Biocompatible photosensors based on crystalline organic semiconductors

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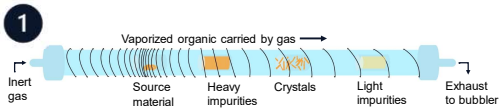
Motivation and Objectives

Photoactive organic semiconductors combine light absorption and photogeneration with light weight, mechanical flexibility and intrinsic biocompatibility → ideal for **biological photodetection applications** (e.g., visual prosthetics) [1,2].
Organic single crystals (SCs), with long-range periodic molecular order and high chemical purity, stand out for their reduced energetic disorder, enhanced charge carrier mobility, and well-defined optical transitions → ideal for stable, wavelength-specific light detection [3,4].

This work focuses on the **fabrication** and **characterization** of **biocompatible photodetectors** capable of **RGB** light sensing with three distinct narrowband **organic semiconductors** in **crystal** form:
- Rubrene, targeting the green-yellow region (~500–550 nm)
- PTCDI-C8 in the orange-red region (~550–600 nm)
- TCNQ for the violet-blue region (~400–450 nm).

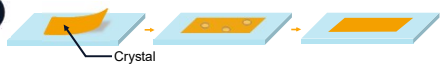
Single Crystal device fabrication
Rubrene and TCNQ

1



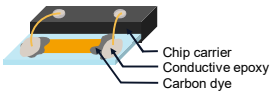
Rubrene and TCNQ SCs are grown using **Physical Vapor Transport** (PVT)

2



Once selected, SCs are **laminated** onto a **glass substrate**

3

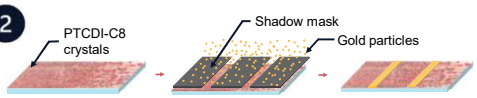


Devices are assembled with metal contacts through **wire-bonding**

Crystalline film device fabrication
PTCDI-C8

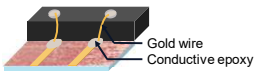
1 PTCDI-C8 crystals are directly grown on the glass substrate using **Physical Vapor Transport** (PVT)

2



Gold contacts are **deposited** using a shadow mask

3



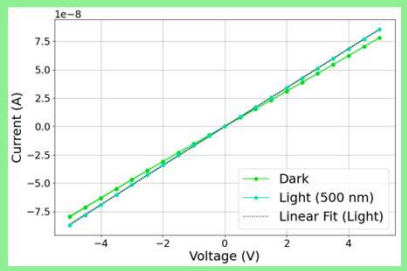
Devices are assembled with metal contacts through **wire-bonding**

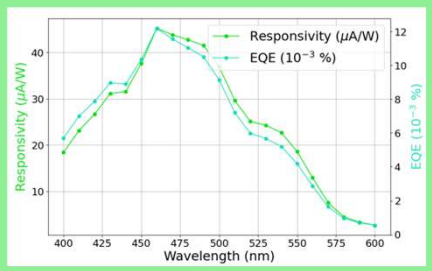
Conclusions

- The results validate the **potential of organic single crystals** (**rubrene** and **TCNQ**) in the fabrication of narrowband biocompatible light sensors.
- For each organic material, **low current values** were detected, leading to reduced values of responsivity and EQE. Such weak conductivities were **expected** for this type of devices.
- **PTCDI-C8** growth will require **further study** to enhance crystal quality and eliminate the non-linear behaviour and hysteresis on the IV curves.
- **Future work** will focus on improving red light detection, exploring TCNQ in thin-film form and assembling combined RGB detection in a single photodetector.

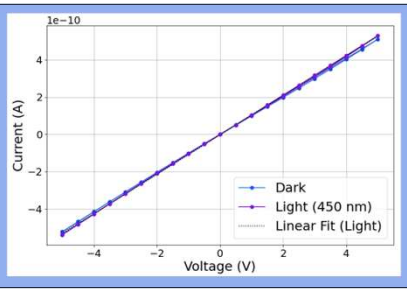
Optoelectronic characterization – Rubrene and TCNQ

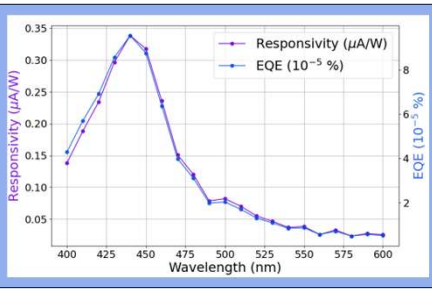
Rubrene





TCNQ

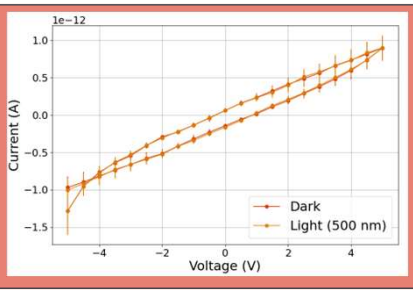


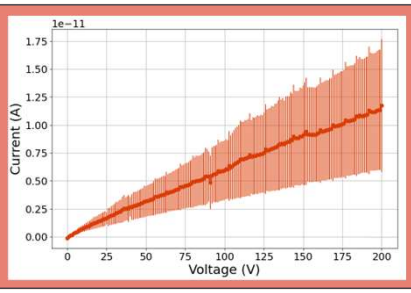


- **IV curves** confirm the **photoconductive behavior** and reveal the influence of crystal quality, contact asymmetry, and interfacial defects on device behavior
- **Sheet resistance** values (from the linear fits):
  - ≈ 60 MΩ for rubrene
  - ≈ 3 GΩ for TCNQ
- Photoresponse profiles show photocurrent enhancement at **specific, material-dependent wavelengths** (near target regions):
  - **Rubrene:** main peak ≈ 460 nm (blue) and secondary peak ≈ 535 nm (green)
  - **TCNQ**: main peak ≈ 430 nm (violet-blue)
- **External Quantum Efficiency** (EQE) reaches 12×10^{-3} % for rubrene and 10×10^{-5} % for TCNQ

Optoelectronic characterization – PTCDI-C8

PTCDI-C8





- **IV curve** does not present a perfectly **linear** behaviour, indicating **issues** in the **photoactive layer** and/or the **metal contacts**
- **Hysterisis** suggests that there could be **charge trapping**
- From the **SCLC** (Space-Charge-Limited Current) analysis, it was not possible to reach the **"trap-filled" limit**, up to 200 V
- This confirms the crystalline film presents excessive **defects** (likely due to fast growth), leading to charge trapping and reduced responsivity

Acknowledgements and References

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