Organic Electronic-based Neutron Detectors

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In memory of our friend and collaborator, Dr Theo Kreouzis, who helped pioneer this work.

Abstract:

Scalable semiconductor neutron detectors are desirable for a range of applications from beam diagnostics and imaging through to homeland security applications. We report on organic electronic based semiconductor neutron detectors. These are fabricated using readily available cheap techniques and materials.

Detectors:

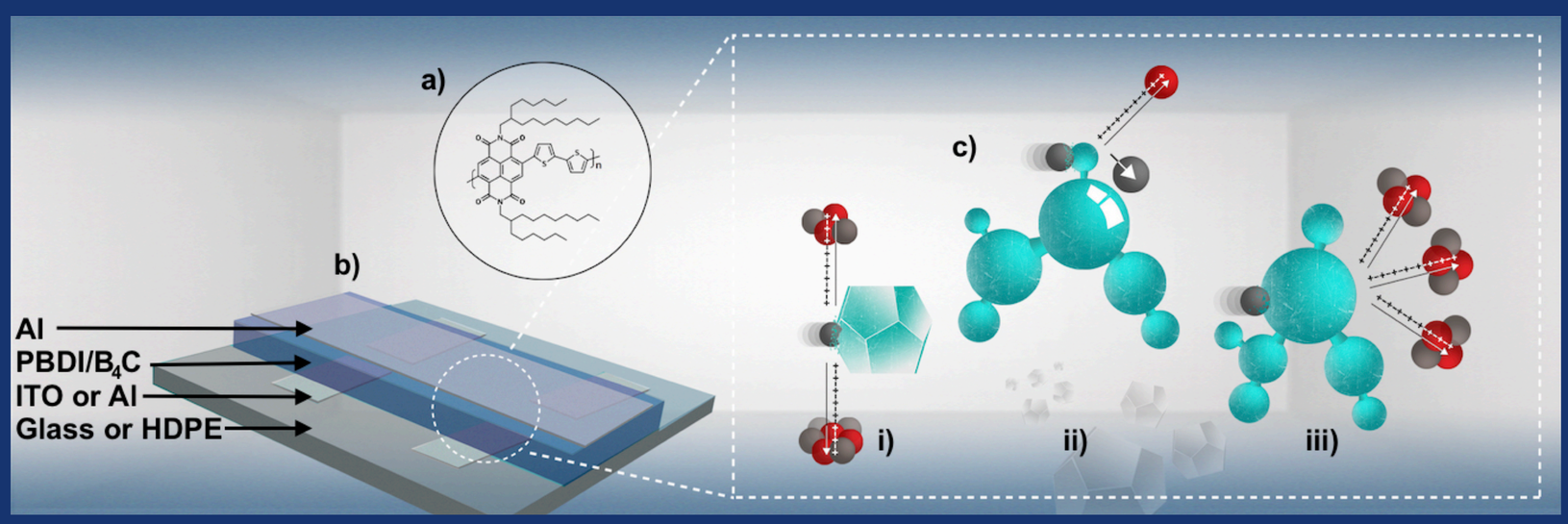
Organic semiconductors like PNDI (naphthalene based polymers) have been studied in detail as hadronic radiation detectors in the laboratory and at the National Physical Laboratory (NPL) neutron test facility in Teddington (UK) [1, 2]. These systems are drop cast on substrates.

Substrates tested:
Glass, HDPE, LDPE, Kapton

Organics tested:
P3HT, PNDI(HD/OD), Carborane

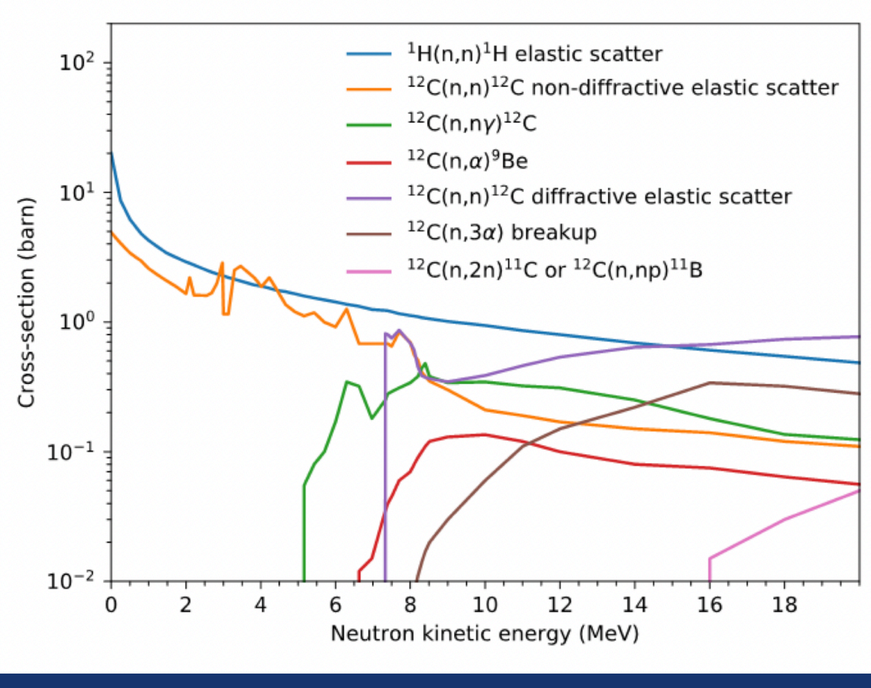
Structures tested:
Diode [1,2,3], FET, and diode+FET [4]

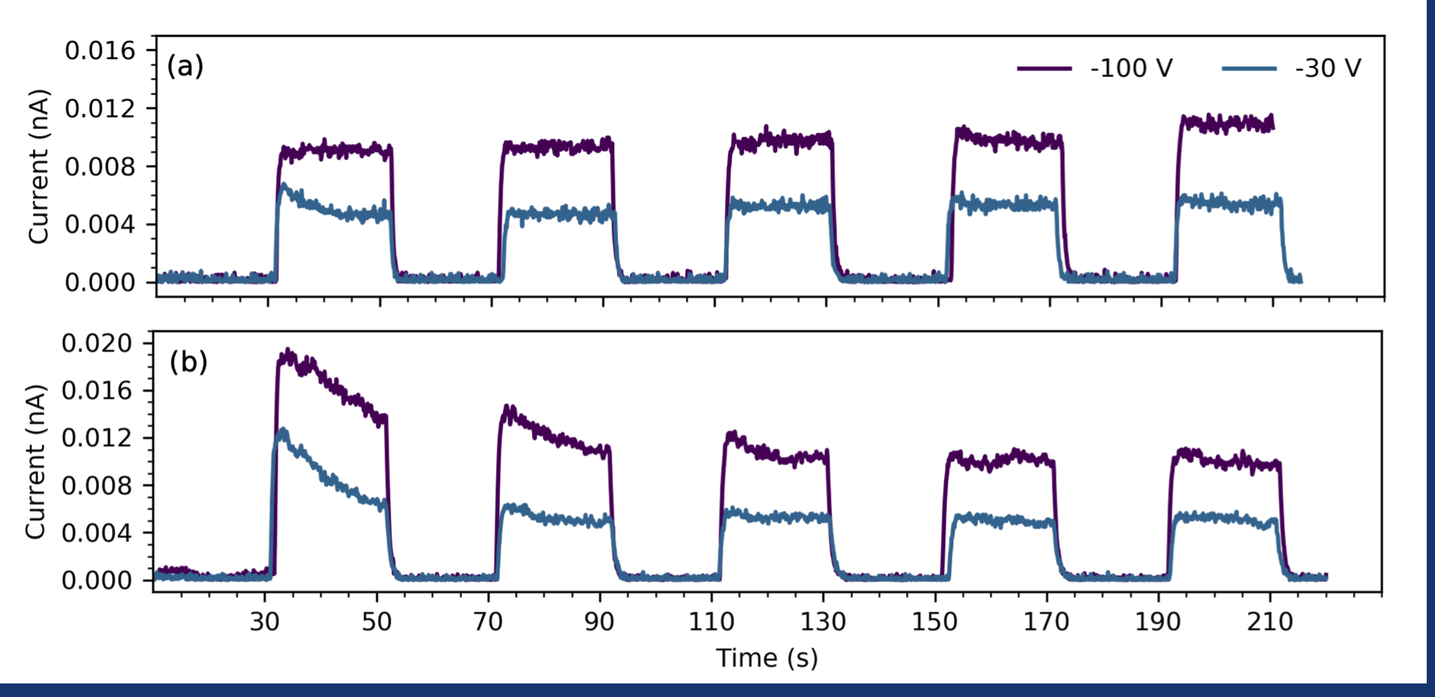
Solution processed and cheap
1m² of organics costs ~£1,000



Fast neutron detection:

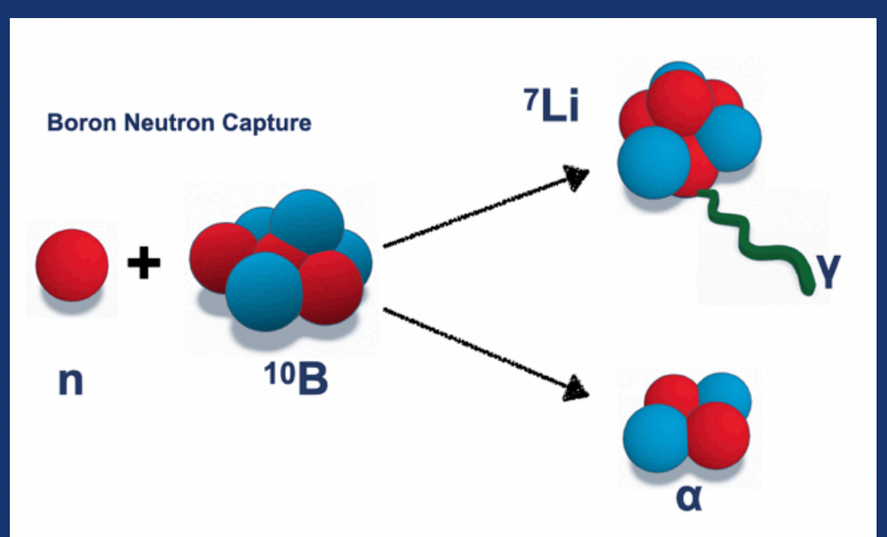
Verified using 0.565 and 16.5 MeV neutron beams and an AmBe source at NPL. The hydrocarbon results in proton and carbon recoil signals at low energies. At higher energies nuclear processes open up, making interpretation of signals more complicated. No sensitivity to thermal neutrons, so only see faster neutrons.





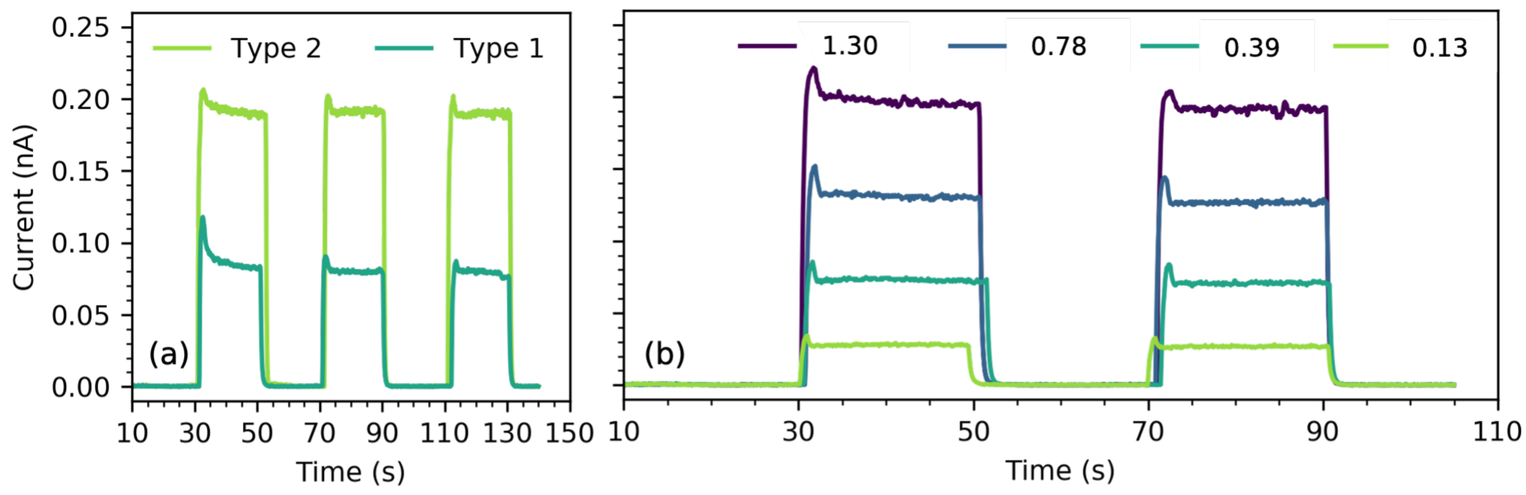
Thermal neutron detection:

Add ^{10}B enriched material as "dirt" to the active region of the sensor [2], or use carborane based polymers with ^{10}B in the backbone of the molecule [3]. These devices measure fast+thermal response - paired with a fast neutron detector we can extract the thermal neutron contribution.



- **Type 1: Fast Neutron Detectors (as above)**
- **Type 2: With ^{10}B added**
- **Thermal neutron signal is the difference between the two**

- **Total response for thermal neutron sensors shown for different beam flux**
- **Linear scaling from 0.13 through 1.3 × 10⁷ n/s/cm²**



Applications:

The current level of technology can be used for fast neutron cameras. Potential use cases include neutron facilities like ISIS in the UK, accelerator facilities such as the DESY test beam, or at particle colliders like SuperKEKB where neutron backgrounds are present. We are currently working on the development of such a system.

[1] F. E. Taifakou et al., ACS Appl. Mater. Interfaces 2021, 13, 5, 6470–6479.
[2] J. Borowiec et al., arXiv:2212.08438.
[3] A. Horner et al., in preparation.
[4] A. Z. Choudhry et al., in preparation.

https://www.qmul.ac.uk/spcs/collaborative-research-centres/detector-development/

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