

# ORGANIC SEMICONDUCTOR RADIATION DETECTORS FOR ALPHA AND NEUTRON DETECTION

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## NUCLEAR SECURITY

- Portal detectors at ports and airports
- Neutrons are not easily shielded like other types of radiation such as alpha, beta, and gamma
- Global shortage of <sup>3</sup>He means the typical method of using this material in proportional counters is not viable for widespread long-term neutron detection

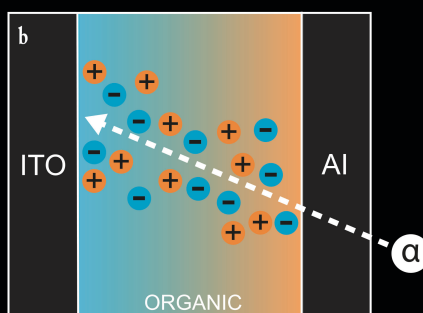
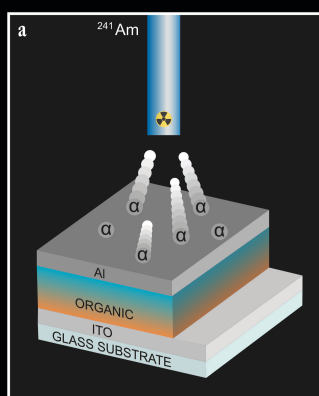


Figure 1: a) Composition of simple "diode-style" devices. b) Formation of electron-hole pairs in organic medium of devices irradiated by alpha radiation (modified from [1]).

## ORGANIC SEMICONDUCTOR DEVICES

- Scalable manufacturing processes
- Tunable devices
- Cheap and abundant supply
- Organic material can be used to make alpha radiation detectors
- Largely beneficial if they can be modified to detect neutrons as well

## CARBORANE-NDI

- <sup>10</sup>B has a high interaction cross section with thermal neutrons
- Carborane: a polyhedral cluster of carbon, boron, and hydrogen
- Carborane-NDI: a variant of PNDI organic polymer with carborane directly incorporated in the molecular backbone
- Novel material never before tested with radiation detection
- Boron interacts with neutrons via boron-neutron capture, resulting in <sup>7</sup>Li and an alpha particle
- *o*CbT<sub>2</sub>-NDI and *p*CbT<sub>2</sub>-NDI isomer device tested by irradiation from 370 kBq <sup>241</sup>Am source of alpha radiation
- Successful detection of alpha particles, it should therefore work with neutrons

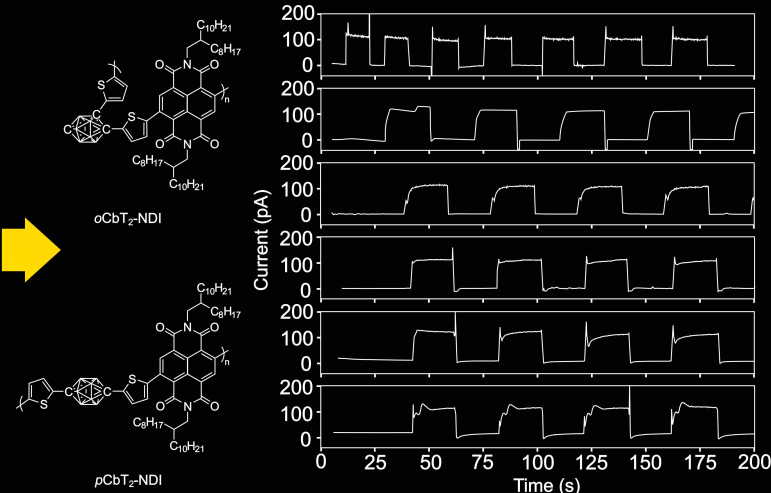


Figure 2: Left: Chemical composition of two isomer forms of carborane-NDI polymers (taken from [2]). Right: Baselined alpha response of *o*CbT<sub>2</sub>-NDI device after one, two, twenty-four, fifty-nine, and one hundred days in air (top to bottom).

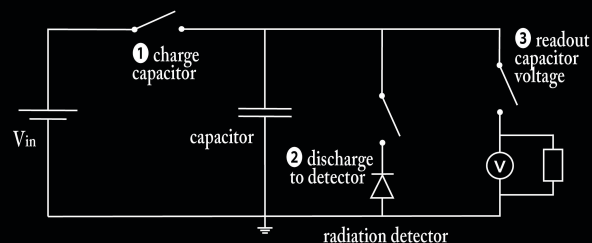


Figure 3: A circuit diagram of a single detector-capacitor system. Switches and voltage readout done by multiple channels of a multiplexer. This diagram may be scaled to include multiple capacitors, detectors, and readouts, all working together.

## ARRAY OF DETECTORS

- An array of detectors may be used to detect over a larger area
- Multiple detectors working together can triangulate a signal
- Capacitor bank to integrate charge over time, allowing higher signal-to-noise ratio and standoff distance
- Readout by a microcontroller such as Arduino or Raspberry Pi Pico

[1] Taifakou, F. E. *et al*, Solution-Processed Donor-Acceptor Poly(3-hexylthiophene):Phenyl-C61-butylric Acid Methyl Ester Diodes for Low-Voltage  $\alpha$  Particle Detection. ACS Appl. Mater. Interfaces **2021**, 13, 5, 6470–6479.

[2] Anié, F. *et al*, N-type polymer semiconductors incorporating para, meta, and ortho-carborane in the conjugated backbone, Polymer **2022** 240 124481