" value="GCR particle fluence"/>
Number of primary particles to simulate: <input type="button" value="average trapped particle fluence"/>	
Warning: Particle track visualisation: <input type="button" value="solar particle fluence"/>	
Incident particle type: <input type="button" value="Ion"/>	<input type="button" value="GCR particle fluence"/>
Ion definition	
Atomic number: <input type="button" value="7"/>	
Isotope: <input type="button" value="N14"/>	
Incident energy spectrum	
<input type="button" value="Mission average spectrum"/>	
Angular distribution	
<input type="button" value="The angular distribution is omnidirectional."/>	
<input type="button" value="Reset"/> <input type="button" value="Create GPS macro"/>	

Tool developed by



Pakistan Space & Upper Atmosphere Research Commission & Institute of Space Technology



SIMULATION AND EXPERIMENTAL ASSESSMENT OF GAMMA RAY SHIELDING EFFECTIVENESS IN EPOXY AND FIBER CLOTH COMPOSITE LAYERS



- Problem statement & objective
- Materials
- Synthesis
- Simulations & Experimental Setup
- Results & Discussion
- Conclusion



Problem Statement & Objective



Problem Statement

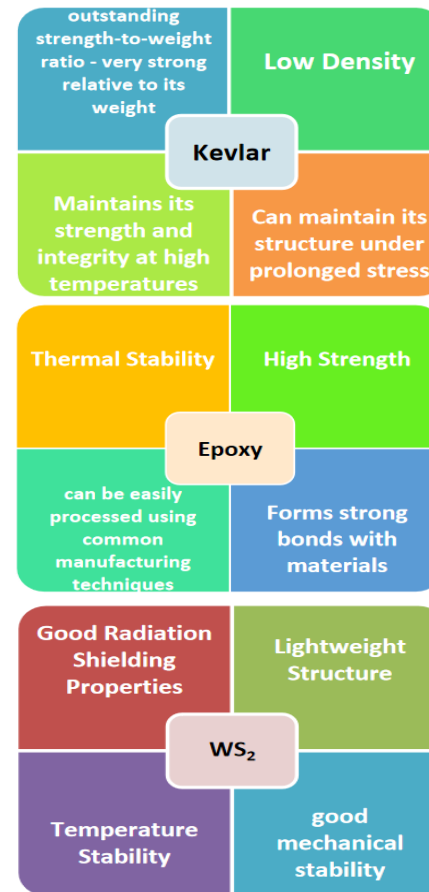
Radiation exposure on long duration missions is one of the main design factor. Gamma rays are very energetic ionizing radiations and thus hazardous due to it's highest penetrating power.

Objective

The research aims to identify a material with good radiation shielding properties which is non-toxic, and cost-effective against gamma radiation.



Materials





Synthesis



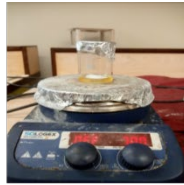
1. Measuring epoxy on weight balance



2. Adding acetone in epoxy



3. Sonication of epoxy for 15 minutes



4. Stirring of epoxy for 15 minutes



5. Measuring WS₂ on weight balance



6. Adding WS₂ in epoxy



7. Sonication of epoxy and WS₂ for 15 minutes



8. Stirring of epoxy and WS₂ for 15 minutes



Sample	Thickness (mm)	WS ₂ %
1	0.64mm	6.1
2	0.97mm	7.4
3	1.19mm	7.9

Fig. Synthesis of composite



Simulations & Experimental setup



Phy-X

PSD: Photon Shielding and Dosimetry

Please enter the chemical formula of the composition you want to calculate in the field below. Eg: $200\text{Gd}^{150}\text{Gd}^{158}\text{Gd}^{160}\text{Gd}^{162}$

Energy range: Standard Grid **PSD**

Chemical Composition: $0.89\text{C}14\text{H}14\text{N}2\text{O}4 + 0.099\text{C}2\text{H}6\text{OSi} + 0.011\text{KVS}2$

Sample Code: **S1**

Fraction By: ☒ Mol ☐ or ☐ Weight

Calculate

or

Refresh

Reference Article:
"Phy-X/PSD: Development of a user friendly online software for calculation of parameters relevant to radiation shielding and dosimetry"

XCOM NIST
National Institute of Standards and Technology
Physical Measurement Laboratory

Element/Compound/Mixture Selection

In this database, it is possible to obtain photon cross section data for a single element, compound, or mixture (a combination of elements and compounds). Please fill out the following information:

[Help](#)

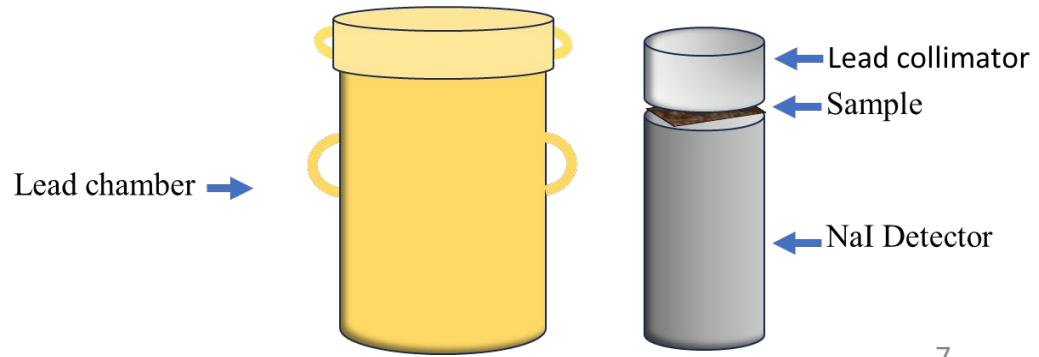
Identify material by:

☐ Element
☐ Compound
☒ Mixture

Method of entering additional energies: (optional)

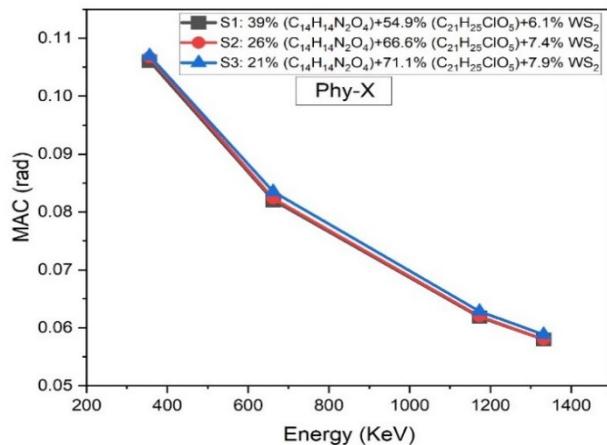
☒ Enter additional energies by hand
☐ Additional energies from file (Note: Your browser must be file-upload compatible)

XCOM

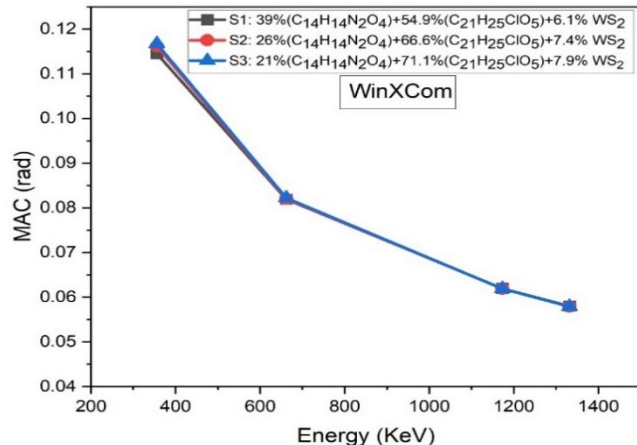




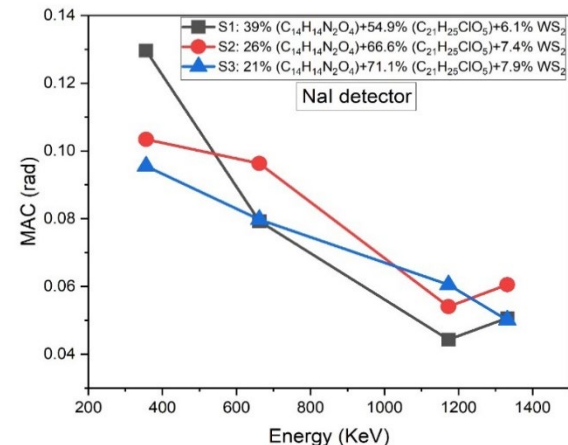
Result: Mass attenuation coefficient



(a)



(b)



(c)

Fig. Comparison of Mass attenuation coefficient (MAC) of samples (a) calculated using PhyX (b) calculated using WinXCOM online tools and (c) measured experimentally by using NaI detector.



Result: Half Value Layer (HVL)

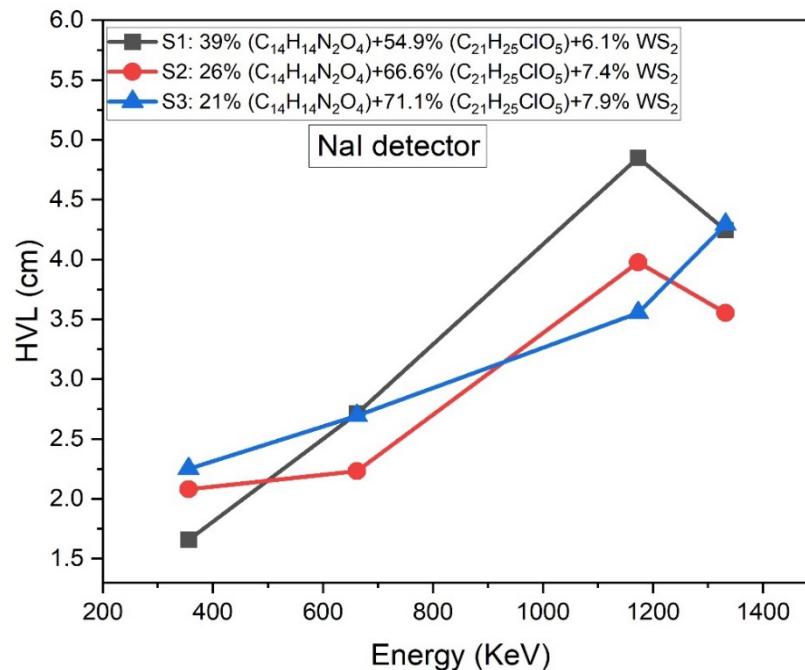
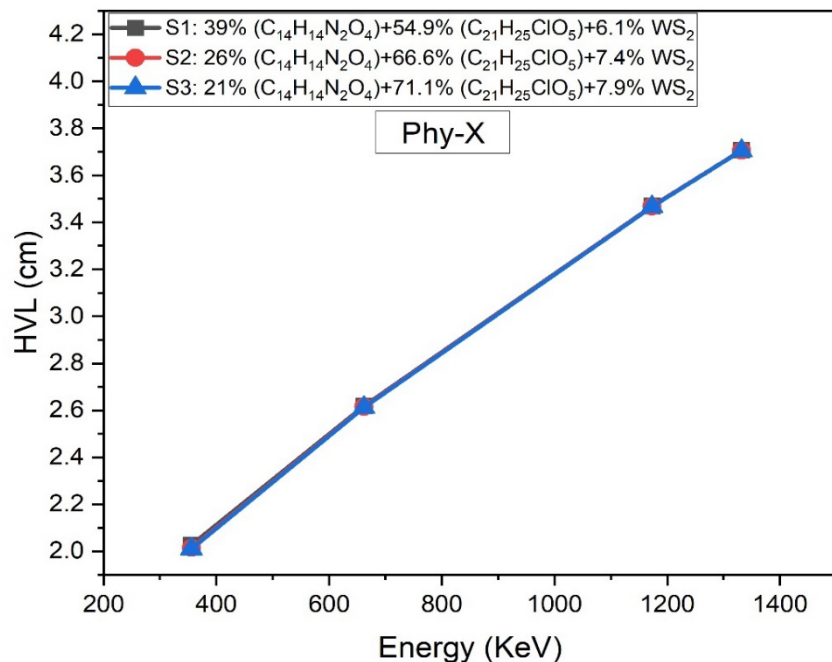
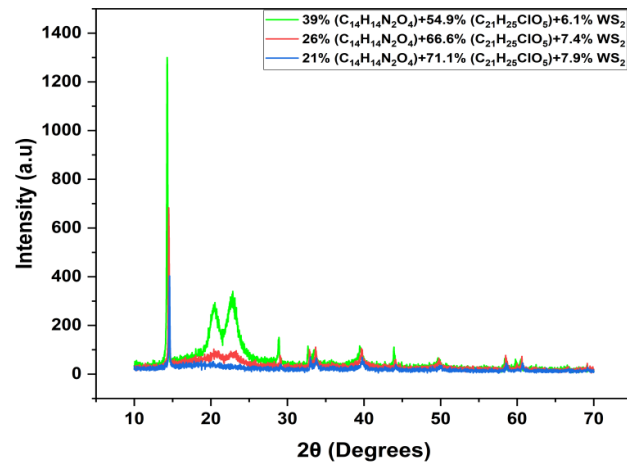
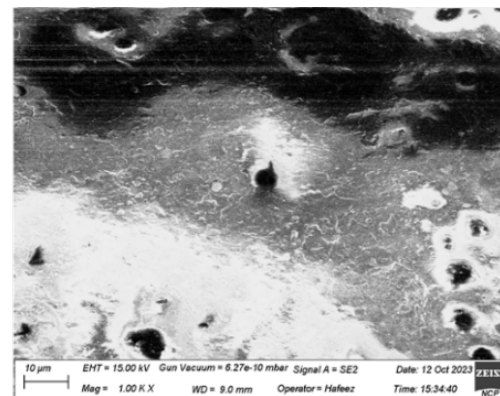
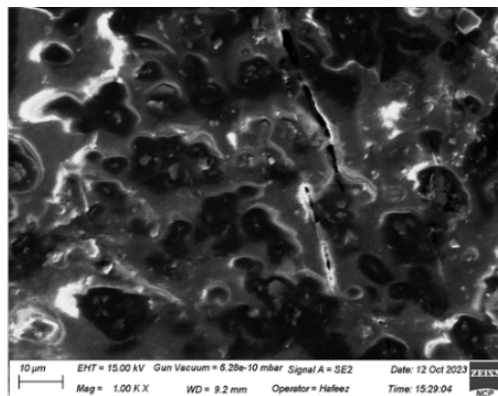
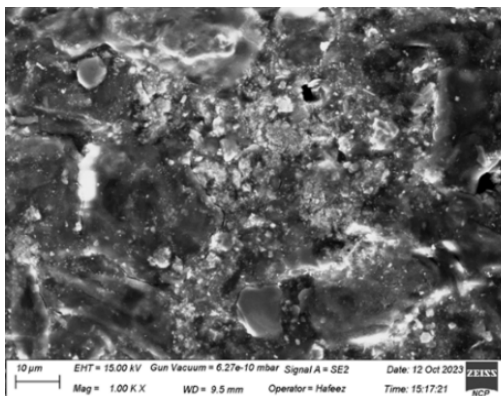


Fig. Comparison of Half value Layer (HVL) of samples (a) calculated using PhyX online tool and (b) measured experimentally by using NaI detector with calculated values₉

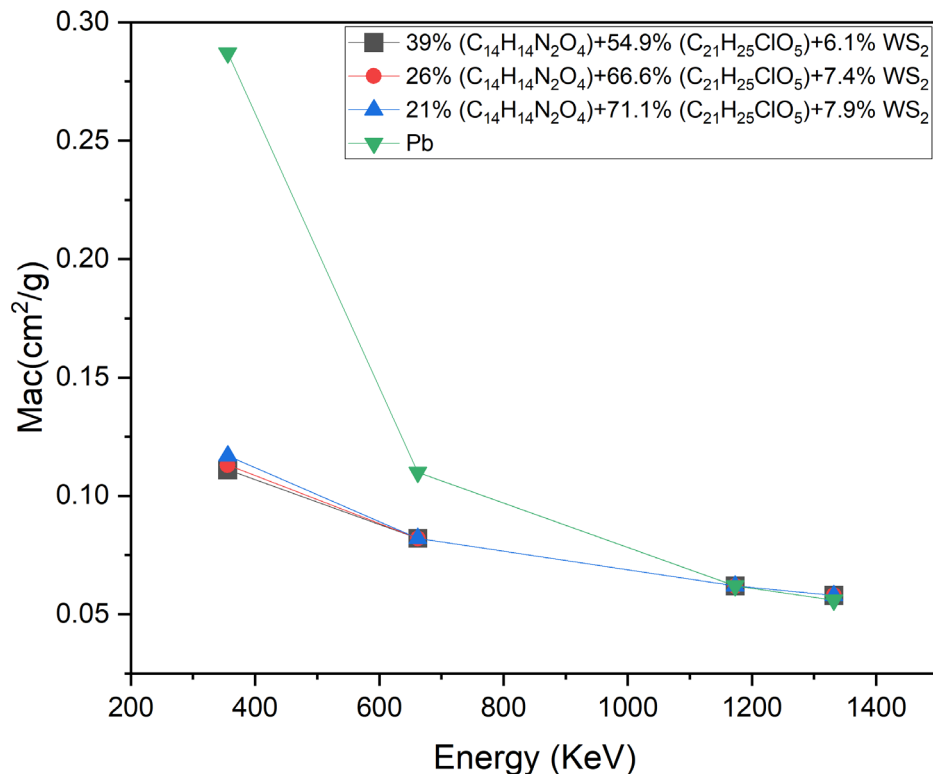


Morphological and Structural analysis





Comparison



- Lead (Pb) shows much **higher MAC** at **lower energies**, confirming its superior attenuation capability at low energies

Decrease in MAC with increasing energy:

- Confirms reduced shielding effectiveness at higher gamma energies
- **Thicker shielding** is required to compensate for higher photon penetration

Composite material density:

- ~3.224 g/cm³, which is approximately **72% lighter** than lead
- This makes the material highly suitable for aerospace and space applications, where weight is a constraint

Best performing formulation:

- 21% (C₁₄H₁₄N₂O₄), 71.1% (C₂₁H₂₅ClO₅), 7.9% WS₂
- Exhibits slightly better attenuation across all energy levels among tested composites



Conclusion of this study



Considering the space environment, although composites do not outperform lead at low energies, they offer a balanced trade-off between performance and weight and emerge as a *favorable choice for gamma radiation* shielding due to their **competitive MAC values**, **non-toxic nature**, and **cost-effectiveness** as compared to the traditional shielding material “**lead**” for gamma radiations. These factors collectively make the composites a *better alternative*. However, the final decision should still be based on a comprehensive evaluation of the specific needs and goals of the space mission.



1) Focus of the Research

- Investigates radiation-driven chemical processes in astrophysical ice analogues
- Explores the influence of ice phases (**amorphous vs. crystalline**) on chemical reactions
- Examines the role of temperature, radiation type, and dose on molecular changes
- Explores key phenomena: **phase transitions, ice compaction, radiolytic decay, and new molecule formation.**

2) Objectives

Systematically study the **effect of radiation** (electrons, ions, photons) on different **ice phases**.

- Prepare astrophysical **ice analogues** in ultrahigh-vacuum, cryogenic environments
- **Irradiate samples** using various radiation sources: electrons, ions, and UV photons
- Acquire **real-time spectroscopic and spectrometric** data
- Quantify:

I. Destruction rates of parent ices

II. Formation rates of new molecules

III. Phase-dependent chemical differences

Thank you!