Temperature-Dependent Photoluminescence of PEDOT:PSS for use as Transparent Electrodes in Time Projection Chambers

May 27, 2024
Nick Swidinsky, Emma Ellingwood, Jon Hucker
Philippe Di Stefano, Peter Skensved
Dual Phase Detectors

- Two-phase noble liquid detectors produce two signals per event [4]:
  1. **S1**: Initial particle interaction with liquid producing scintillation light.
  2. **S2**: Signal produced by drift electrons created by the initial interaction and accelerated by an electric field.

- Electrodes need to be transparent so that scintillation light can be detected.

TPC schematic diagram
Clevios

- Clevios is a conductive polymer that is optically transparent in thin films.
- Will be used for the electrodes in DarkSide-20k.
- Testing the fluorescent properties of Clevios in our optical cryostat.

<table>
<thead>
<tr>
<th>Layer</th>
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<tbody>
<tr>
<td>Photodetectors (SiPMs)</td>
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<tr>
<td>Transparent vessel (Acrylic)</td>
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<tr>
<td>Electrode (Clevios)</td>
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<tr>
<td>Wavelength shifter (TPB)</td>
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<tr>
<td>Scintillation Medium (LAr)</td>
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</tbody>
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Order of coatings on the acrylic vessel for DarkSide-20k. Layers not to scale.
Experimental motivation

- Fluorescent properties of acrylic (PMMA) and 1,1,4,4-tetraphenyl-1,3-butadiene (TPB) have been studied in our lab [2, 3].
- Previous studies have indicated that Clevios may fluoresce, with maximum fluorescence occurring under UV excitations [5].

Fluorescent emission of Clevios under different excitation energies. Figure from Koyama et al [5].
Samples – Acrylic

- Acrylic samples are used to mimic the conditions within the detector.
- Samples are cut into shapes that will fit into our optical cryostat.
- Four samples are created:
  - Blank acrylic
  - 3 µm TPB
  - Thin Clevios (≈ 40 nm)
  - Thick Clevios (≈ 175 nm)

**Top:** Schematic of acrylic substrate.

**Bot:** TPB coated acrylic sample fluorescing under UV excitation.
Samples – Fused Silica

- Fused silica samples are used to study the spectral properties of Clevios independent of acrylic.
- three samples are created:
  - Blank fused silica
  - Thin Clevios ($\sim 50$ nm)
  - Thick Clevios ($\sim 185$ nm)

Uncoated fused silica sample.
Absorbance Spectra

Absorbance spectra of Clevios coated Fused silica samples. Vertical lines are the excitation energy used for time resolved (267nm) and emission spectra (260nm).
Emission Spectra Apparatus – Cryostat

Schematic diagram of the apparatus used for emission spectra.
Emission Spectra Results – Cryostat

- All samples taken with the same excitation.
- No distinguishable peaks from Clevios.
- Temperature dependence follows trend seen previously in acrylic.

Emission spectra for blank acrylic, thick Clevios, and thin Clevios at 300K, 87K and 4K.
Schematic diagram of the apparatus used to take same side emission spectra.
Emission Spectra Results – Same Side

A: LED
B: Acrylic additive
C: Clevios
   Fluorescence
D: Acrylic
   fluorescence
E: LED harmonic

Emissions spectra for Clevios on acrylic substrates (top) and fused silica substrates (bottom)
Time-resolved – Apparatus

Schematic diagram of the apparatus used to take time-resolved measurements
Time-resolved – Analysis

Integral histogram from the thick Clevios sample. Fit has been done to determine the Single Photo Electron (SPE) value.
Light yield of each sample’s fluorescence relative to TPB as a function of temperature.
Conclusion

- Clevios fluoresces around 350 nm.
- Fluorescence from Clevios is small when compared to the acrylic substrate, which itself is very small compared to TPB.
- Further work is needed to fully characterize the fluorescence from the Clevios independent of the acrylic.
- Manuscript currently under internal review.
References


References II


References III


Backup Slides
Clevios Extended analysis

- Quantify the amount of fluorescence coming **only** from the Clevios.
  - Majority of fluorescence is coming from the acrylic.
  - Use optical properties of the Clevios to determine how much fluorescence there is from the acrylic.
Acrylic fluorescent model

- Fluorescence quantified using intensity.
- Linear fluorescent model
Each Clevios thickness has a quantified transmission.

The blank acrylic sample can be used to model how much fluorescence comes from acrylic from a given excitation.
Light Yield Results – Acrylic Subtracted

![Graph showing light yield results for different samples as a function of temperature. The graph includes data points for Acrylic, Clevios thin, Clevios thick, Clevios Thin - acrylic subtracted, and Clevios Thick - acrylic subtracted.]
SPE Fitting Model

\[ S_r(\varepsilon) = \sum_{n_1, n_2=0}^{\infty} \sum_{k_1=0}^{\infty} \frac{m_1^{n_1} e^{-m_1}}{n_1!} \frac{m_2^{n_2} e^{-m_2}}{n_2!} \frac{(n_1 \ast k)_{k_1} e^{(-n_1 \ast k)}}{k_1!} \]

\[ \ast \frac{1}{\sqrt{2\pi(s_0^2 + (k_1 + n_2)s_1^2)}} e^{-\frac{(\varepsilon - (x_0 + (k_1 + n_2)x_1))^2}{2(s_0^2 + (k_1 + n_2)s_1^2)}} \]

Model used to fit the SPE histogram [6].
Acrylic Absorbance

absorbance measurements from samples with acrylic substrates.