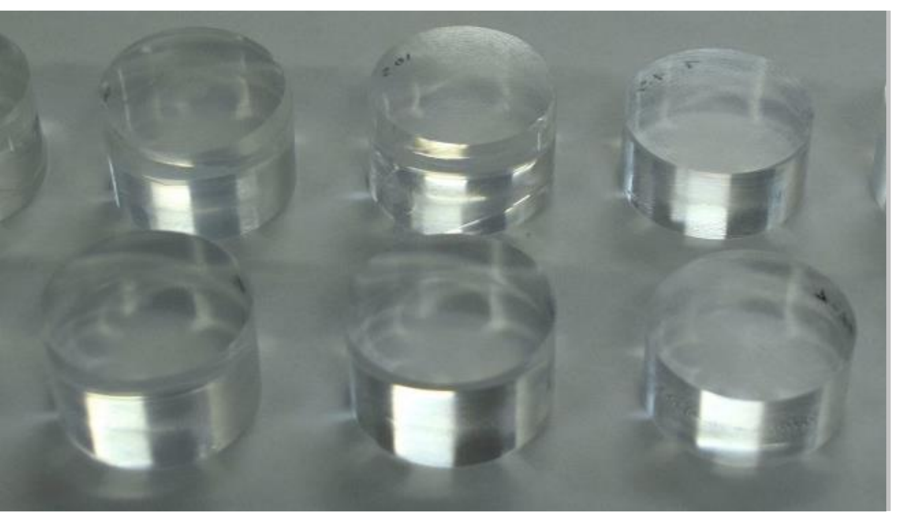
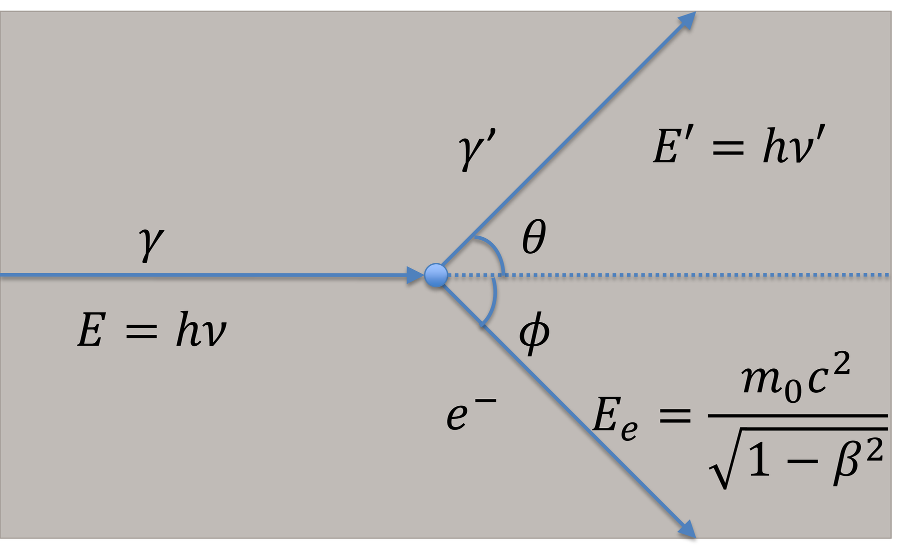
SAND2015-5932O

Characterization of Organic Scintillation Materials

Trevor A Kyle, Purdue University, B.S. Nuclear Engineering, est. May 2016
Patrick L Feng, Organization 8126: Radiation and Nuclear Materials Detection & Analysis
July 29, 2015





Sandia National Laboratories

Exceptional service in the national interest

The motivation for this research stems from the need for a more versatile scintillation material for widespread use in critical applications. As the threat of nuclear terrorism becomes more pronounced, advanced radiation detection methods have become increasingly necessary. Standard Radiation Portal Monitors have proven ineffective at international borders and ports, as the gamma ray scintillation materials that they use are not sensitive enough to distinguish between naturally radioactive cargo and potentially hazardous materials. This research presents the development of plastic scintillators for cheap and effective gamma ray detection as a possible alternative to traditional inorganic NaI(Tl) or HPGe.

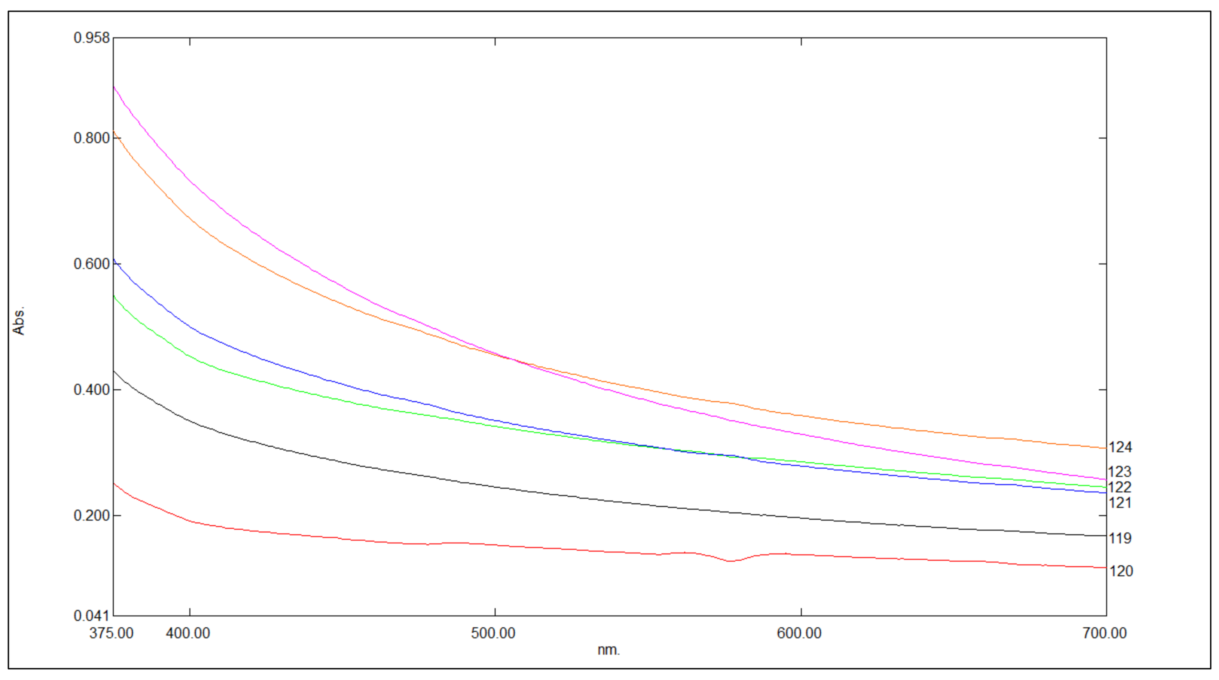
Methods

Plastic samples were prepared using varying amounts of matrix (usually styrene), electron transport additives, fluorophores, and heavy metal additives. After the samples had polymerized and were percussively extracted from their containers, small specimen shavings were used to perform photoluminescence and fluorescence timing measurements. Using a powder cell, excitation and emission spectra were gathered for each specimen, and based on the wavelength of maximum emission, timing measurements were taken. Samples were polished and absorbance/transmission measurements were made using a UV-Vis spectrophotometer. Scintillation pulse height spectra were collected using Cs-137 as a gamma source to determine light yield. For promising specimens, multiple gamma sources were used to ensure that the detector response was linear with respect to the expected photopeaks.

Metrics

In searching for an effective plastic scintillator, the following three metrics were used:

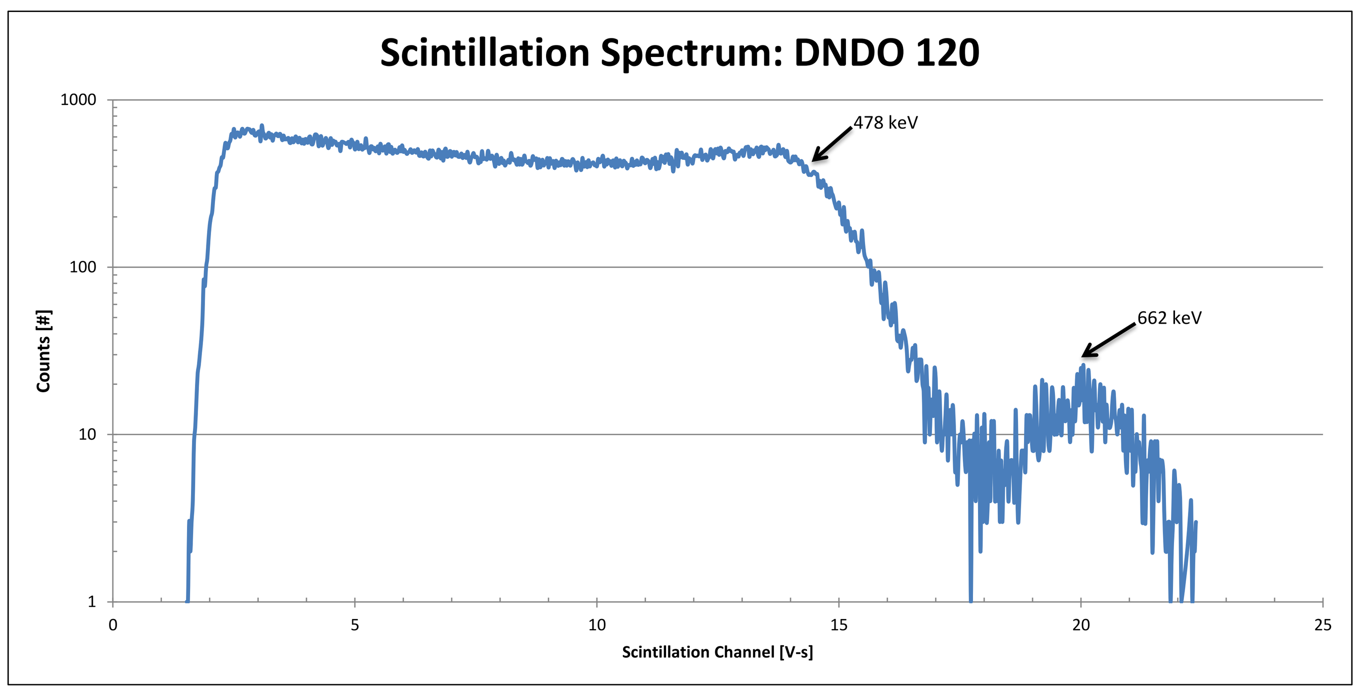
- High light transmission (>50% for light between 375 nm and 700 nm)
- High scintillation light yield (photopeak distinct from background)
- Detector Linearity (>99% of variation in peak channel explained and no clear residual pattern)



DNDO 119-124 Absorbance

Results

The sample series DNDO 119-124 was analyzed and after absorbance measurements revealed that DNDO 120 transmitted at least 56% of incident light for the tested spectrum, further tests were performed.

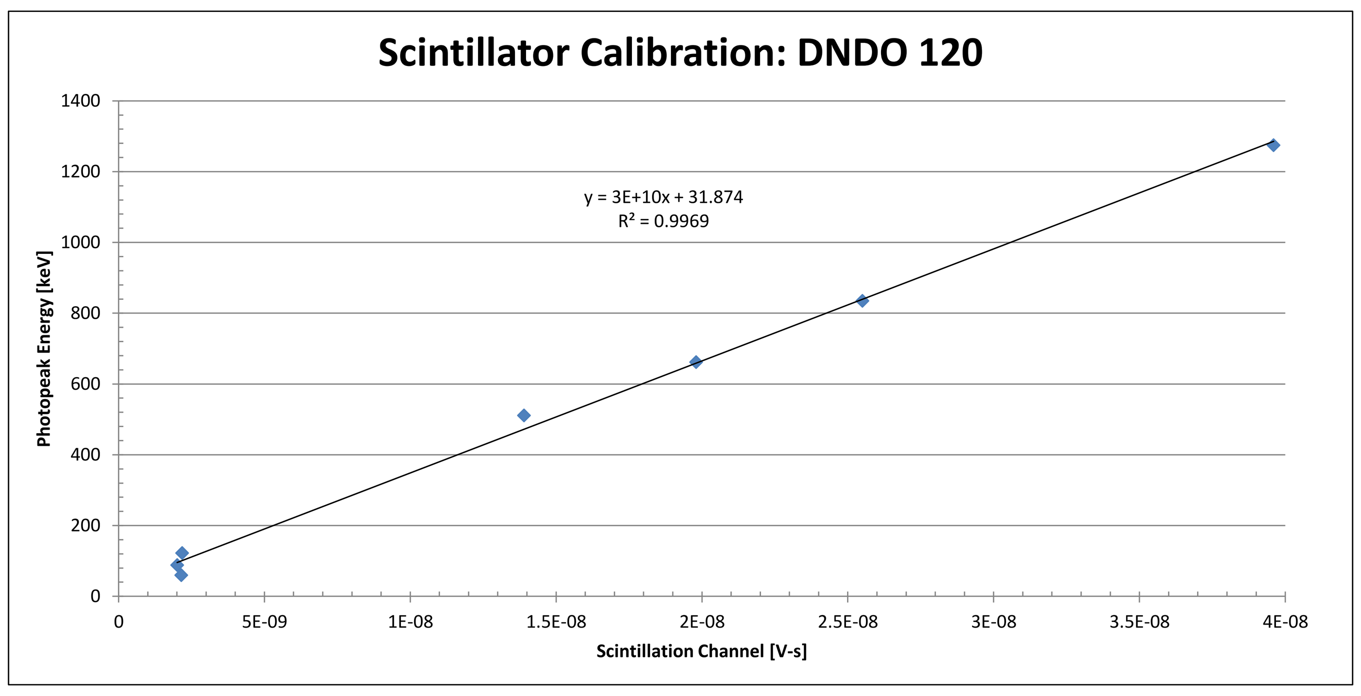


DNDO 120 Scintillation Yield

A 30-minute count with Cs-137 yielded a clear scintillation spectrum. The iconic 662-keV photopeak of Cs-137 is present at a channel of about 19.8 nV-s and the Compton Edge can be estimated to be at about 14.5 nV-s, making its energy 479 keV, a value consistent with the Compton Equation:

$$E_{CE} = h\nu - \frac{h\nu}{1 + \frac{2h\nu}{m_0 c^2}}$$

Using a host of gamma-emitting nuclides, scintillation pulse height spectra were collected for DNDO 120. The detector showed a high level of linearity for gamma energies above 122 keV, with 99.69% of the variation explained. However, for energies below this threshold, the detector response was generally constant and the pulses registered were anomalous and misshapen, suggesting that the instrumentation, specifically the photomultiplier tube, may be responsible for the breakdown more than the organic scintillator itself.



DNDO 120 Scintillation Linearity

Discussion and Future Work

The additives in this sample increased the gamma interaction rate and decreased the decay time to create a high efficiency specimen that exceeded all three metrics:

- 56% light transmission
- Clear photopeak and Compton Edge
- 99.69% detector linearity

While linearity breaks down in low energy ranges, this sample shows promise for large-scale gamma discrimination. Potential future work in this field would include slightly altering the sample composition in order to reap a higher light yield. Even slight changes in preparation techniques or conditions can lead to different polymerization processes and properties, so future research would help to correlate relevant changes.

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.
SAND No. 2011-XXXXP

U.S. DEPARTMENT OF ENERGY

National Nuclear Security Administration