Flexible, Ultra-Low Voltage, Fully Printed Radiation Detectors Based On Organic Semiconductors

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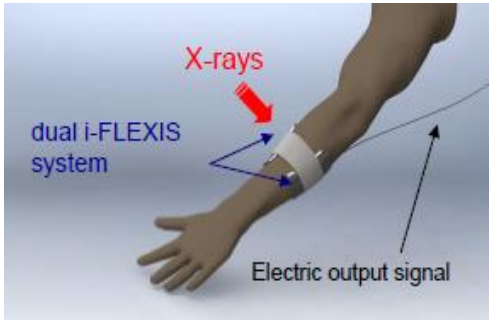
Motivation:
Large area, flexible x-ray detectors



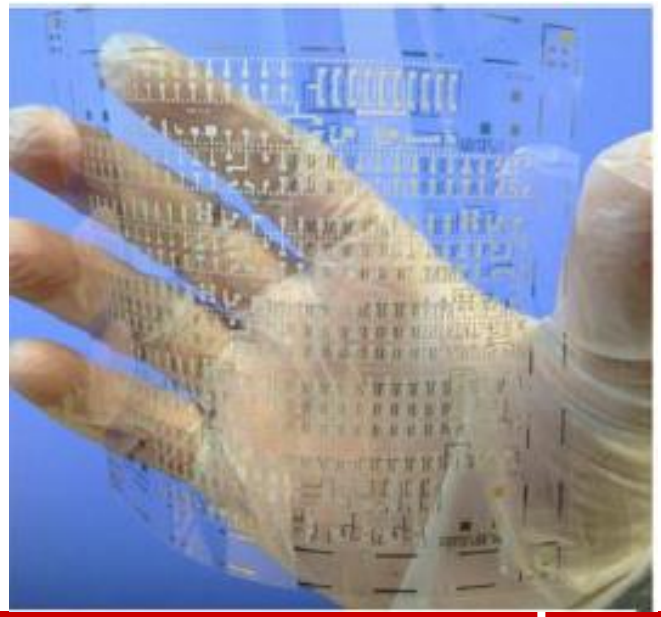
health diagnostic applications

Citizens security: “smart walls/pillars”

Airport security

Radiotherapy

Cultural heritage



Why Organic Materials?

- ✓ flexible and light-weight materials
- ✓ solubility in organic solvents → INKS!
- ✓ low cost printing techniques on flexible substrates (plastic);
- ✓ large area applications -scalability
- ✓ Biocompatibility
- ✓ Human tissue-equivalent materials

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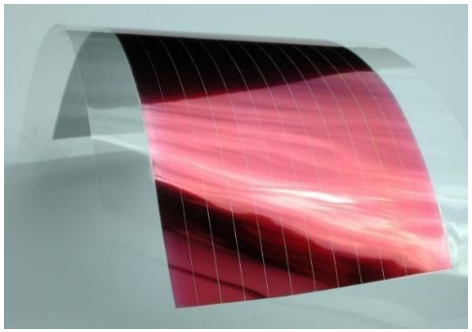
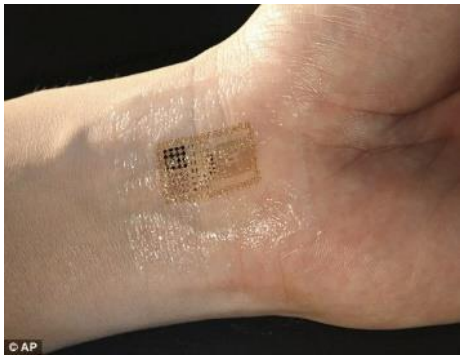


Organic Solar Cells



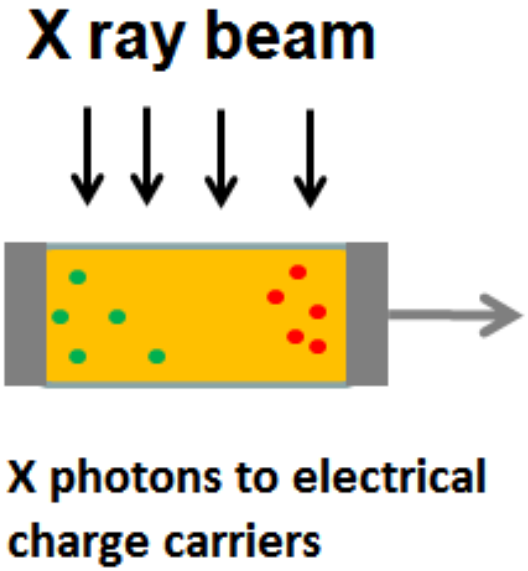
HD Sensors

Our goal #1: use Organic Single Crystals

investigate **organic semiconducting single crystals** grown from solution, for **X-ray direct detection** (i.e. the direct conversion of X-ray photons into an electrical signal) **at room temperature and in air**

DIRECT DETECTION

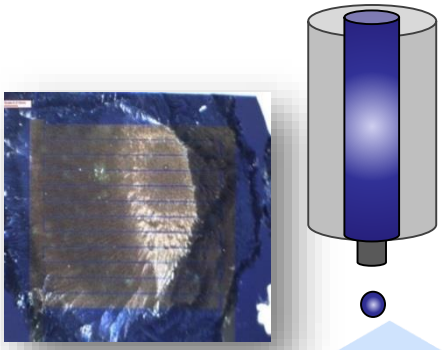
- ✓ low degradation in air and light
- ✓ large band gap (i.e. low dark current)
- ✓ good charge transport/collection properties



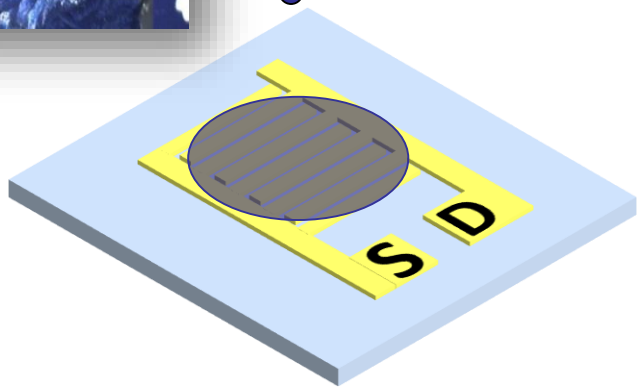
A.Ciavatti et al., Adv. Mater., ***27****, 7123 (2015)*

B.Fraboni et al., Adv. Funct. Mater., ***26****, 2229 (2016)*

Our goal #2:
a printed pixelated matrix detector



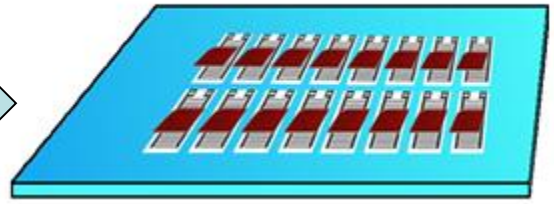
Matrices/arrays fabricated by inkjet prinitng processes on flexible substrates of large dimensions
Organic semiconductors are the active solid state detecting material.

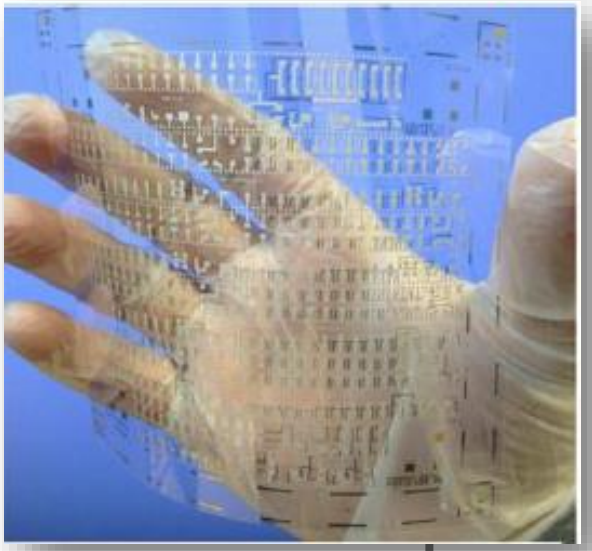


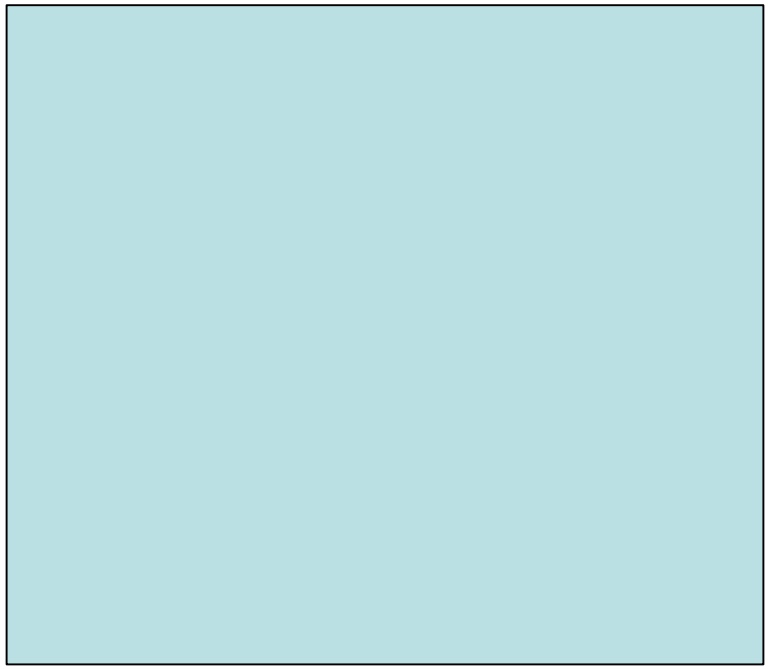
PET substrate

Gold electrodes

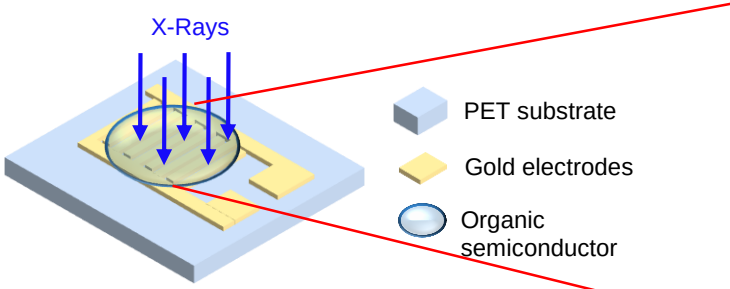
Organic Semiconductor

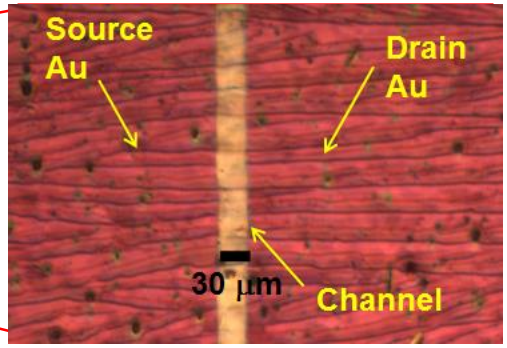






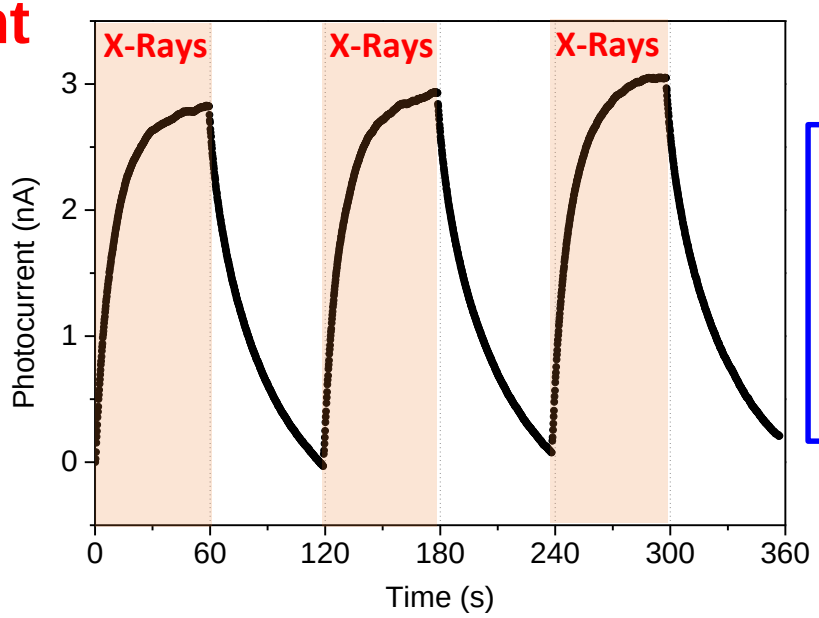
Flexible organic radiation sensors





X-ray photocurrent

Synchrotron X-ray beam
Energy 17 keV
Dose rate 19 mGy/s



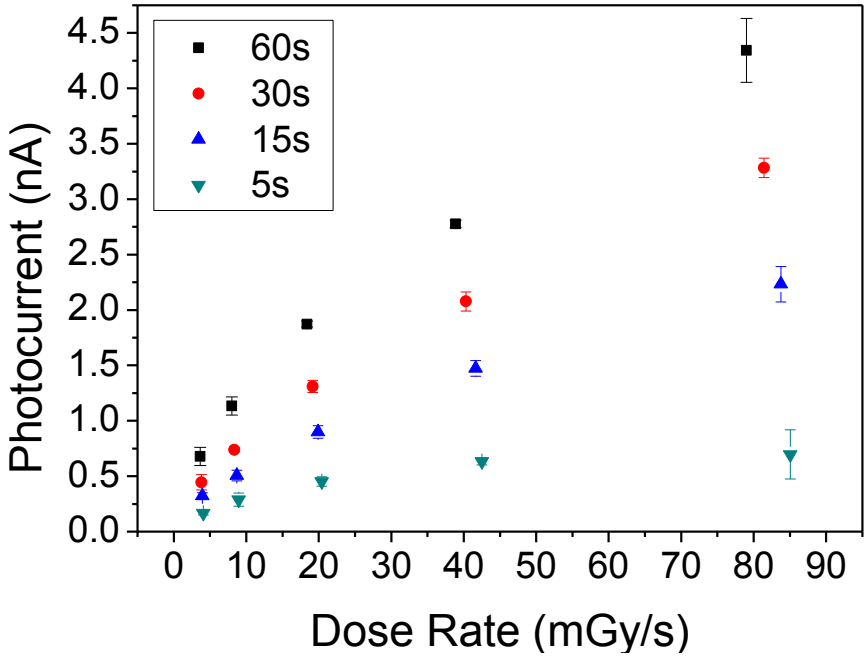
ΔI = 3 nA (max 30nA)

bias voltage 0.2 V

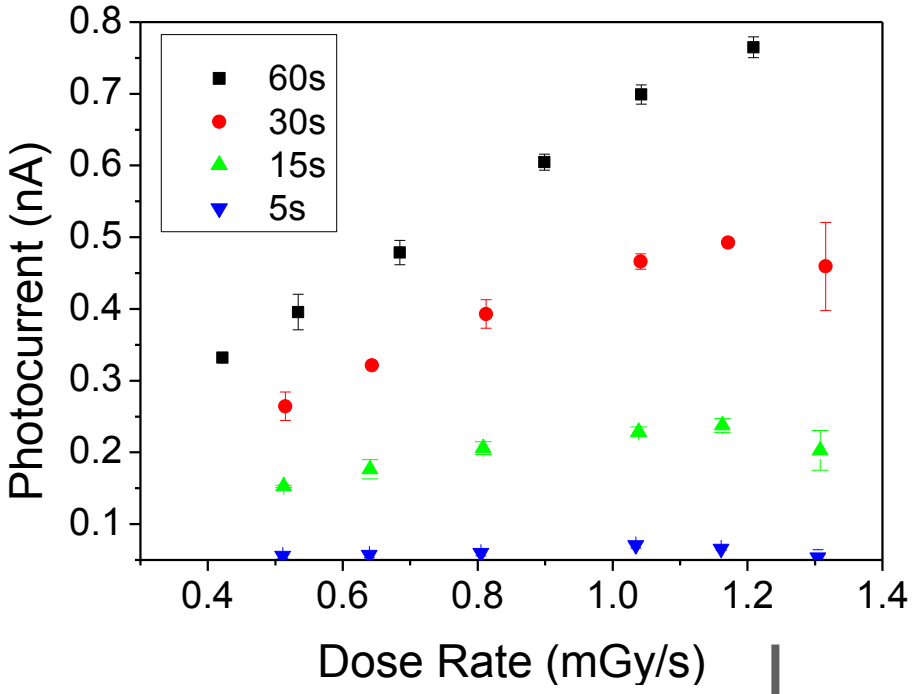
Slow response (TIPS Pentacene molecule)

Linear response to increasing dose rate

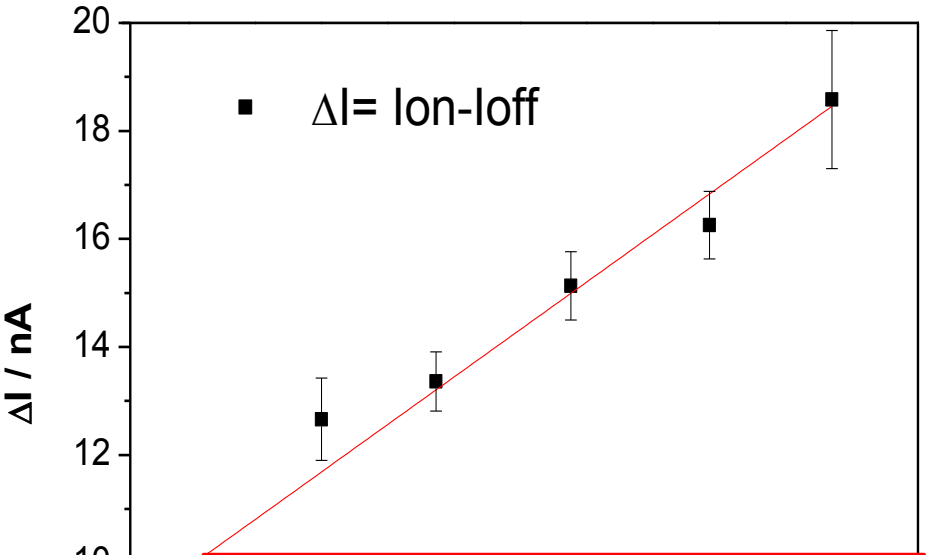
E = 10 keV

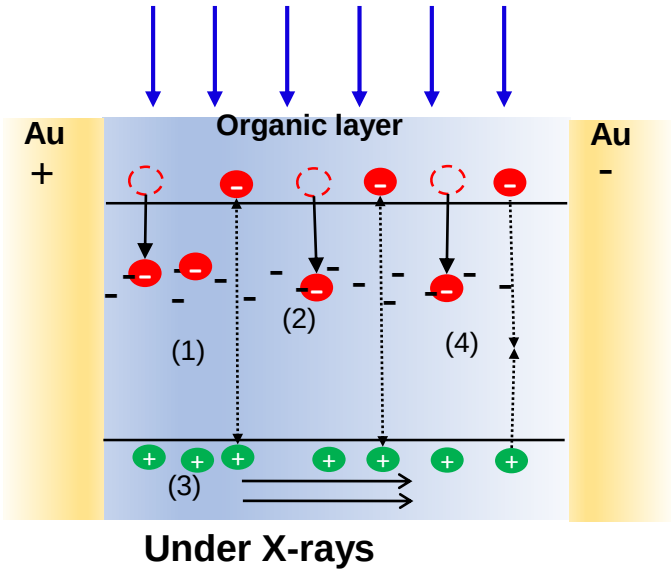


E = 25 keV



Sensitivity & Photoconductive gain model





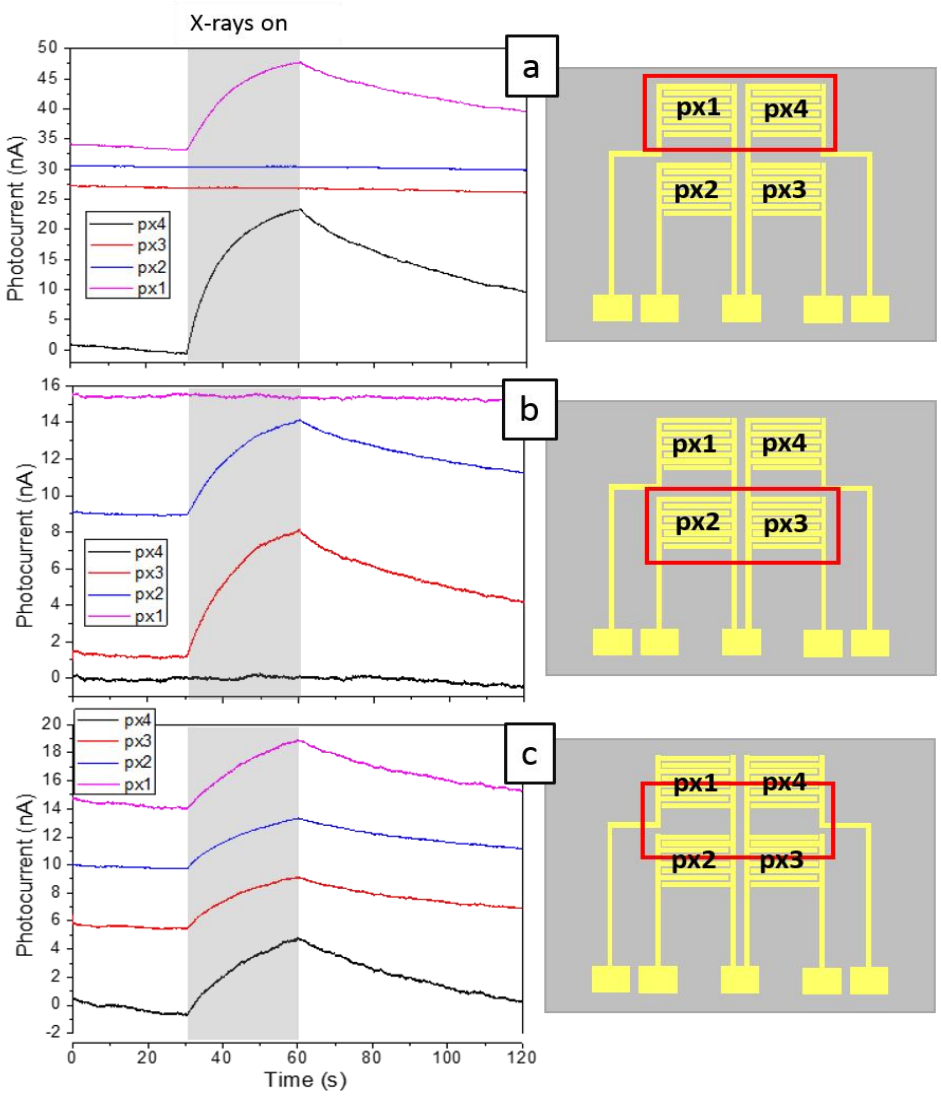
Up to 180 nC/Gy (72000 nC/mGy cm^3) @0.2V

one order of magnitude higher than thick polymeric films or bulk organic single crystals (biased at several tens of volts)

Room temperature and real-time operation

*L. Basiricò et al. Nature Comm.**7**,13063 (2016)*

2x2 pixel matrix: organic printed direct X-ray imager



Pixel size 5 mm

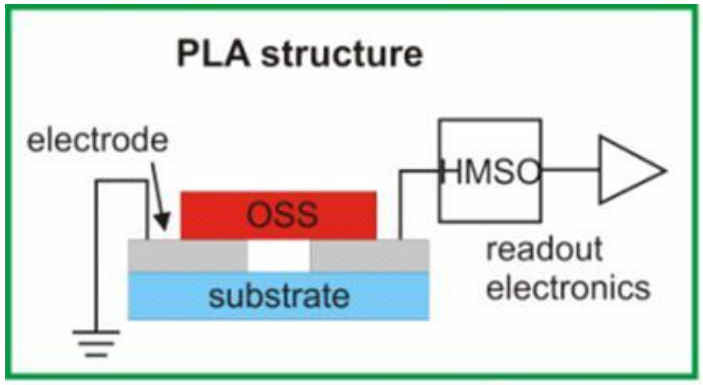
Ultra-low voltage: 0.2V

pixel matrix organic detector

a) only pixels 1 and 4 are irradiated
b) only pixels 2 and 3 are irradiated
c) all the pixels are irradiated.

Radiation source :monochromatic synchrotron X-ray beam at 17 keV with a dose rate of 28.5 mGy/s.

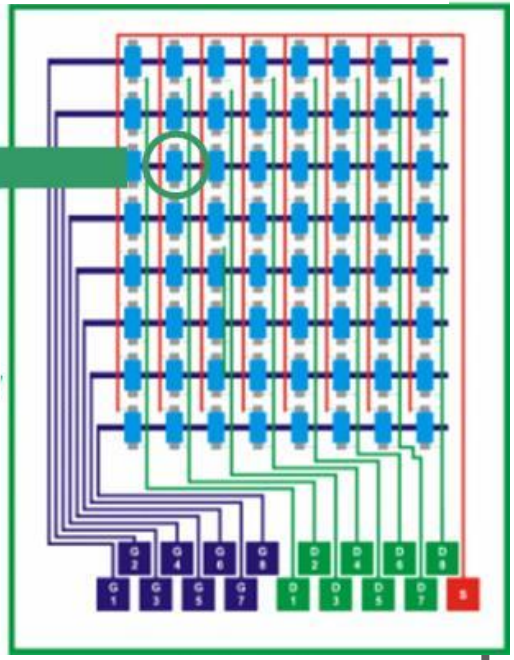
i-FLEXIS (EU project): Integrated printed X-ray sensor system

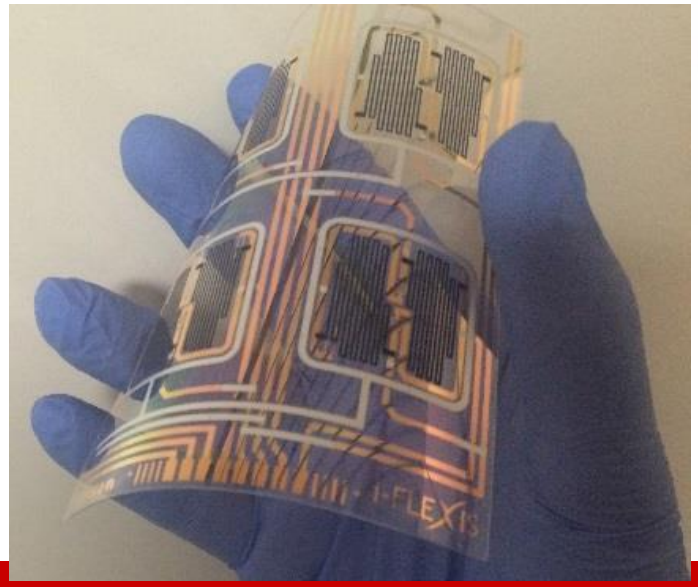


i-FLEXIS
Integrated flexible photonic sensor system

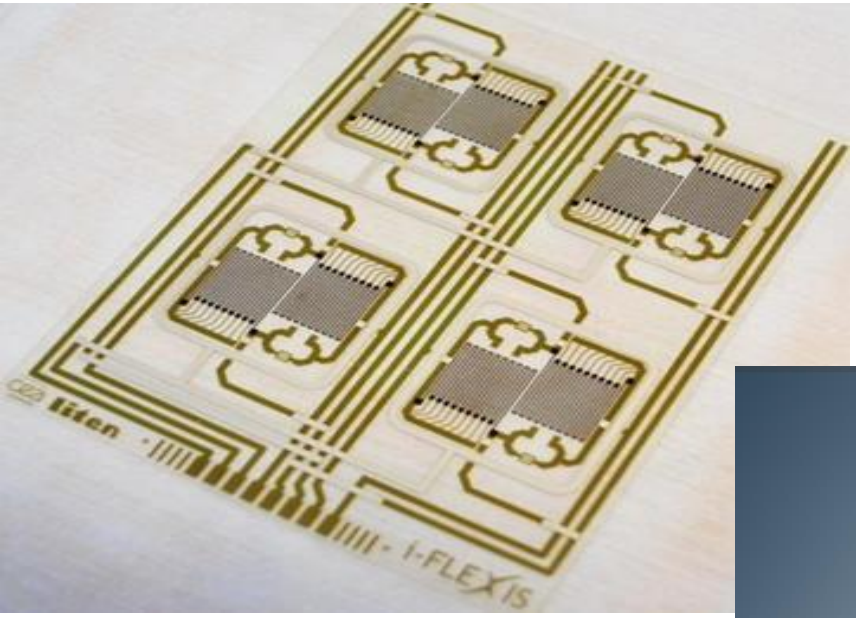
www.iflexis.eu

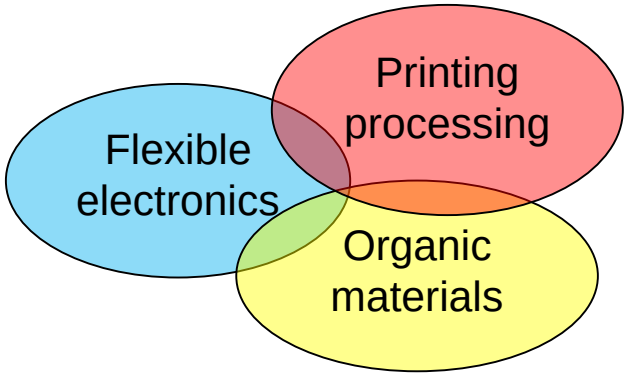
Printed readout organic electronics

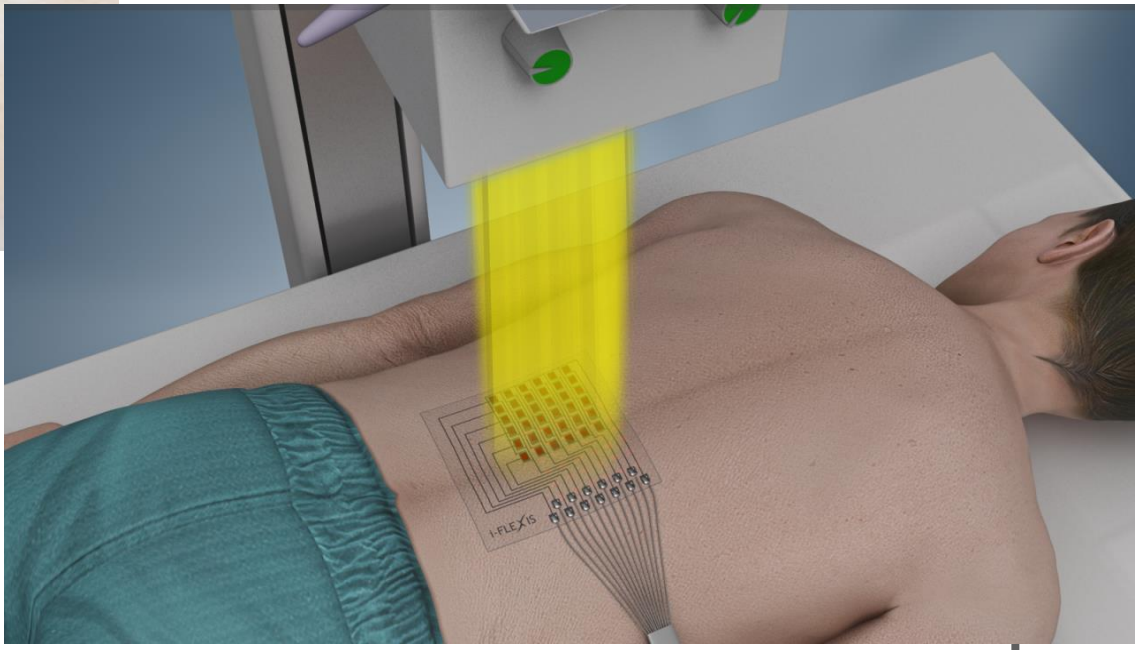




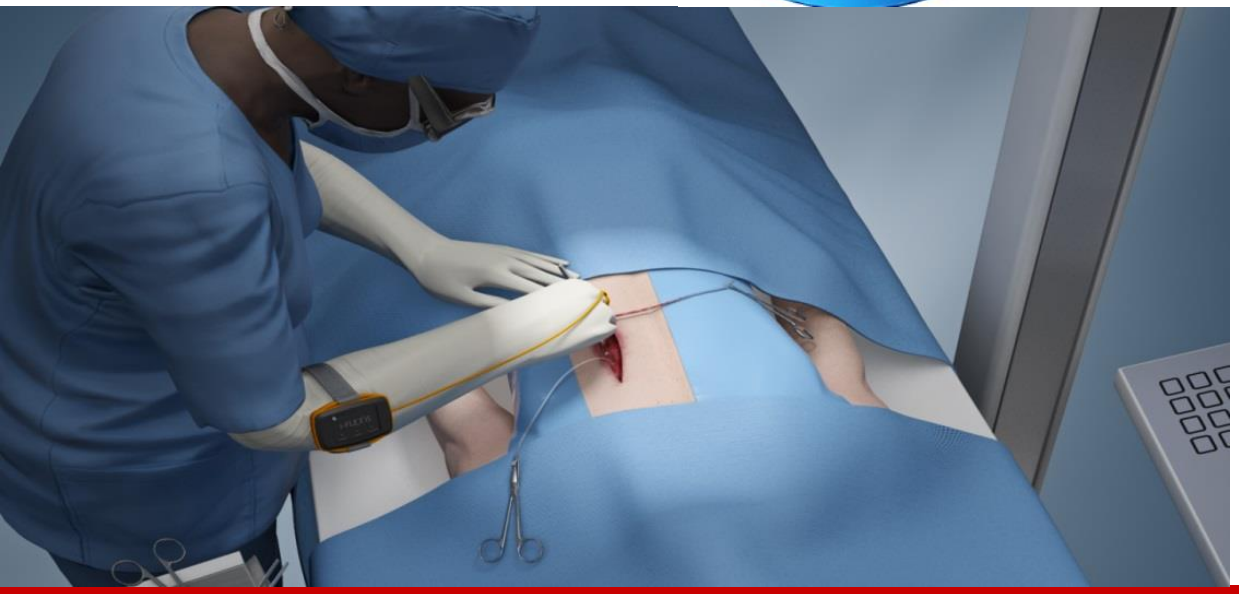
Health Dosimeter: flexible large-area detectors - I





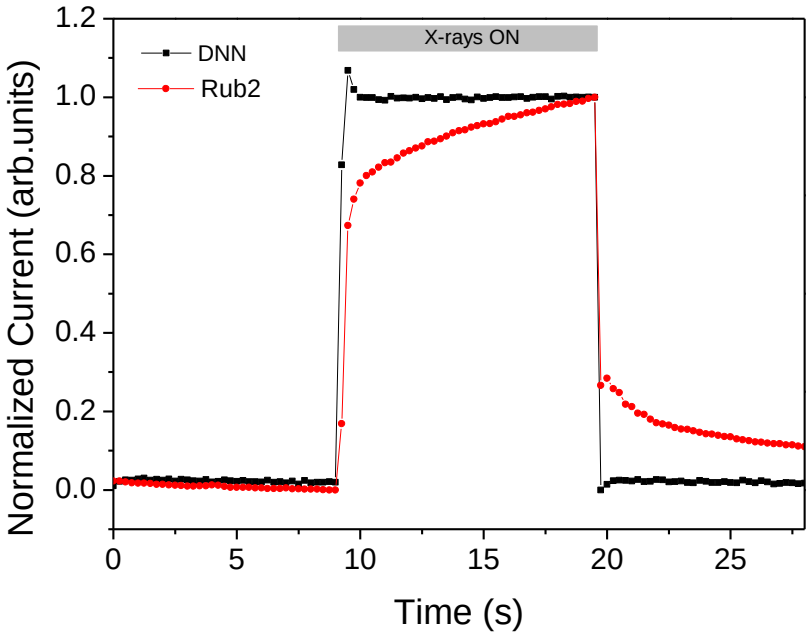


Health Dosimeter: flexible ring for surgeons detectors - I



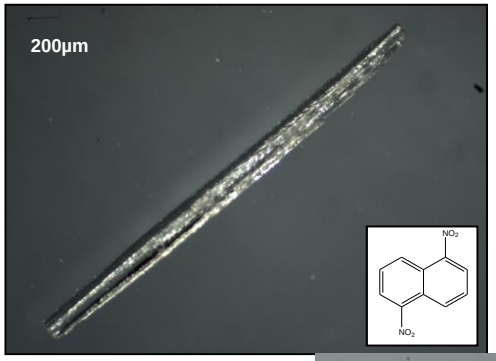
Roadmap ……..

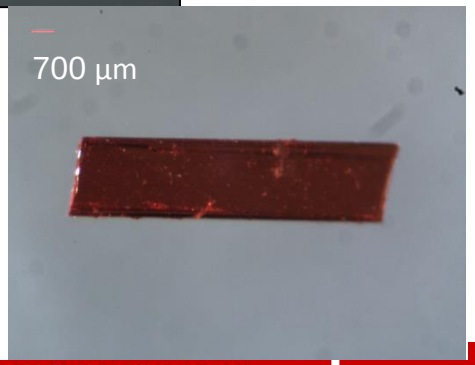
- Reduce pixel size and pitch ⟶ X-ray Imager
- Develop and investigate «fast» responding organic molecules/crystals



L. Basiricò et al. IEEE TRANS. ON NUCL.SCIENCE, 62, 4, (2015)

DNN(6F): 1,5-dinitronaphtalene

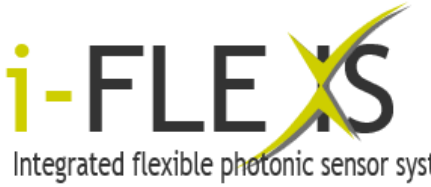




Conclusions

- Organic semiconductors can **directly detect ionizing radiation** (i.e. convert an X-photon into an electric signal)
- Novel **flexible, large-area** X-ray detectors based on organic semiconducting **thin films**, deposited from solution, operating at **very low bias** (0.2V).
- Printed **2x2 pixelated flexible matrix** → possibility of fully printed organic X-ray imager
- **High sensitivity**, **human tissue-equivalent** material (very low X-ray absorption)

Acknowledgements



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