### Organic optoelectronic systems for optical biosensing in agri-food

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Chemnitz, December 4° 2024

### **Organic/Hybrid Photonics @ CNR-ISMN**

- Flexible organic light-emitting devices
- Organic photovoltaics
- Multifunctional organic transistors
- 2D materials: functionalization
- Organic bioelectronics
- Bioderived polymer for sensing
- Integrated systems for point-of-need

Source

Drain

50 µm

Multicolor Organic Light-emitting Transistors (OLETs)







Flexible transparent heterojunction OPV

Free-standing keratin Biosensor



Integrated organic system for cell stimulation and recording



White top-emitting OLED on conformable metal substrate



Light-Emitting OFET



Integrable Organic-Hybrid Photonic Structure



Epitaxial growth of organic moieties onto phosphorene

### Organic optoelectronics in analytical monitoring







### Organic Optoelectronics

- Nanometer-thick films
- Low cost
- □ Conformable and light-weight devices
- □ Integrability

# Standard methods for diagnostics and monitoring

- Bulky with dedicated power sources
- Expensive
- Dedicated labs
- □ Very limited applicability when PON

### **Optical sensing modes**



#### Fluorescence

- Environmental monitoring, clinical diagnostics, DNA sequencing
- o Sensitive and selective
- o Quantitative
- o Labeling needed
- o Multiple interferences
- o Multiple bulky components (e.g. Optical filters)
- o Bulky, expensive and high-power consuming optical components



#### Surface Plasmon Resonance (SPR)

- o Environmental and food monitoring, clinical diagnostics
- o Label free
- o Quantitative
- o Sensitive and selective
- o Bulky, expensive and high-power consuming optical components

### Safety and competitiveness in the food chain



Multiplex phOtonic sensor for pLasmonic-based Online detection of contaminants in milK



MOLØKC

### Integrated SPR sensor based on organic light-emitting transistor





### Integrated SPR sensor based on organic light-emitting transistor





### Integrated SPR sensor based on organic light-emitting transistor



Array of OPD-integrated OLETs



Miniaturized SPR-sensor



SPR signal from 10 ng mm<sup>-2</sup> of proteins (commercial SPR method)

estimated LOD of miniaturized sensor



M. Prosa et al., Adv. Funct. Mater. 2021, 31, 2104927

### A miniaturized and multiplex SPR biosensor



### A miniaturized and multiplex SPR biosensor

#### **SENSORGRAMS** with spiked sampkes



#### DATA ANALYSIS

- 1) Baseline subtraction
- 2) Data normalization
- 3) Principal Component Analysis
- 4) Algorithm to define data regions of maximum stability, maximum slope, and elbow points
- 5) Data referencing
- 6) Channel-specific correction





#### BENCHMARKING with golden SPR standard





### Sensor prototyping





### photonic system for Adaptable muLtiple-analyse Monitoring of fOod quality



### Modular portable optical biosensor



#### Instrument including:

- sensor module
- communication electronics
- microfluidic module
- **Reagent cartridge** taking up the sample and providing all necessary reagents
- **Sensor module** with a matrix specific biofunctionalization according to the analytes

### SOFTWARE



• App providing access to data analysis and management

### SPR- and fluorescence-based detection in a single device

**Enlarge the dynamic range** of detectable concentrations of a specific analyte

- Derivide a built-in control for techniques which are sensitive to **different interferences**
- □ Perform in a single sensor detection of **multiple analytes from different classes**



- ✓ 1 OLED for exciting SPR
- ✓ 1 OLED for exciting fluorescence
- ✓ Cut-off excitation filter
- ✓ Broad band OPD
- ✓ Stacked configuration



*F. Floris et al., Mater. Proc. 14 (2023) 1–5. M. Angelini et al., Nanomaterials. 12 (2022) 1–16.* 

E. Benvenuti et al. Org. El. 2024, 128, 107023

### **On-chip all-organic fluorescence sensor**





Benvenuti, E. et al. J. Mater. Chem. C, 2024, 12, 4243-4252

### **On-chip all-organic fluorescence sensor**

Università di Genova

EL OLED • abs Rhodamine 700

em Rhodamine700



The OPD photocurrent arises only/mainly from the fluorophore emission

- Good spectral overlap
- o High in-plane DBR uniformity
- OLED as Lambertian light source + DBR angular response

Benvenuti, E. et al. J. Mater. Chem. C, 2024, 12, 4243-4252





### **On-chip all-organic fluorescence sensor**



### Conclusions

- Design of innovative bimodal integrated sensors for fluorescence and SPR based on organic
  optoelectronics as PON or screening methods
- Monolithic integration of light source and detector for SPR detection
- **On-chip all-organic** fluorescence sensor comprising optical component
- Multiple analyte detection (low- and high-molecular weight)
- Prone to **DNA detection** (fluorescent nucleic acid stain conc. = 5 mM)
- LOD of 10<sup>-4</sup> RIU: only 1 order of magnitude lower than the reference benchtop SPR instrument

### Acknowledgments





Mario Prosa Margherita Bolognesi Salvatore Moschetto **Federico Prescimone** Previous members of the group:

**Emilia Benvenuti** Marco Natali

FARM Portable Optical Biosensor for Multi-Analyte Detection in Dairy Farms with a One Health Perspective Bandi a cascata ECOSISTER PNRR Dr. Mario Prosa

E-SPF digit - Emergent soil, plant and food onsite digital services on chemical and biological contaminants Grant Agreement No 101157922 Information Dr. Ria Pechlivani



**Bilateral ccoperation project CNR - IDEA GTO** 

(Guanajuato, Messico) Prof. Marco Bianchetti





Photonic system for adaptable multiple-analyte monitoring of food quality Grant Agreement No 101016706



Photonic system for adaptable multiple-analyte monitoring of food quality Grant Agreement No 101016706

## Thank you for your attention!

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