Polymer Based Radiation Detectors

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Laboratory Capabilities in Istanbul University-Cerrahpasa, Institu of Nanotechnology and Biotechnology

Two Main Laboratory Section

- Nanotechnology and Biotechnology (16 Lab)
- Experimental Medicine Research Laboratory (18 Labs)

- Nanotechnology and Biotechnology (16 Lab)
- 200 m^2 Clean Room
- RIE, PVD, CVD, Sputter, SEM (Nanolithography Stage), Maskless Lithograhy, AFM
- Chemical Labs
- X-Ray Char. Lab. (XRD&XRF)
- Optical Characterization Lab. (2 Laser Source and two monochromator)
- Electrical Char. Lab. (Keithley SCS4200, Four Point Probe, Electrometer, …)
- Infrared Spectroscopy (FTIR & Dispersive Raman)
- Epitaxy Lab (E-Beam & Molecular Beam Epi.)
- Cell Culture
- Histology

İSTANBUL ÜNİVERSİTESİ CERRAHPAŞA

Experimental Medicine Research Laboratory

- 18 Labs
- > 600 Live Animal (Rats, Mice and Rabbits)
- Transgenetic Animals (Mice)
- Rontgen Room
- Operation Rooms
- Living Rooms
- Intensive Care Rooms
- Quarantine Rooms
- Behaviour Labs

Polymers

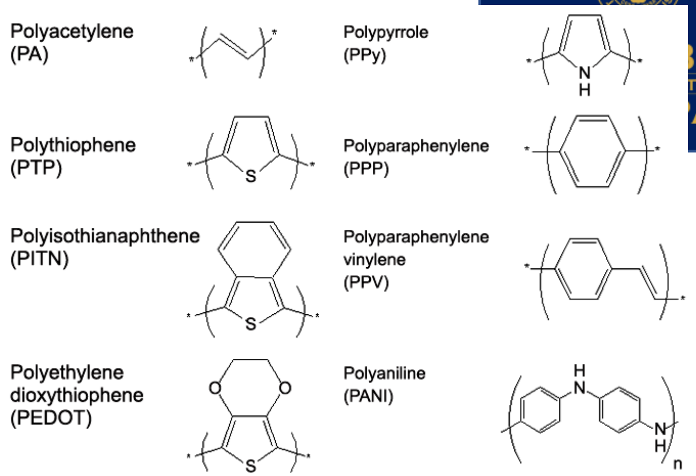
- Until 1970s, Polymers was known as insulating materials
- At 70s, Science and technology reached to a milestones and so a new materials was discovered
- Nobel Prize in 2000
- Organic Semiconductors as (polyacetylene, (CH)x)

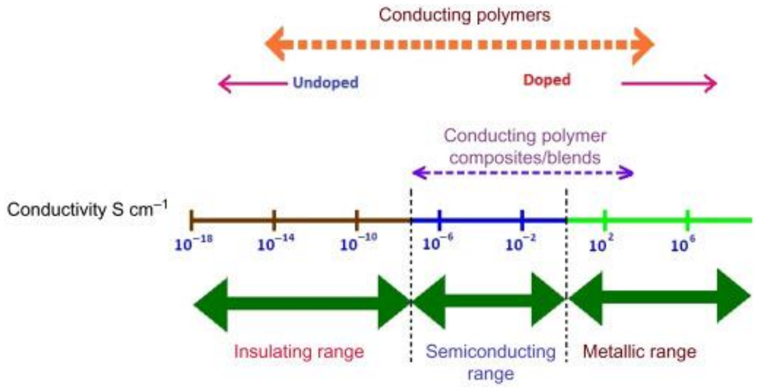
- Advantages
  - Metallic and semiconducting properties by doping
  - Combination of plastic with electronic properties
  - Solubility in organic solvents, variable processibility
  - Use of printing technologies
  - No vacuum and no high temperature processes

  Low-cost production

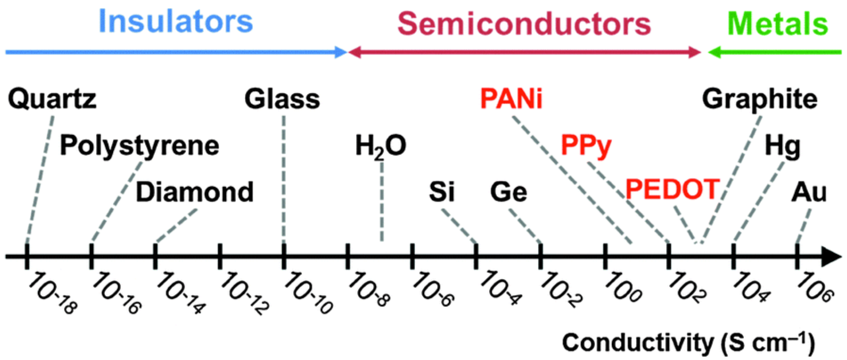
- **Disadvantages**
  - Low integrated devices and circuits (in the very near future)
  - Degeneration in O2- and H2O-atmosphere

  Long-term stability is still a critical point



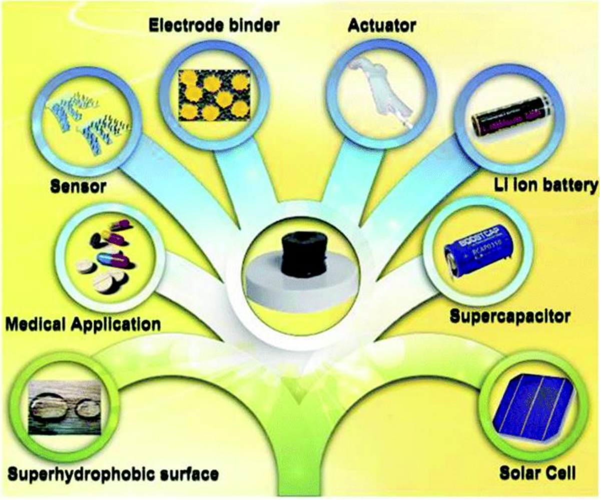


Nobel Prize in 2000



Applications of Conductive Polymers

- After 2010, conductive polymers was used for detection of ionizing radiation started with X-Ray
- Detection of γ *(gama)* radiation and also β *(Beta)* and α (Alpha) particle radiation is still a mystery
- Moreover, Published paper on this topic is very limited about fabrication of devices and detection mechanism
- ~340 Scientific papers on Web of Knowledge
  - Keywords: Polymers+Radiation+Dedectors
  - Nearly %30 out topic about ionizing radiation



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ELSEVIER

A novel radiation detector based on Gd_2O_3 doped organic semiconductor for the detection of γ and β-particles

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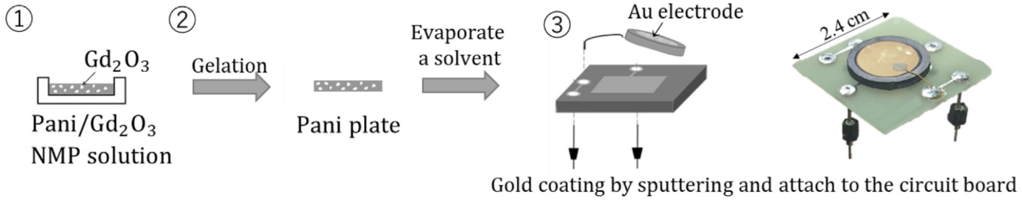


Fig. 1. Fabrication process of the organic semiconductor radiation sensor.

1. To reduce the detector costs and to find a suitable alternative to large inorganic semiconductor detectors, which are difficult to fabricate
2. Organic semiconductor sensors have reported detection efficiencies of 30% for α-particles and of 1%–10% for β-particles
3. The density of the Pani/Gd2O3 hybrid was 1.5 times higher than the density of the Pani. Its detection efficiency for γ-particles improved by approximately four times.

Our Experimental Works

- Blended Conductive Polymer Structure
  - Poly(3-hexylthiophene) (P3HT)
  - Phenyl C61 butyric acid methyl ester (PCBM)
- Different Molar ratios of Polymers in Blended Structure
  - P3HT:PCBM
  - as (1:0), (1:0.5), (1:1), (1:2)
- Bulk Resistive Heterojunctions
- Non-Metal Top Contact
  - Soluable Graphite Electrode
- Structural and Electrical Characterisation
- X-Ray Detection

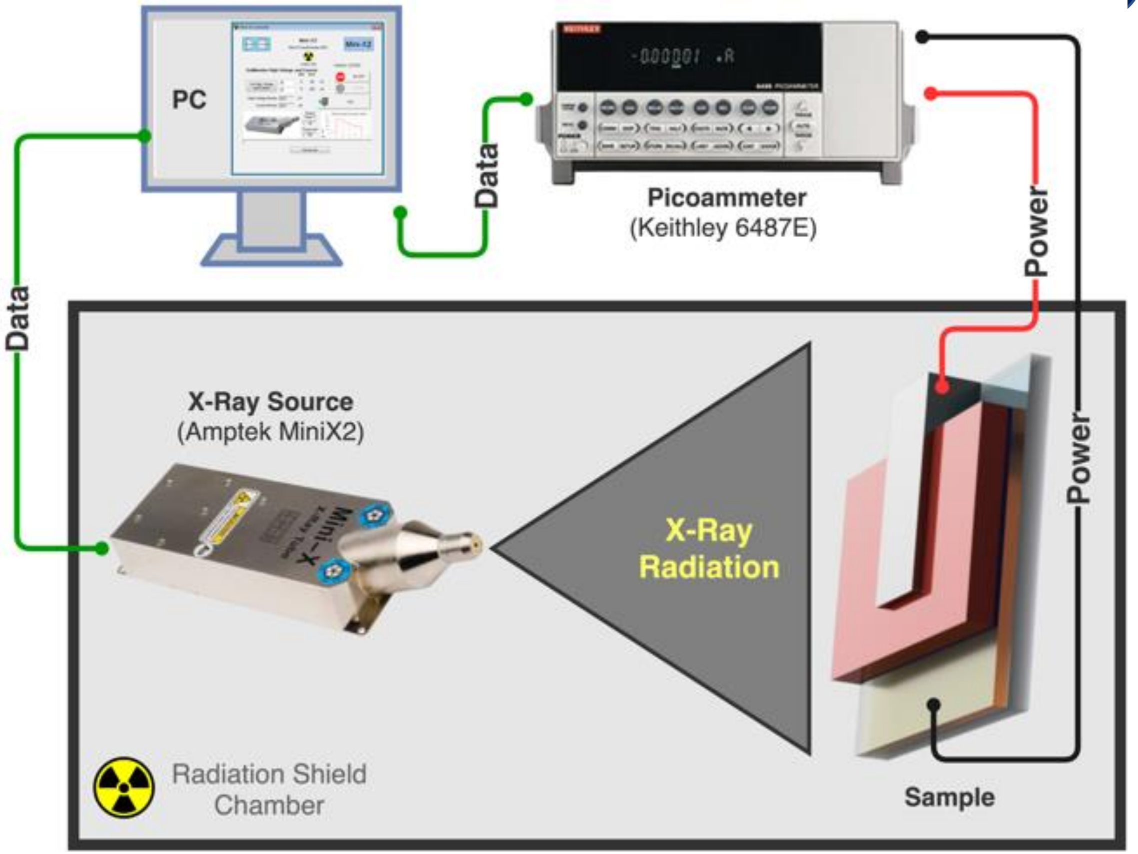
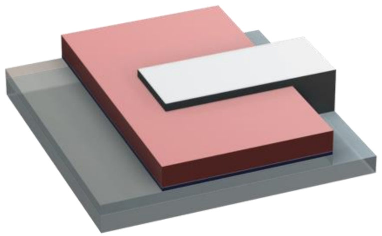
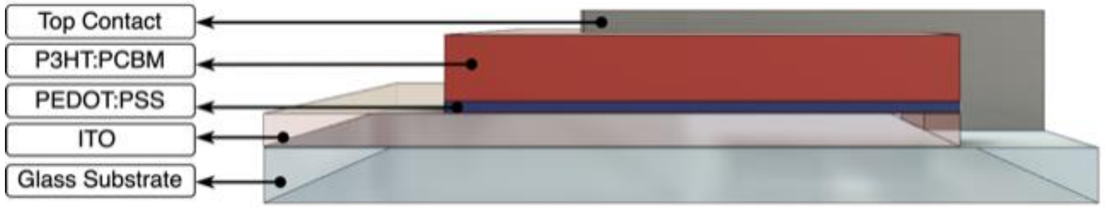


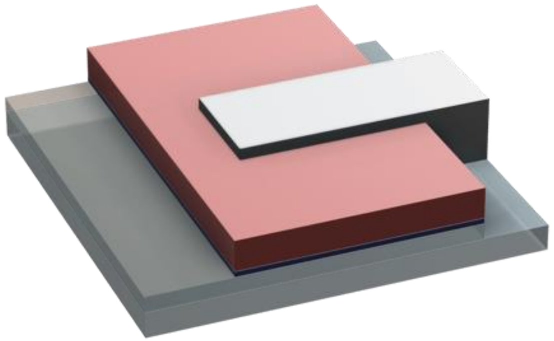
Figure 1: Schematically illustration of the X-Ray Measurement Set-up





Results

- SEM
- FTIR Analysis
- Electrical Characterisation



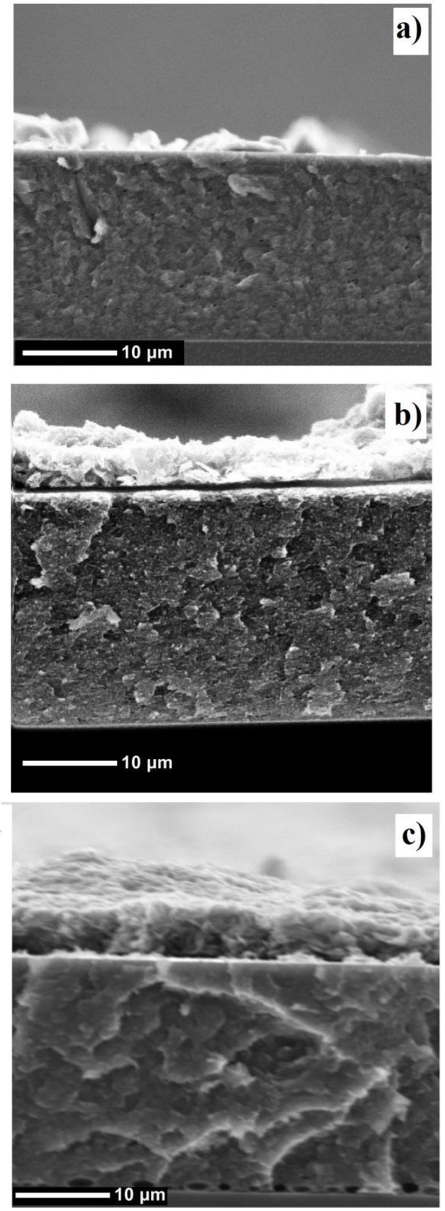


Figure 2: SEM images of the PCBM loaded P3HT for different concentration of P3HT:PCBM mixtures a) 1:0.5 b) 1:1, c) 1:2.

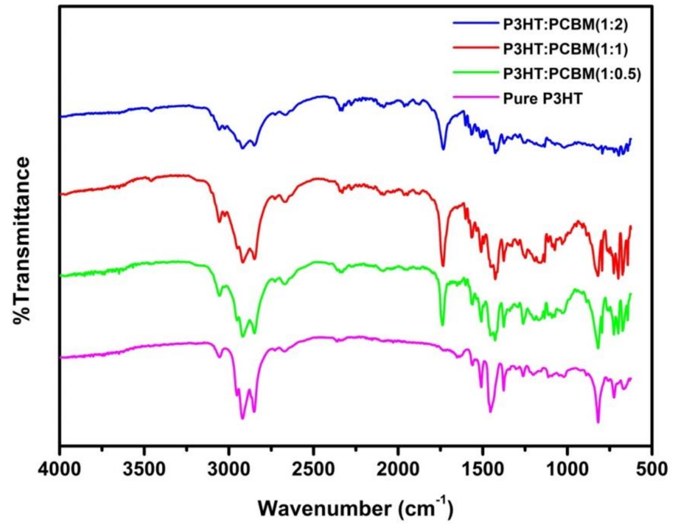


Figure 3. FTIR spectrum of the polymer materials

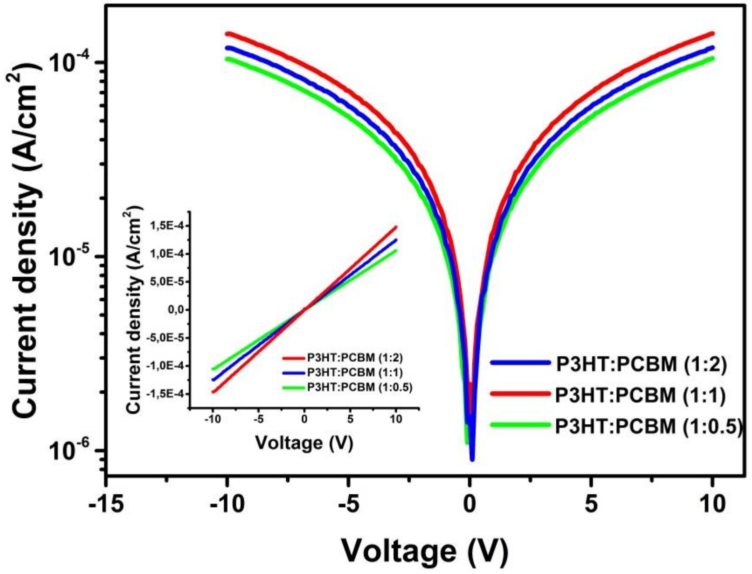
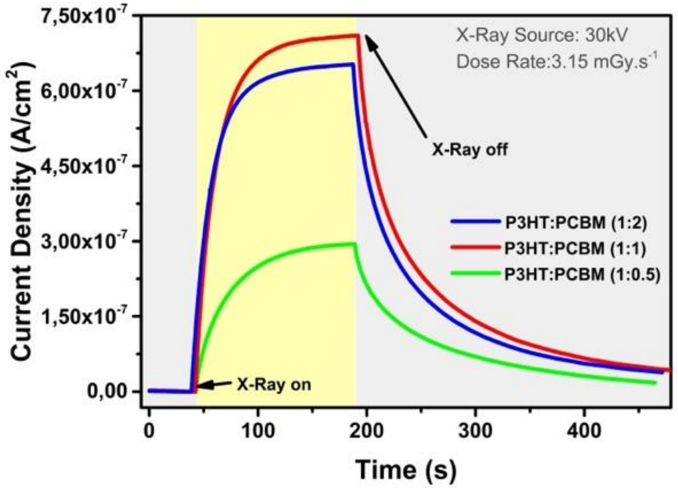
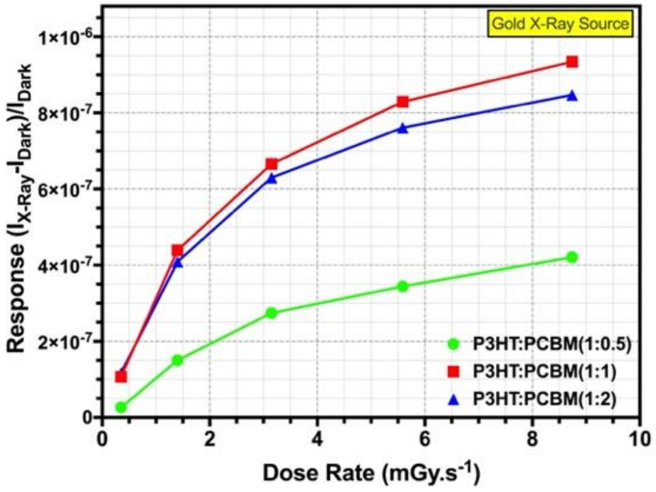


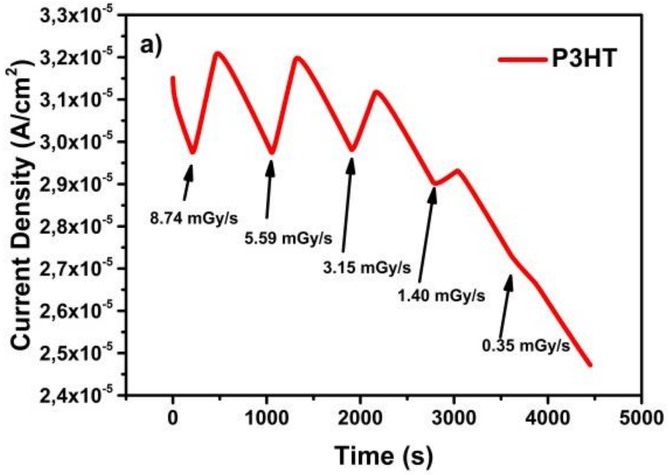
Figure 4: Current-Voltage Characteristic of the fabricated devices under dark conditions

Results: Photocurrent Responses

- X-Ray Radiation Dose Rates (*mGy.s*$^{-1}$)
  - 8.74-5.59-3.15-1.40-0.35
- On X-Ray Time
  - Pure P3HT: 300s
  - P3HT:PCBM Blend: 150s
- Off X-Ray Time
  - Pure P3HT: 150s
  - P3HT:PCBM Blend:300s







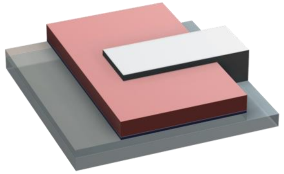


Figure 5: X-ray photocurrent responses of fabricated pure P3HT

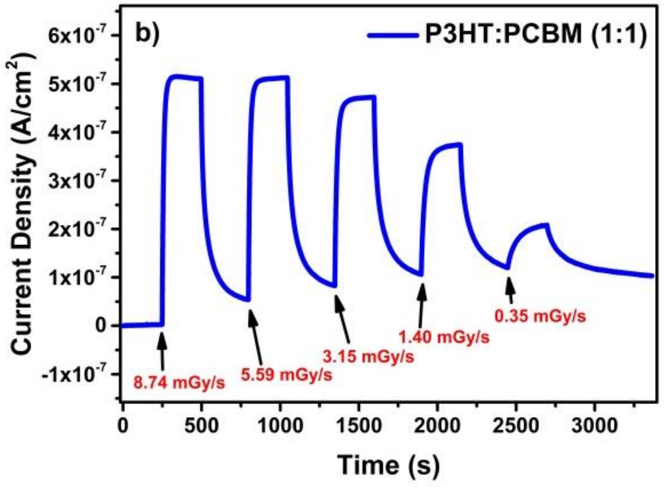


Figure 6: X-ray photocurrent responses of fabricated pure P3HT, P3HT:PCBM bland structure devices

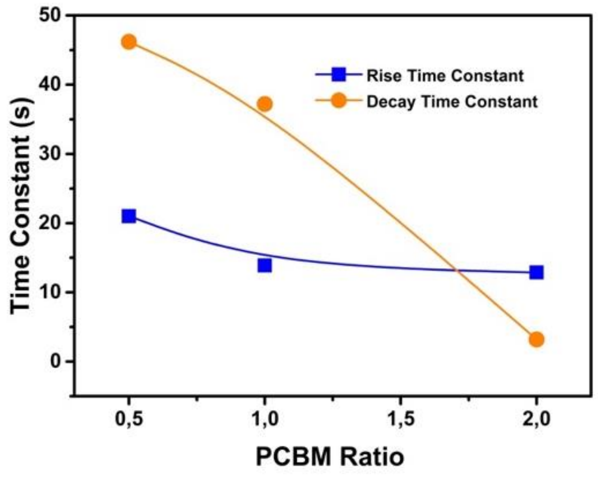
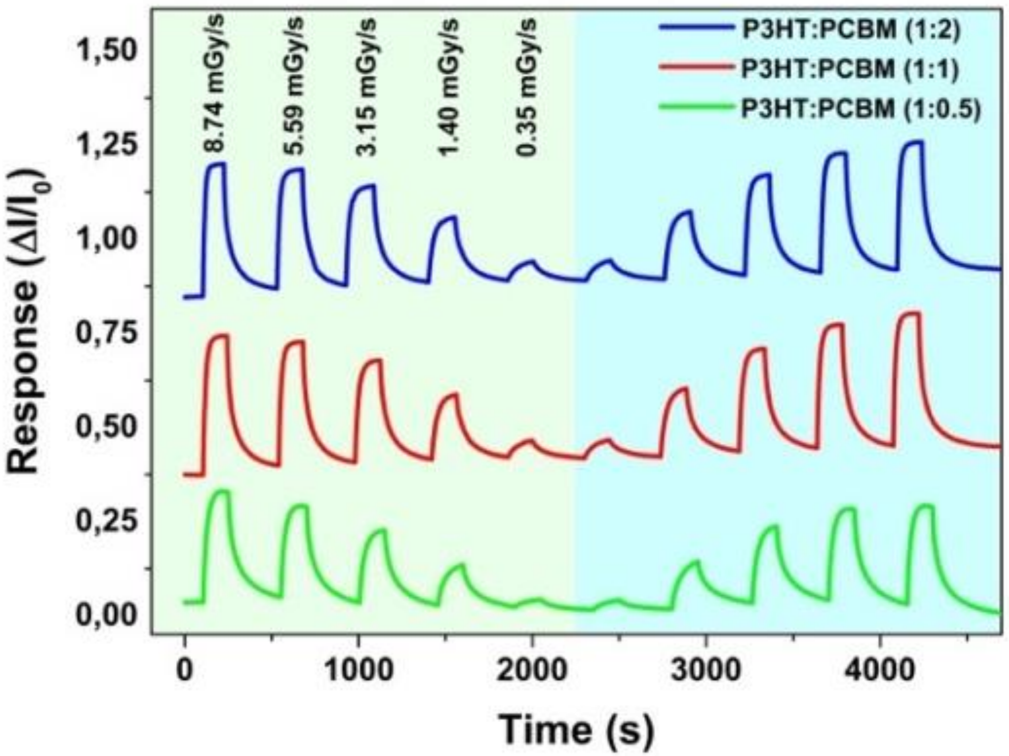
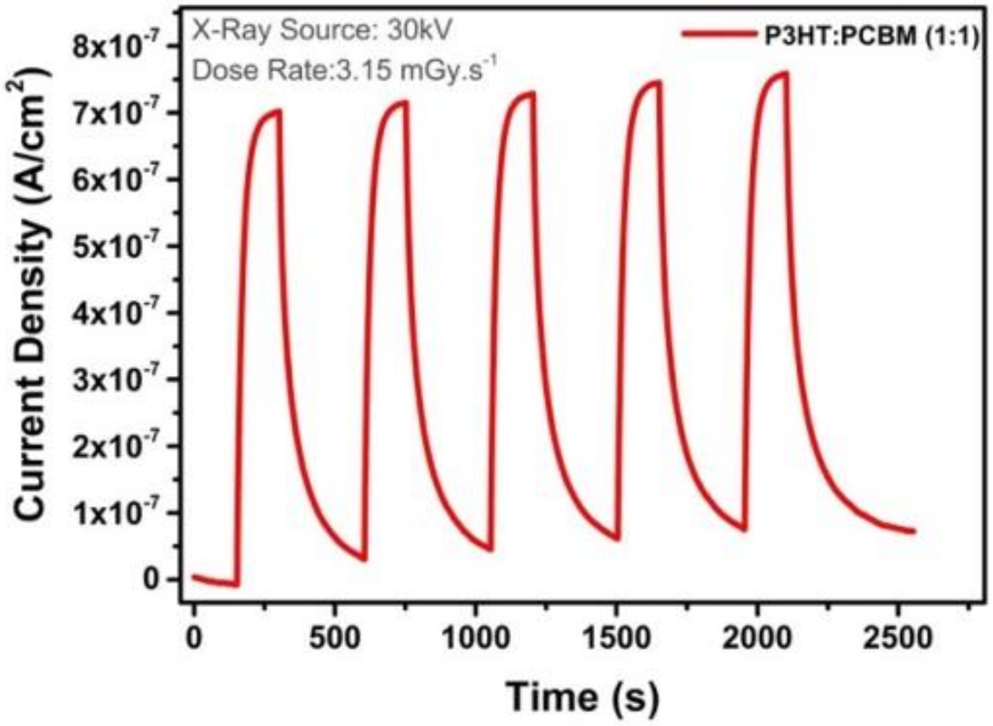


Figure 7: Response versus Dose rate graphs for different PCBM loading ratio (a) and Rise and decay time constants for devices with increasing PCBM loadings under 10 V bias (b).

Results: Repeatibility of Photocurrent Responses over X-Ray Measurement

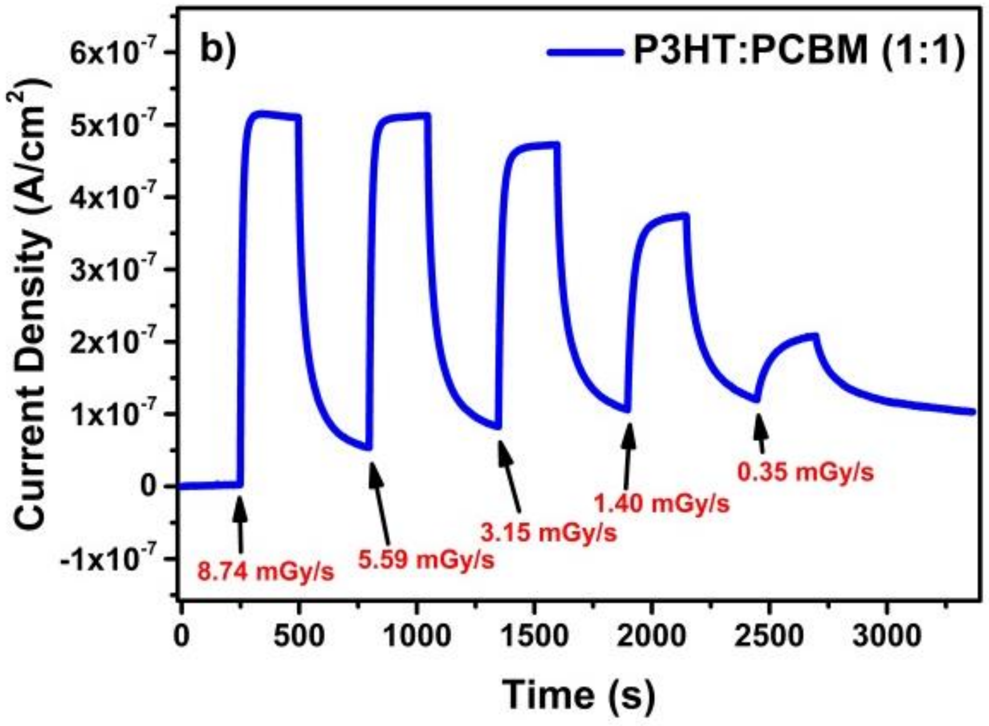
- Investigated three blended polymer based devices
- Max Dose Rate to Min Dose Rate and then Min Dose Rate to Max Dose Rate
- On/Off X-Ray Test

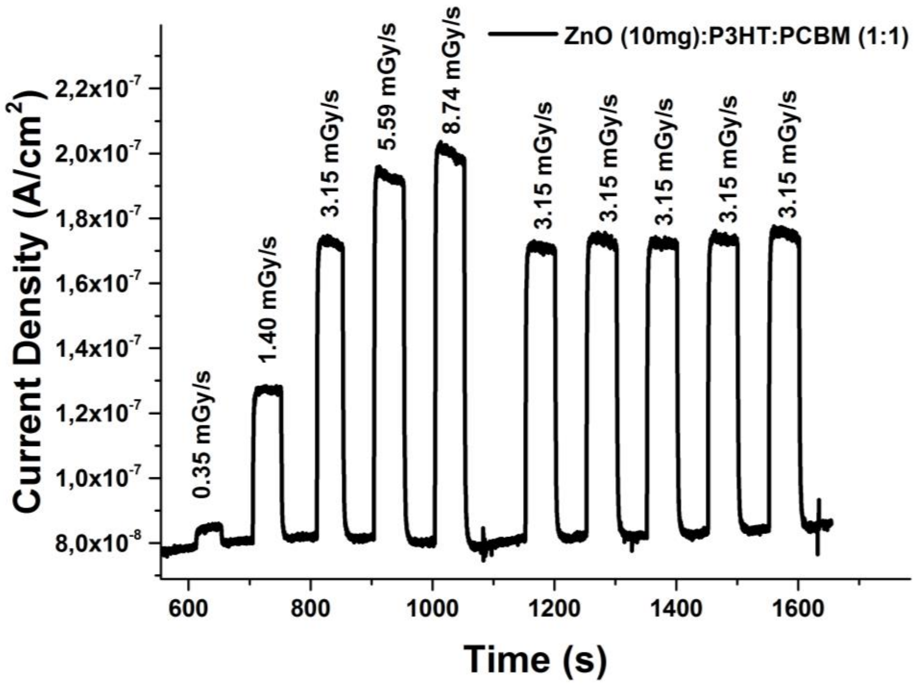




Nanoparticle Modified Polymer Based X-Ray Dedections

- ZnO nanoparticles added in the P3HT:PCBM mixture
- Response times decreases with ZnO nanoparticles (50nm-60nm)





Rise Time (t_{90}):22s

Decay Time (t_{90}): 48s

Rise Time (t_{90}):0.79s

Decay Time (t_{90}): 1.34s

Future Plans

- Investigation of New Polymer Materials and Combination on Ionizing Radiation
- Medical Aplications
- Effects of Nanoparticles: Materials, Size and Ratio
- Detection of Gama, Alpha and Beta Radiation with Polymer Based Device
- Polymer Based Radiation Detector Arrays with MEMS Technology
- Hard Radiation
- Collobration with RD50 and Joining

Expected Advantages of the Collaboration

- Expanding the Application Area of Radiation Detection of Polymers
- Common Projects with Other Members
- Opportunities for new graduate students
- International Usability to Our Laboratories and Technical Facilities
- Opportunity to Test Our Developed Detector Prototypes (Test Beam etc.)
- Using Laboratory, Library and Computer Server Structures at CERN