Jennifer 2
kick off meeting Vienna 2019

Stefania De Rosa (INFN Roma Tre)

on behalf of task4.4 working group
in the Jennifer2 collaboration

Organic Photodetectors in Jennifer 2

Where we are?

WP4- 2.1.4 Development of innovative photodetectors

a) Silicon photomultipliers (SiPMs) as single photon counters in neutron irradiated areas
b) Development of long-lived microchannel-plate photomultiplierss (MCP-PMT)
c) Development of multi PMTs for a large water Cherenkov detector
d) Organic photodetectors

The materials used for radiation detection today are mainly inorganic semiconductors and scintillators

The study of photo-absorption and luminescence of organic semiconductors and enhancement of the photon sensitivity of such devices were performed on devices with the following structures: (i) phototransistor in an indirect detector where an element of the sandwich-like structure can be a photo-sensitive material; (ii) direct light detection where the organic polymer used is blended with a different material;

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Organic electronics… Why?

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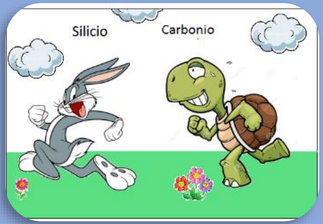
1.Thin and flexible devices.	1. Vey low charge mobility.



2. Very low cost production

2. Low fequency devices

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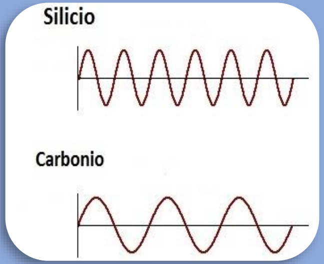

3. Spread of materials

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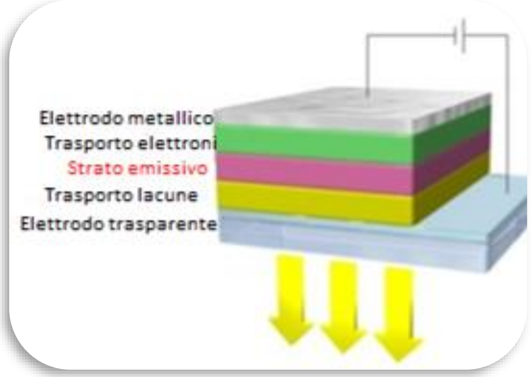
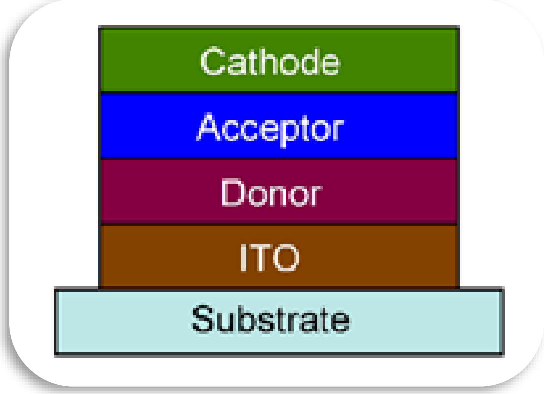
Different Application of Organic Electronic

Organic Light Emitting Diode



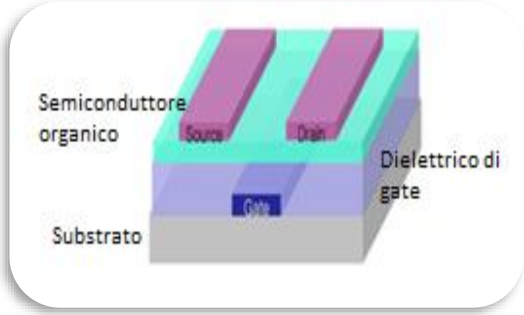
OLED

Organic Photovoltaic Cells



OPVC

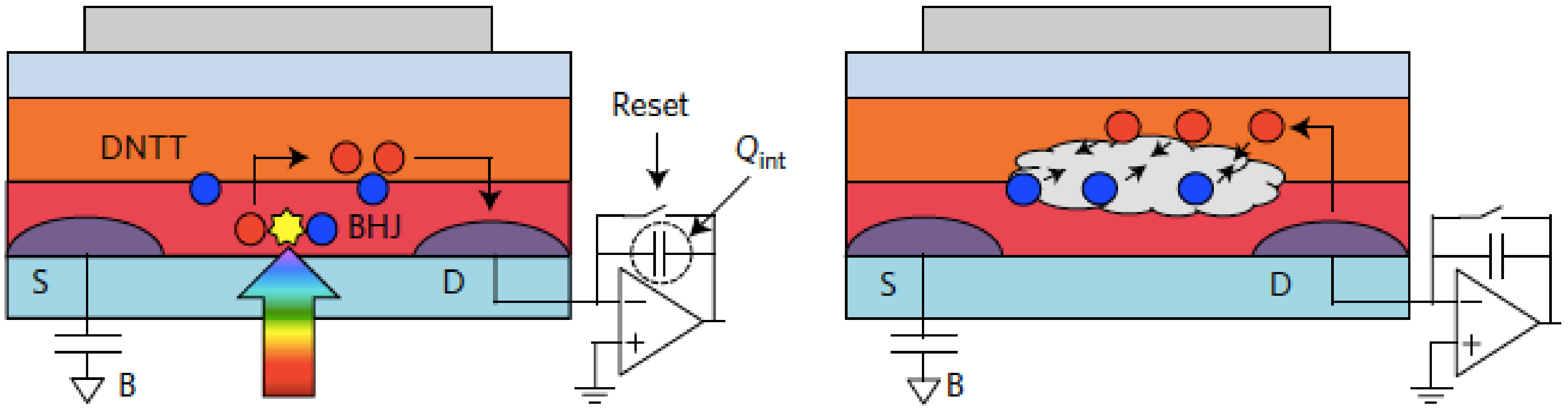
Organic Thin Film Transistor



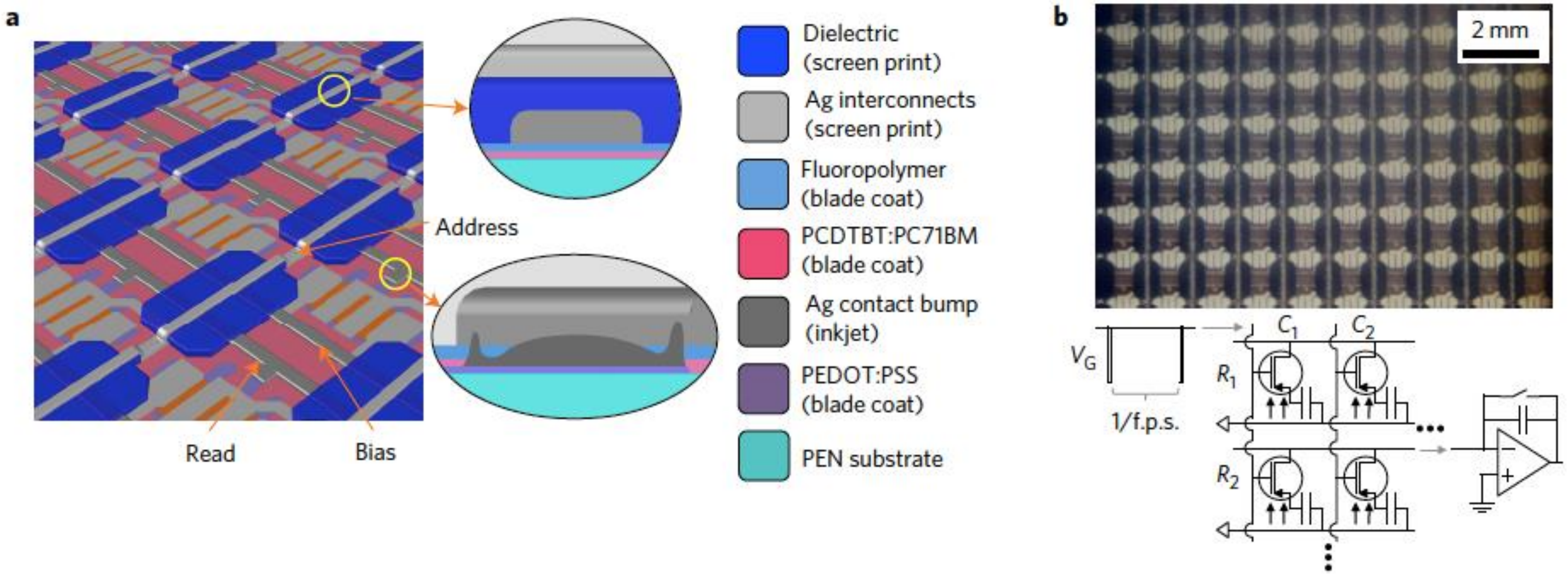
Top Contact OTFT

State of the Art: Organic Photo Transistor

Nature Photonics feb 2017 http://dx.doi.org/10.1038/nphoton.2017.15



The first phase and vast majority of the frame period is charge integration of electrons (blue) followed by a fast discharge of the electrons through recombination with injected holes (red) to quickly read out the signal.

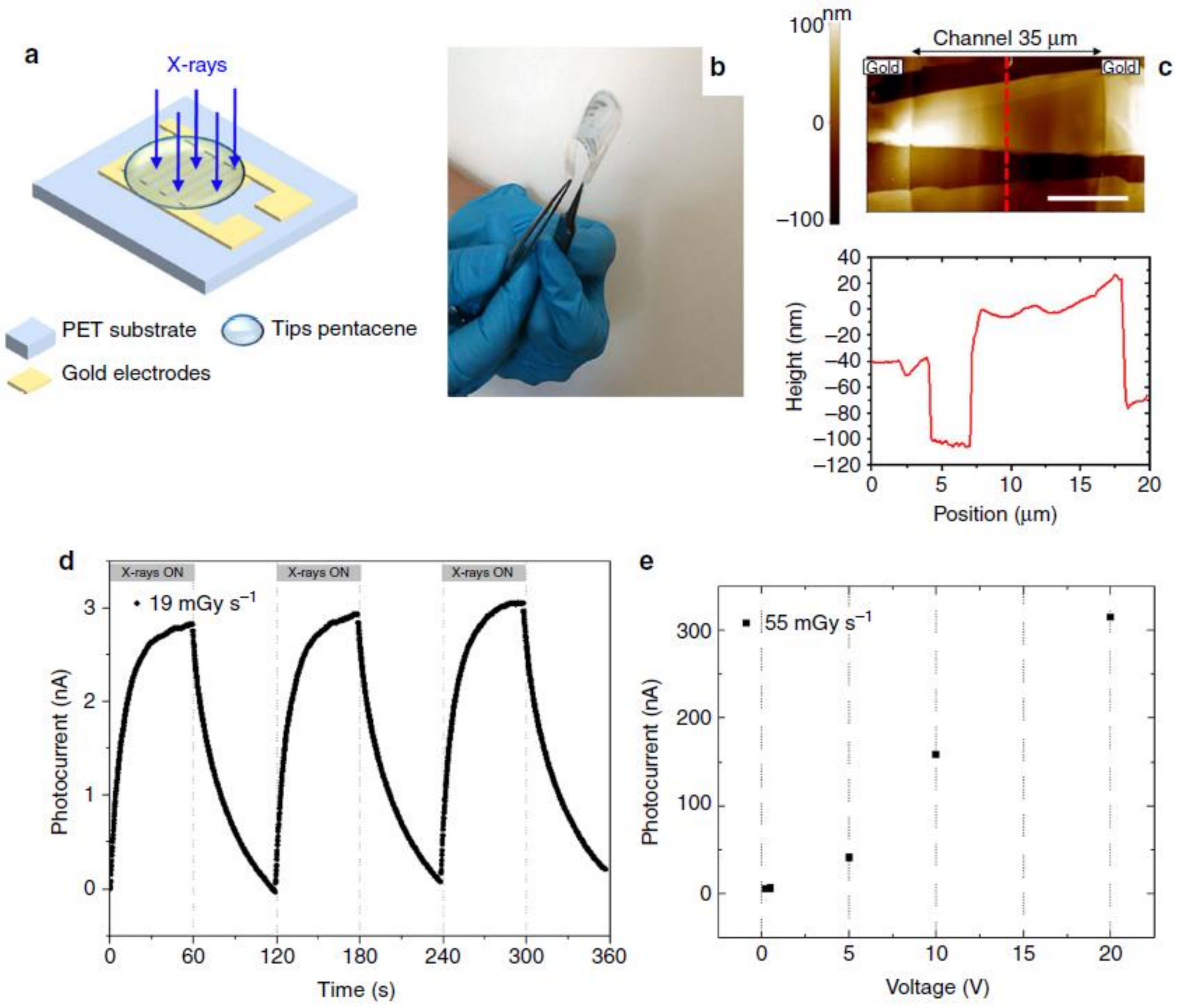


Schematic view of phototransistor-based image sensor with the top and bottom insets showing screen-printed address-readout line overlap and a via interconnect to an underlying drain electrode

State of the Art: Organic Thin Film Transistor

Basirico et al. Nature communications 2016: DOI: 10.1038/ncomms13063

Direct X-ray photoconversion in flexible Organic thin film devices operated below 1V.



In this work, it is proposed a model, based on the accumulation of photogenerated charges and photoconductive gain, able to describe the magnitude as well as the dynamics of the X-ray-induced photocurrent.

The devices are realized by drop casting solution-processed bis-(triisopropylsilylethynyl)pentacene (TIPS-pentacene) onto flexible plastic substrates patterned with metal electrodes; they exhibit a strong sensitivity to X-rays, despite the low X-ray photon absorption typical of low-Z organic materials.

Description of Work and Role of Specific Beneficiaries / Partner Organisations

Task 4.4: Study of innovative organic photosensors [INFN,KEK] Person Months allocated = 6

- Study of Organic FET (IV and in CV characteristic, response to light). Study of photo-absorption and luminescence of organic semiconductors. Characterization of charge transport, signal formation and timing response
- Institutions' roles: INFN - development of organic FETs samples, characterization of samples, simulation studies, KEK, development of new OFET

Milestone: Report on electrical characterization of photo-transistors (month 24)
Deliverable: Final R&D report on organic light detection (month 48)

Roma Tre and Naples INFN sections are involved with 6 experienced researhers and 1 PhD student, already involved in italian projects like EOS and FIRE and leaded by Prof. Alberto Aloisio (NA) and Dr. Paolo Branchini (RM3)

Established research partnership in this field with CNR, KEK and NIMS through an international collaboration agreement

Thanks to INFN support it is planned the secondment of 2 Japanese researchers to our well equipped labs (1 month per researcher) -> it is the only secondment Japan->Europe in the entire Jennifer2 project

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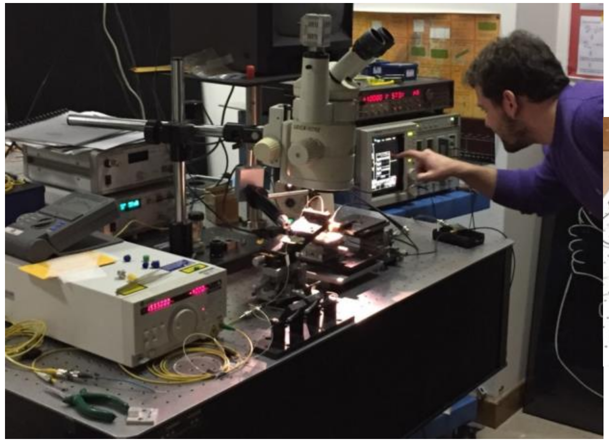
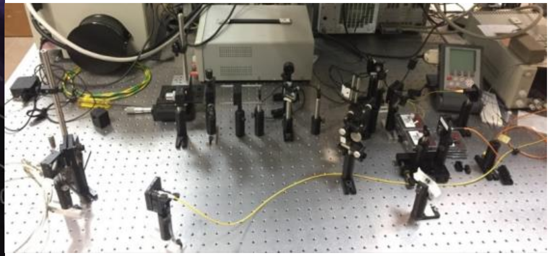
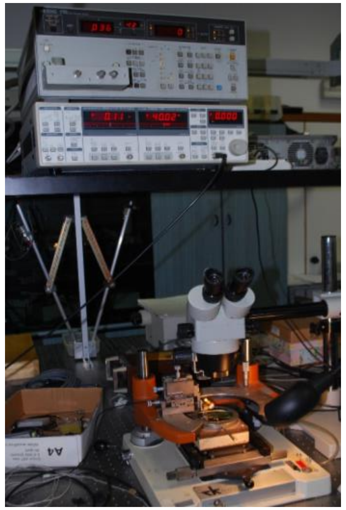
Roma Tre Laboratory holds classy equipments and valuable expertise for the characterization of charge transport, signal formation and timing response

SDLab
Semiconductor Device Laboratory





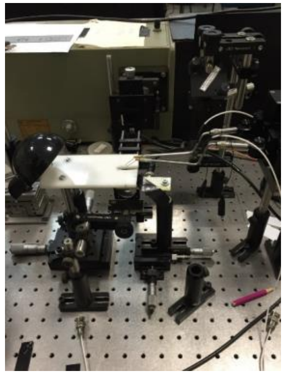


Expertise:

- Semiconductor devices development
- 2D-3D device simulations (TCAD)
- Opto/electric device characterization
- Development of dedicated measurement setup +
- Development of front end electronic for sensor charactherization
- Project and development of different kind of sensors
- Nanostructural material processing and deposition
- Planar photoligraphic process
- Vacuum deposition of semiconductors and metals
- Photovoltaic device charachterization

Instrumentation and setup:

- I-V DC Characterization (SMU)
- Responsivity measurements(SMU, Lockin)
- VIS-NIR spectral response
- Pulse and sinusoidal response
- Sensitivity and noise measurements (Ultar-low-noise TIA+SA)
- Pulsed and CW VIS-NIR optical sources
- Solar Cell characterization (Solar simulator + SMU)



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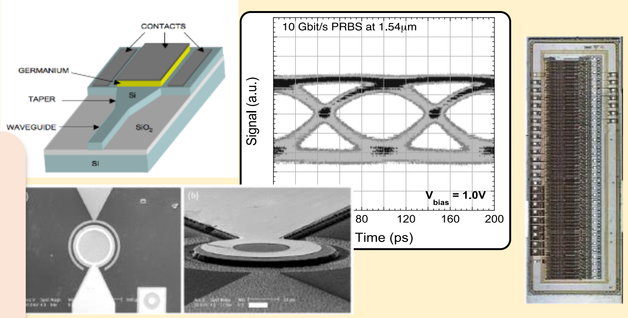
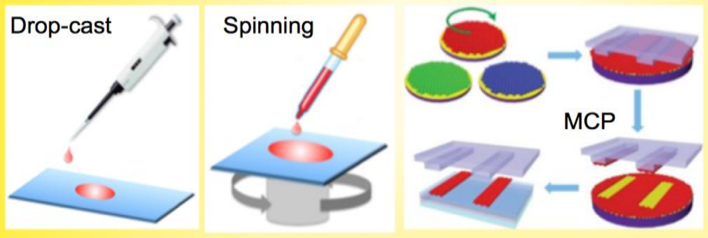
Study of photo-absorption and luminescence of organic semiconductors.

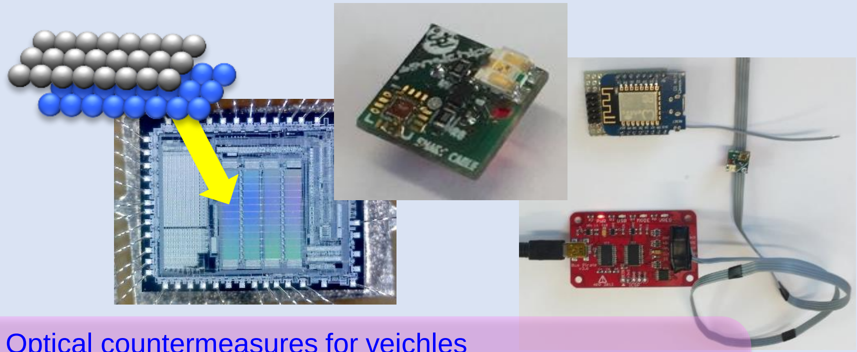
SDLab
Semiconductor Device Laboratory

SiGe Photo detector on standard Si microchip

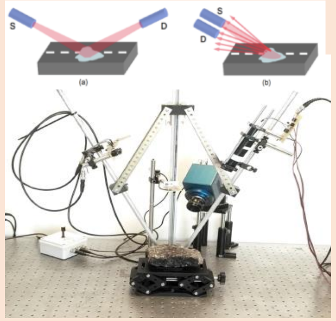


Nanostructure material devices

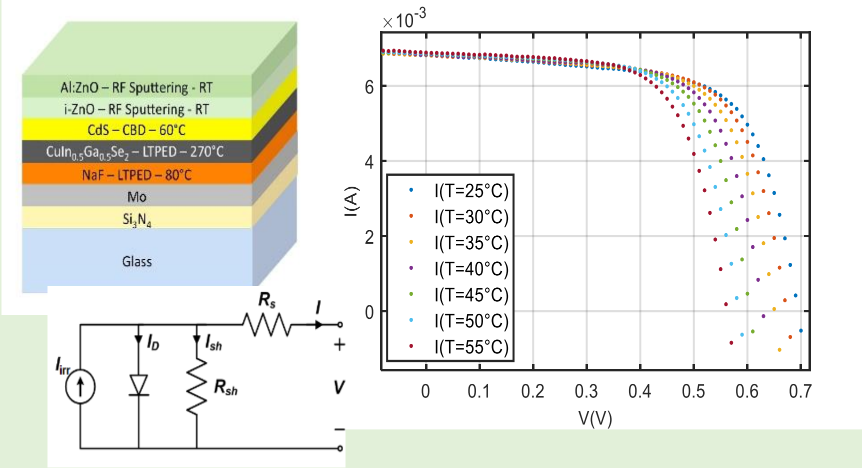




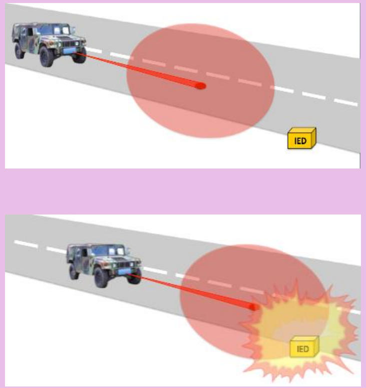
Optical sensor for surface analysis

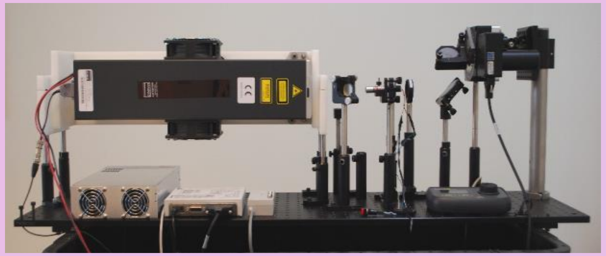


Photovoltaic devices



Optical countermeasures for veichles





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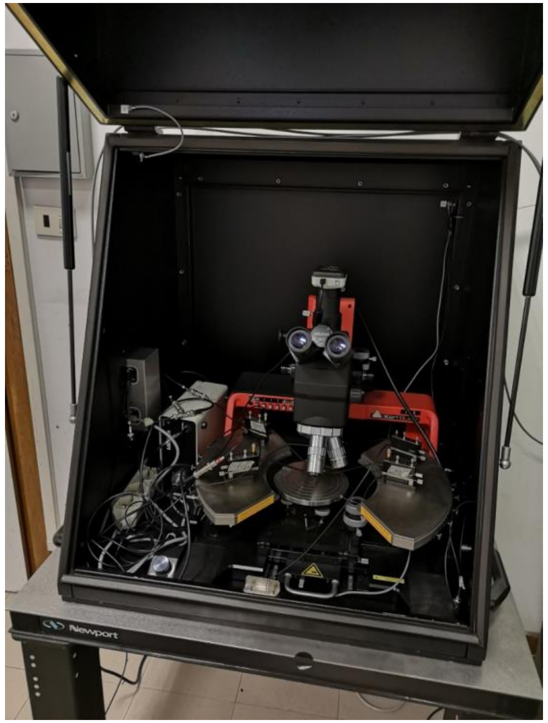
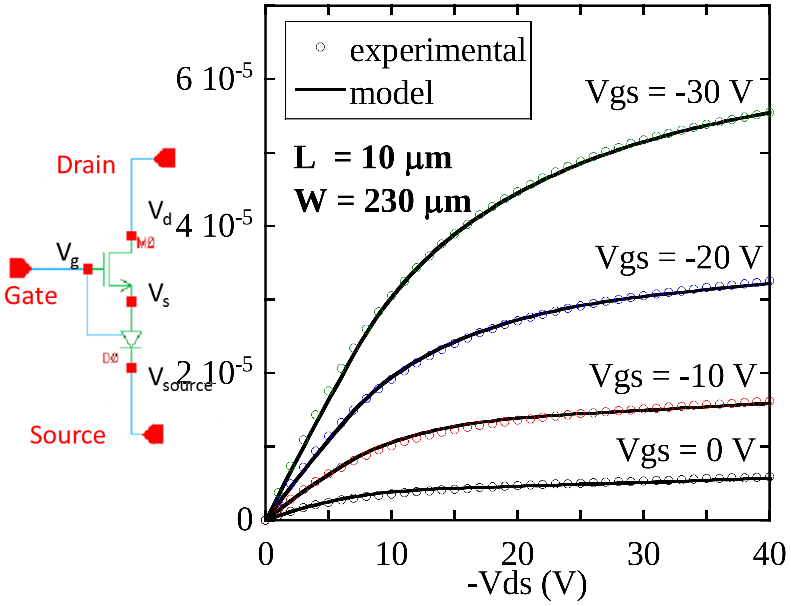
Study of Organic FET (IV and in CV characteristic, response to light).



Probe Station

Up to six micro-manipulator inside a black box.



Semiconductor Device Analyzer

I-V, C-F, etc…

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Characterization of samples (chemical and structural characterization)

Stilus Profilometer

- z resolution < 1 nm
- Large area analysis (stitching)

FTIR

Study between 100 cm^{-1} and 27000 cm^{-1}

Equipped with microscope

- Molecolar analysis
- Functional group determination

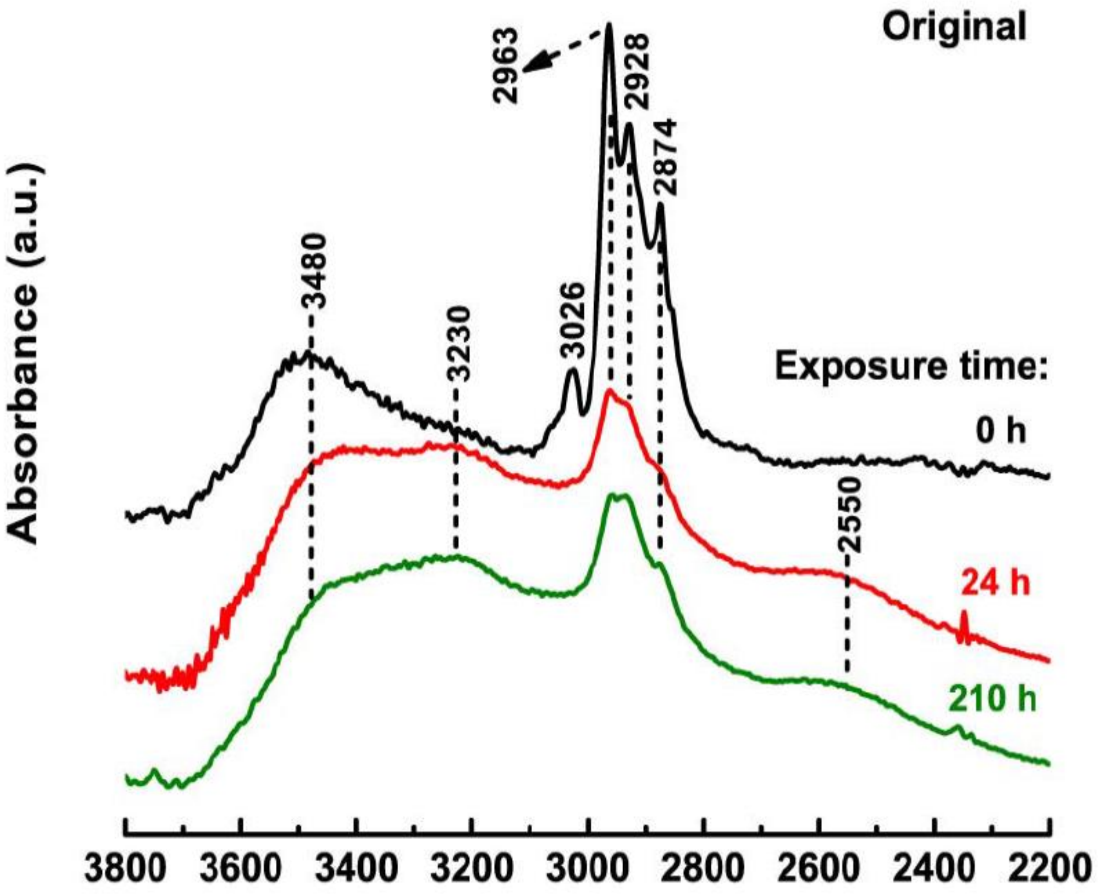
Low-energy ion beam analysis (ToF-SIMS)

- Gun 1: Bi^{+} 30keV
- Gun 2: Cs^{+} 0.2-11 keV
- Gun 3: Electron floodgun (20 V)
- Mapping with a lateral resolution < 100 nm
- Depth profiling < 1 nm
- 1 a.m.u. - 15000 a.m.u. detector range
- Detector ToF
- Limit of detection ~ ppm

Pubblications of our lab:

FTIR: https://www.mdpi.com/2076-3417/9/15/3016
ToF-SIMS: https://www.sciencedirect.com/science/article/pii/S0169433218310572

FTIR Spectra example



FTIR spectrum of an epox sample versus UV exposure time.

Conductivity measurements can be done on the same sample allowing us to track down the reason of eventual perfomance degradation of the device. In this way we could select the best material we choose.

Z. An et al.: Evolutions of Surface Characteristics and Electrical Properties of the Fluorinated Epoxy Resin

Characterization of samples (chemical and structural characterization)

Single Photon Spectroflorimeter FLS1000-SD-st.

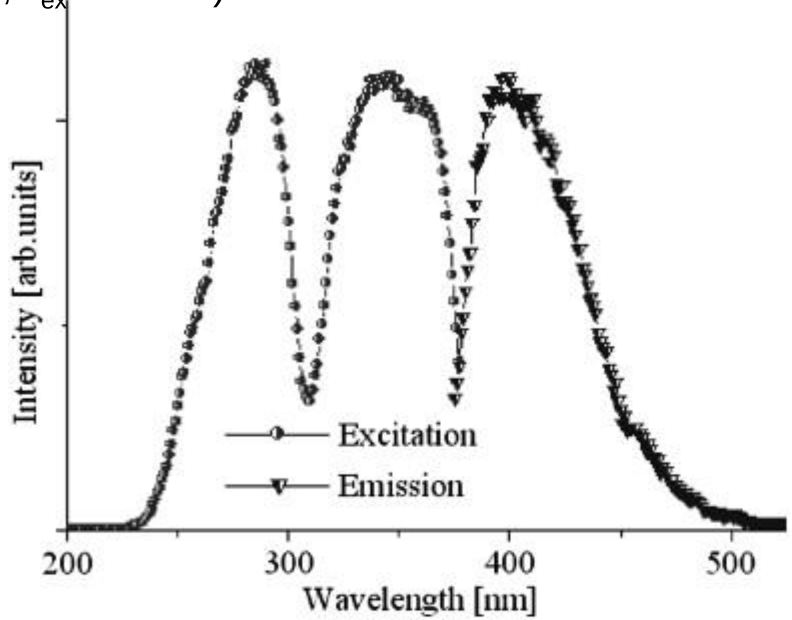
Brand new

Growth and characterization of Ce-doped $Ca_3(BO_3)_2$ crystals for neutron scintillator:

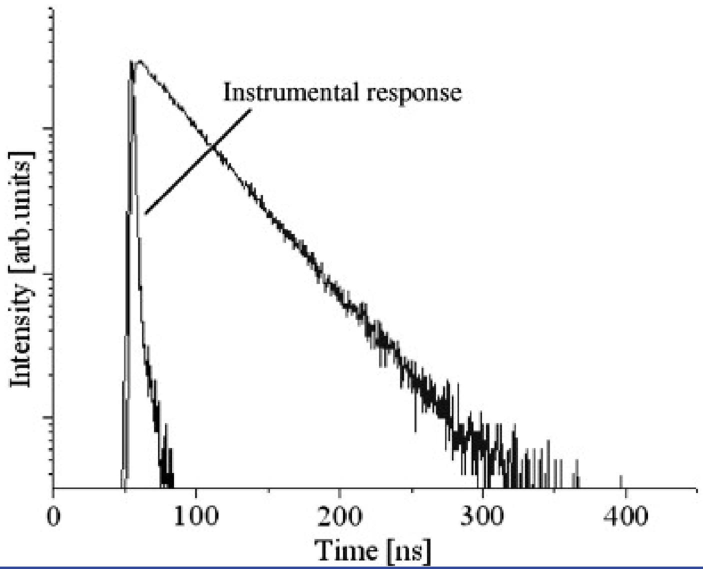
YutakaFujimoto[ab]TakayukiYanagida[a]HidehikoTanaka[a]YuuiYokota[a]NoriakiKawaguti[d]KentaroFukuda[ad]DaisukeTotsuka[e]KenichiWatanabe[f]AtsushiYamazaki[f]AkiraYoshikawa[ac]

It'll be available in time frame of the project

Excitation (*circle*) and emission (*triangle*) spectra of 1.0% Ce-doped CBO single crystal (λ_{em}=400 nm, λ_{ex}=345 nm).



Decay curve of 1.0% Ce-doped CBO single crystal (λ_{em}=400 nm, λ_{ex}=345 nm).

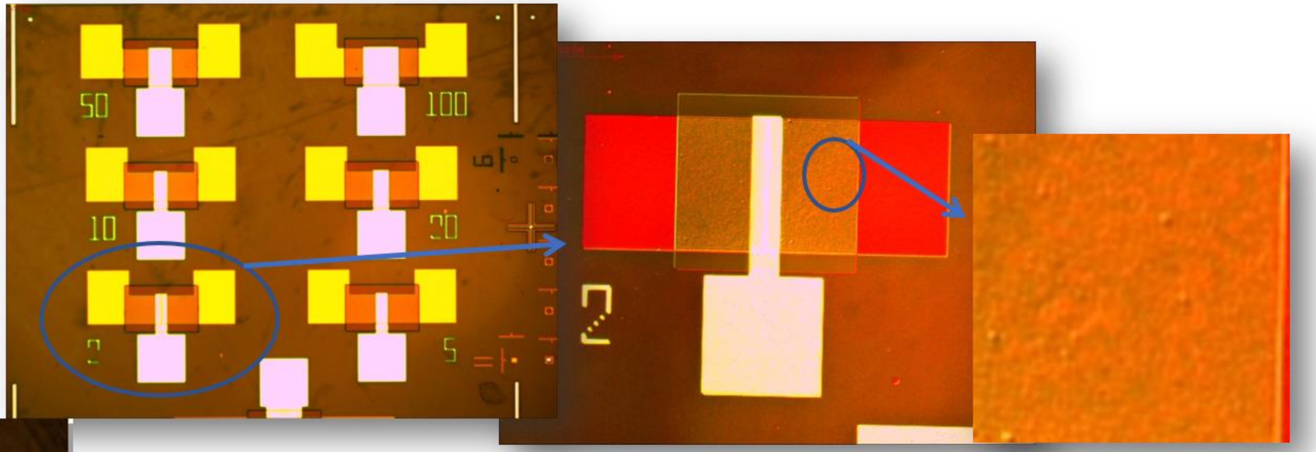


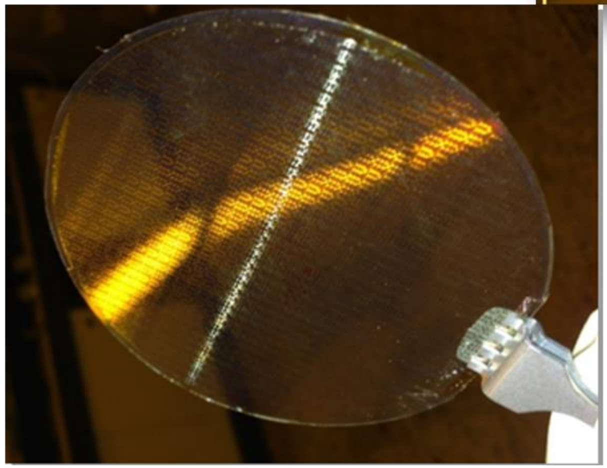
Past collaborations

- In the past our group won a «progetto premiale»: EOS (Organics Electronics for Innovative Research Instrumentation). Within this project (2014-2018) several device samples were developped.

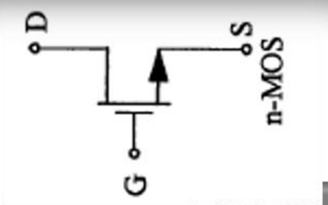
Institutions involved: CNR-IMM, CNR-SPIN, RM3-INFN, RM3 University, Naples INFN.

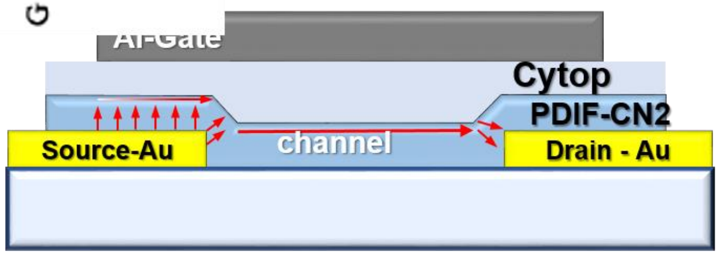
- **Au S/D contact** (no Self Assembling Molecule)
- ***HMDS treatment before PDIF-CN2 evaporation to increase chemical stability***





- PEN flexible substrate
- Bottom-Contact/Top-Gate
- Au- S/D contacts, ***no SAM***
- PDIF-CN_2 evaporated (SPIN) (T_{sub}=100 °C)
- Gate dielectric: Cytop (550nm)
- Metal gate: Al





On-going collaborations

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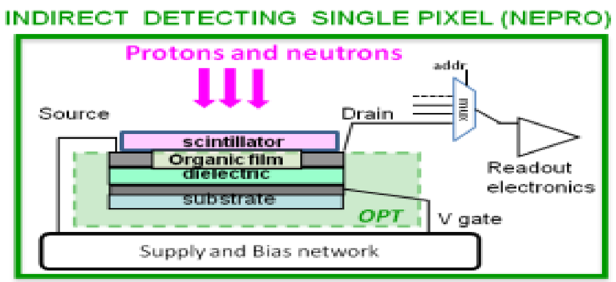
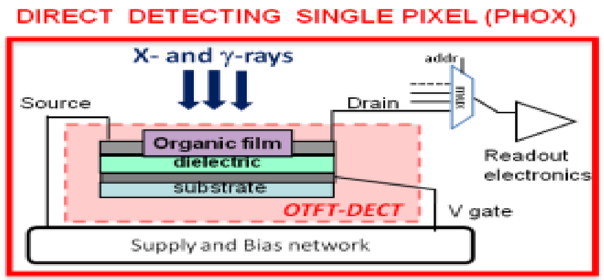
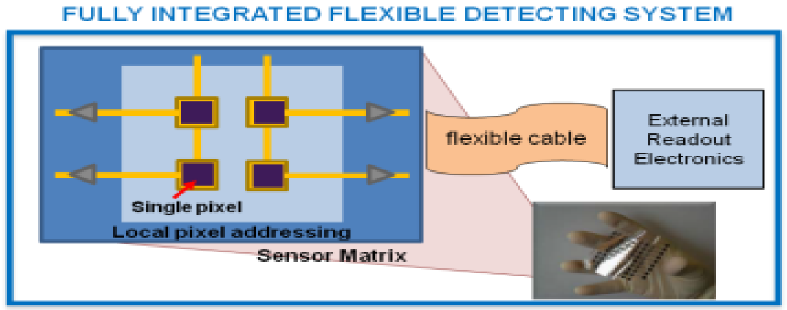
We are now involved in the project FIRE on Organic Electronics.

Institutions involved: RM3-INFN, Na-INFN, TIFPA, BO-INFN, LNL-INFN.







	NEPRO (protons and neutrons)	PHOX (X- and gamma-rays)
Proton Energy range	50-230 MeV (10^9 – 10^5 p/s x20 min.)	
Neutron Energy range	0.025 eV – 14 MeV	
Photon energy range		15 keV- 1MeV
Sensitivity	10^5 p/s cm^2	>20 μC/Gy/cm^2
Limit of Detection (LoD)		100 μC
Radiation hardness	>10^{10}p/cm^2	>100 Gy
Bending radius	>0.5cm	>0.5cm
Dark current		<10^{-8}A
2D matrix area	Up to 5x5cm2	Up to 5x5cm^2
No of pixel in each matrix	up to 9	up to 9
Operating voltage	<25V	<5V

At the core of each one of the two modular units, there are OTFTs. In the NEPRO indirect detector, the OTFT is optimized to work as organic phototransistor (OPT). In the PHOX direct detector, the OTFT is tuned to enhance its direct electrical response to X and gamma-rays (OTFT-DECT).

Conclusions:

- INFN laboratory can perform very nice and interesting measurements to qualify the material of Photo detectors.
- JENNIFER2 task 4.4 is connected to a wide range of collaborative projects in the field of organic photo detection
- Close collaboration with italian CNR and Japanese institutions (KEK, NIMS) has been established.

Thanks for the attention!