# USING EUD$_4$TEA AS THE ACTIVE ELEMENT FOR SPACE-BASED RADIATION SENSORS

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The hazards posed by radiation in space pose a serious challenge and threat to human and robotic exploration missions to the Moon, Mars, and beyond. Table 1 shows the particle types, energies, and the annual surface doses for a selection of space radiation sources [1]. These radiation hazards include galactic cosmic rays (GCR) and solar energetic particles (SEP). GCRs are present in the near Earth space environment and produce chronic, but not acute exposures [1-2]. GCRs are very difficult to shield against when astronauts are beyond Earth's atmosphere and magnetosphere. Sudden intense bursts of SEP events can last several days with an intensity that increases and decreases with time [1-2]. On Earth, these particle affect radio transmissions, the upper atmosphere composition, and ozone layer [1-2].

**Table 1.** Particle Types, Energies, And Surface Doses For Space Radiation Sources [1].

| **Source of Space Radiation** | **Type of Radiation** | **Energy (MeV)** | **Annual Surface Dose (Gy)** |
|---|---|---|---|
| Sun | Protons<br>Electrons | 20 to 100<br>0.05 | 10 to 100<br>100 to $10^5$ |
| Galaxy | Protons | 100 to $10^3$ | 0.01 to 0.1 |
| Internal Radiation Belt (Earth) | Protons<br>Electrons | $10^{-3}$ to 70<br>0.02 to 1 | $10^8$<br>$10^{10}$ |
| External Radiation Belt (Earth) | Protons<br>Electrons | ≤ 60<br>0.02 to 5 | <br>$10^9$ to $10^{11}$ |

As we consider long duration missions, the risk from radiation exposure increases. After all, protons with ~30 MeV can penetrate spacesuits and spacecraft walls, and higher energy radiation produces secondary penetrating particles such as neutrons and nuclear fragments inside the shielding material [1-2]. Some types of shielding material can actually increase the radiation hazard [1-2].

Recently, research was started to investigate a new type of dosimeter capable of measuring low levels of radiation in real time. This concept will be based on organic materials such as europium tetrakis dibenzoylmethide triethylammonium (EuD$_4$TEA), which emits a red luminescence that can be seen in bright daylight with the naked eye [3]. Over the past several years, we have optimized the synthesis process by making it more efficient and cheaper. We also discovered that it is possible to combine EuD$_4$TEA with polymers such as poly(methyl methacrylate) (PMMA), and investigated the effects of various dopants such as dimethyl methylphosphonate (DMMP), dysprosium, samarium, and even uranium [3-7]. To date, DMMP was the best dopant creating a triboluminescent yield that is 400% larger when compared to the base EuD$_4$TEA [3-7]. EuD$_4$TEA also emits light when its crystals are broken [3-7].

When uranyl acetate, which had an activity of 0.2 μCi/g, was added to EuD$_4$TEA, the resultant product was found to be sensitive to radiation exposure [7]. After the product formed, the samples with 4 mol% uranium initially increased the light emission yield over the pure sample by approximately 80% [7]. However, gains in yield decreased with time owing to radiation exposure from the depleted $^{238}$U in these samples. It is likely that ionizing radiation emitted from the decay of $^{238}$U and its corresponding daughter products caused the reduction in emission yield. In fact, the reduction in yield upon exposure to ionizing radiation from heavy charged particles appears to be similar to what is described by the Birks and Black equation [8]. These radiation particles break chemical bonds, thus reducing the radiative emission in doped EuD$_4$TEA. After 120 days, results showed that the emission yield for the 4 mol% doped uranium samples was reduced by approximately 20% over the initial value measured when the sample was synthesized [7]. At this rate, it should take approximately 335 days for the emission yield to be reduced to half of its original value [7]. These preliminary results indicate that EuD$_4$TEA has great potential to be used as the active element for low-level space-based radiation sensors. This presentation will detail our research into EuD$_4$TEA and how it can be used as a radiation sensor for space applications.

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