SORMA West 2008 – Supporting Material for "Correlation of Proton and Photon Induced Conductivity of a Poly(*p*-phenylene vinylene) Derivative"

By Wilson, Chinn, Morse, Antolak, Olsen, and Doty

Semiconducting polymers have been shown to be sensitive to radiation, and a patent has been issued for this development [1]. Using a film of substituted poly(*p*-phenylene vinylene), $OC_{10}PPV$, we have demonstrated a distinct ion-induced conductivity transient response using the Sandia 3 MeV tandem accelerator in Livermore, CA, as shown in Figure 1 below. For comparison, the photoconductivity transient results are also shown for the same sample, using a 590nm laser. The charge collection efficiency is calculated assuming 1000 ion pairs per micron of track length, a polymer band gap of 2.5 eV, and the observation that 3 to 4 times the gap energy is required to produce an ion pair in typical crystalline semiconductors.

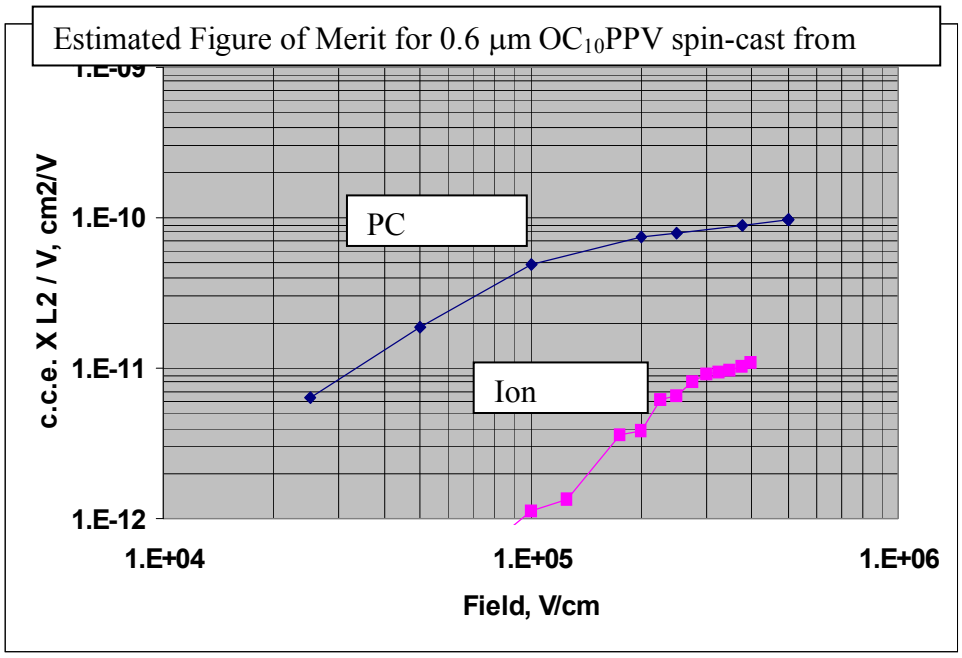

Figure 1. Figure of merit using 3MeV proton beam stimulus, showing photoconductive (PC) transient with 590nm laser for comparison.

Though the ion transient appears lower than expected based on photoconductivity, the two curves can be brought into excellent agreement by assuming either higher quantum efficiency for photo-generated carriers, lower dE/dx for protons in the polymer, or larger energy dissipation per ion pair in the polymer, which would be in agreement with Birk's rule for light output in plastic scintillators. Disregarding the efficiency calculations and related assumptions, the maximum total charge collected thus far was approximately 20 electrons per micron of track length in the polymer, demonstrating a definitive proof of concept, and encouraging further evaluation of the use of this material for radiation detectors. This indicates that direct electronic detection of single fission neutrons is feasible in conjugated polymer-based detectors using standard laboratory electronics or available ASIC readouts at room temperature.

System gain is shown in Figure 2 below for a 0.6μm thick film. The gain is near one with 50 Volts, indicating that the device can be operated at this relatively low voltage. This plot can be shifted with modification and optimization of the film thickness.

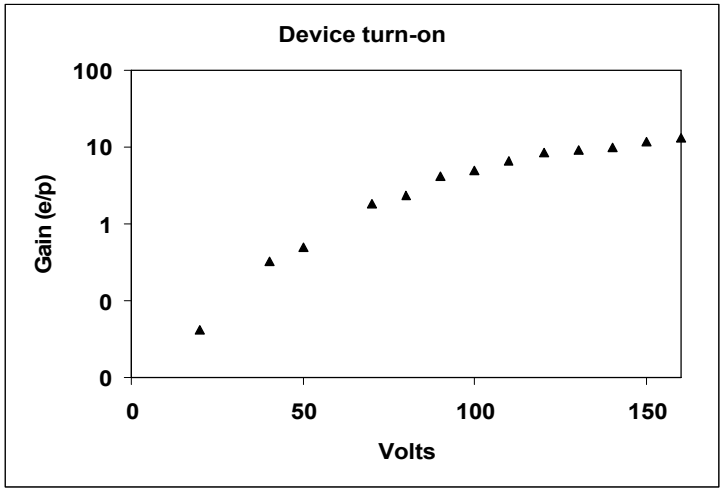

Figure 2. Gain as a function of bias voltage for a 0.6μm thick film of OC10PPV in a proton beam.

The polymer film was also tested for ion-induced degradation of the response, and the results are displayed in Figure 3 below, for two different locations. The onset of degradation appears to occur at an absorbed dose of about 1 Mrad, which is similar to the dose that typically degrades thin plastic scintillator films.

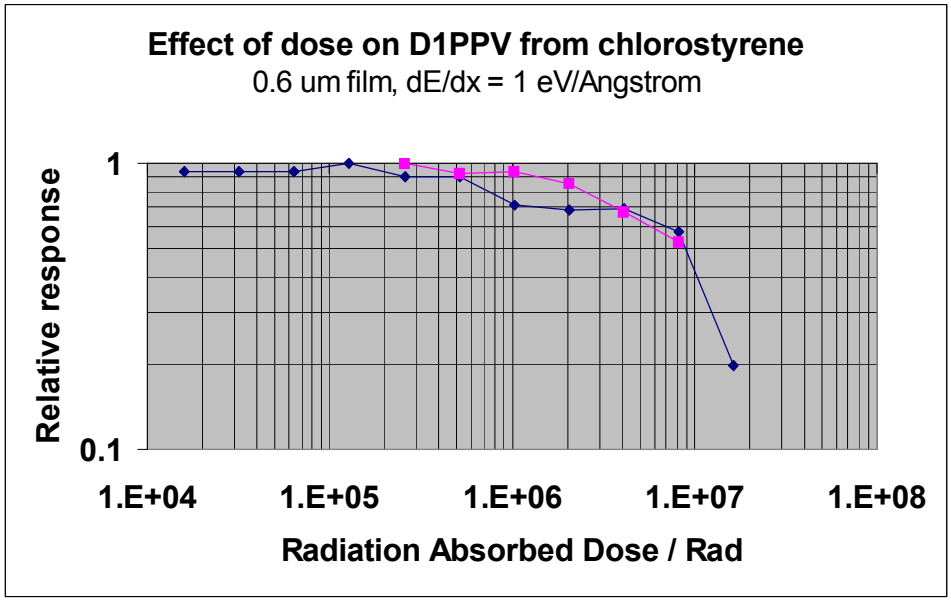

Figure 3. Proton radiation tolerance of OC_{10}PPV device, tested in two locations. Mrad radiation tolerance is comparable to plastic scintillators, proving the viability of organic semiconductor detectors for the proposed application.

We have demonstrated the viability of using π-conjugated organic materials for neutron detection and show that the material property improvements can be tested via photoconductive response and correlated to neutron response. Additional work is being done to improve carrier mobility, and thus charge collection, to improve detector performance.

[1] F. Patrick Doty and Douglas A. Chinn, United States Patent No. 7186987 (March 6 2007).