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NANOSCIENCES

3rd year PhD report

Supervisor: Andrea Camposeo

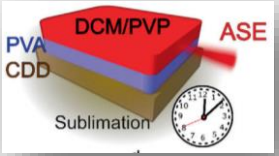
Pisa, 20/10/2020

Francesca D'Elia

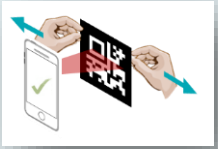
Research goals

PhD goal: development of printing methodologies for stimuli-responsive materials

OBJECTIVE 1: Multilayers with transient optical properties based on **naturally-degradable** optical systems

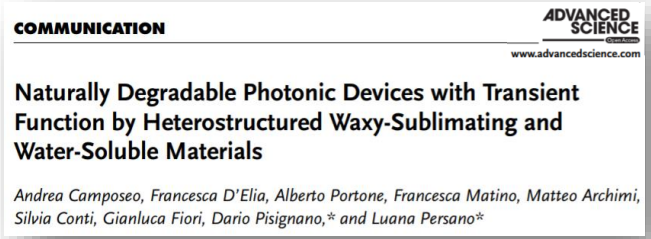


OBJECTIVE 2: Additive manufacturing of **mechanically deformable** free-form optics



OBJECTIVE 3: 3D printing of **white-light-emitting** system

Naturally-degradable optical systems


COMMUNICATION

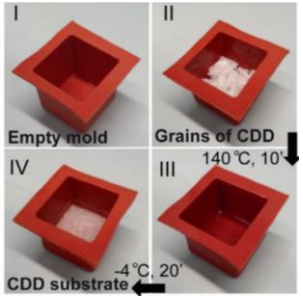
ADVANCED SCIENCE

www.advancedscience.com

Naturally Degradable Photonic Devices with Transient Function by Heterostructured Waxy-Sublimating and Water-Soluble Materials

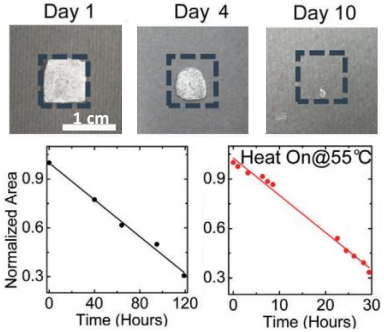
Andrea Camposeo, Francesca D'Elia, Alberto Portone, Francesca Matino, Matteo Archimi, Silvia Conti, Gianluca Fiori, Dario Pisignano, and Luana Persano**

1. CDD substrate fabrication



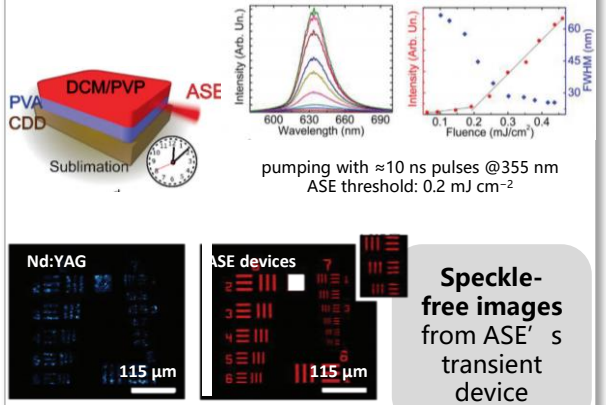
Silicon molds generate substrates with smooth surfaces (Rq = 70 nm)

2. CDD Sublimation properties



Sublimation rate can be controlled changing the environmental conditions

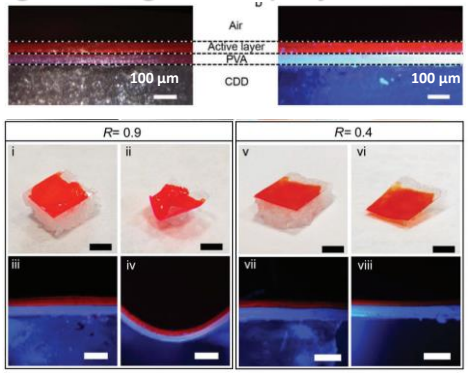
Light-emitting heterostructures



pumping with ≈10 ns pulses @355 nm
ASE threshold: 0.2 mJ cm^{-2}

Speckle-free images from ASE's transient device

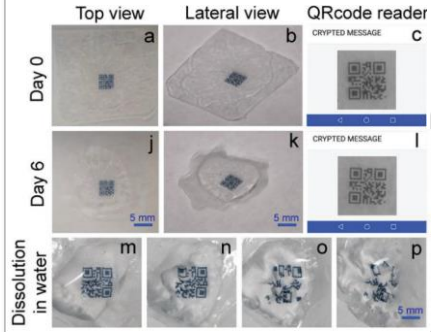
3. Engineering of the polymeric bilayer



Bilayer thickness ratio of **R = 0.4** keep the light emitting structure unbent.
(scale bar: 200 µm)

Intelligent optical labels

QR-code pattern realized **inkjet printing** PEDOT:PSS on CDD/PVA/PVP heterostructure



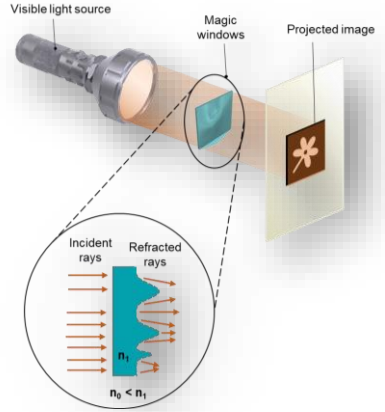
CDD sublimation: unbent device
↓
QR-code decrypted

Polymers dissolution In water
↓
QR-code destroyed

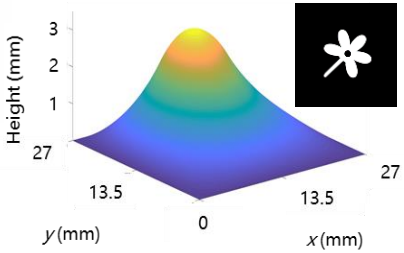
Mechanically deformable free-form optics

In collaboration with Prof. **A. Tredicucci**

Magic Windows (MW)



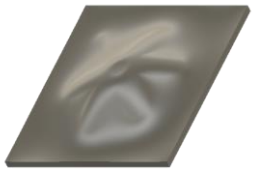
1. MW design

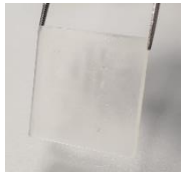


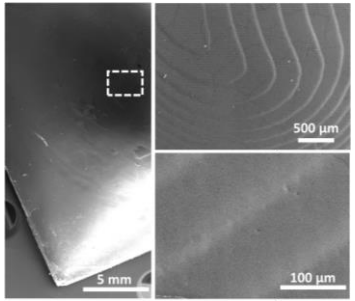
@F. Pisani

2. MW fabrication by **Digital Light Processing** system

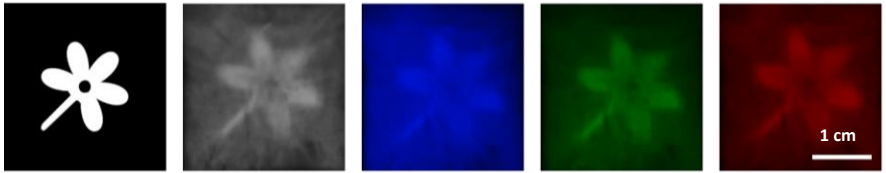
Material: E-Shell600 ® EnvisionTEC
Single layer thickness:15 µm
Time exposure: 3 sec



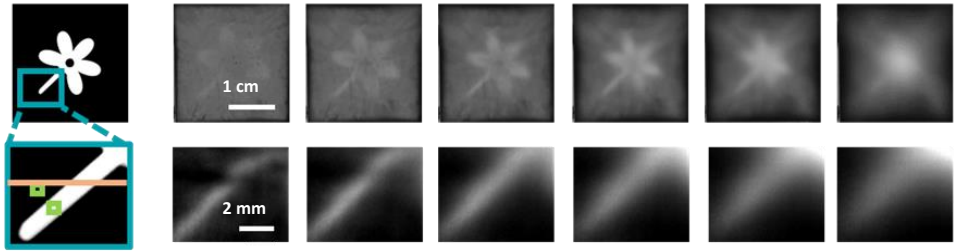




3. Characterization of MWs projection



- MWs has a focal distance of **3 mm**
- The intensity profiles projected by MW are
- **wavelength independent**

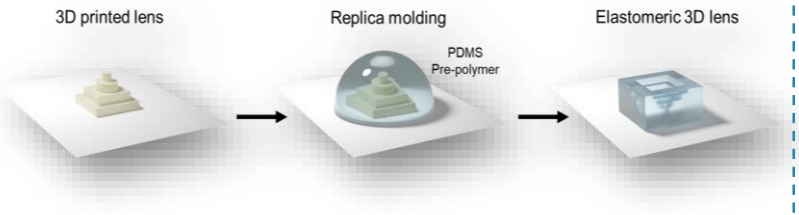


Screen distance (mm) 0 +3 +6 +9 +12 +18

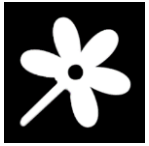
Mechanically deformable free-form optics

In collaboration with Prof. **A. Tredicucci**

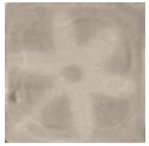
4. Elastomeric MWs fabrication by **replica molding**



Target image

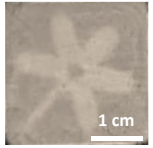


3D printed MW



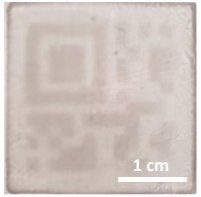
Target mold

Elastomeric MW



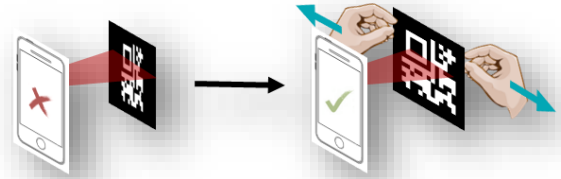
microQRcode MW design

microQRcode MW projection



Fabrication of a complex MW projecting a microQRcode of encoded data **'ABVZ'**

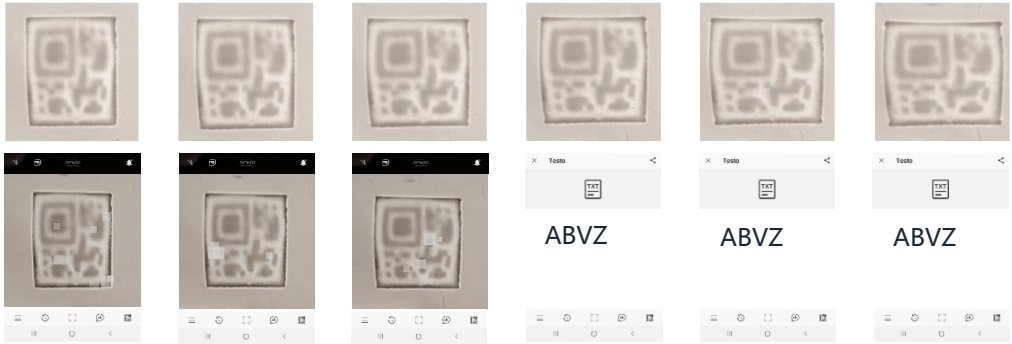
5. Mechanical deformation test



microQRcode pattern with **20% of uniaxial deformation**

Mechanical strain (ε) measured on the elastomeric MW

$\varepsilon_{0\%}$ $\varepsilon_{8\%}$ $\varepsilon_{15\%}$ $\varepsilon_{20\%}$ $\varepsilon_{25\%}$ $\varepsilon_{30\%}$



Pattern generated by the unstretched MW: not readable by the scanner

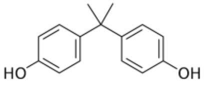
Pattern generated by a 15% strained MW: reading of the information encoded

White-light-emitting 3D printed system

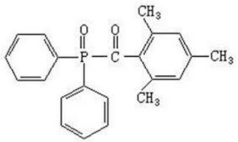
3D printing by **SLA** of engineered transparent host matrix

Material: Bisphenol A + 2 % TPO (% wt/wt)

Monomer: BPA

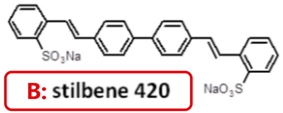


Photoinitiator: TPO

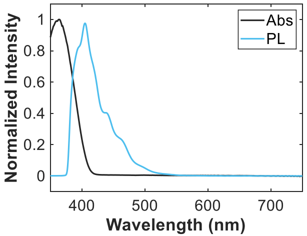


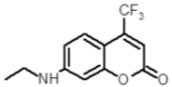
3D printing parameters
Single layer thickness : 100 µm
Laser scanning rate: 130.000 µm/s
Laser Power Ratio: 20%

Selected photo-luminescence molecules

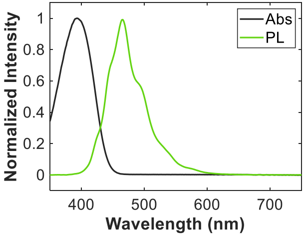


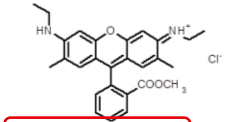
B: stilbene 420



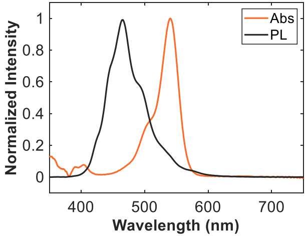


G: coumarin 500

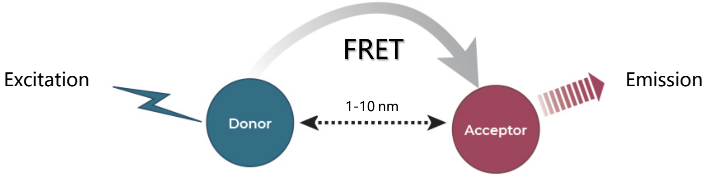


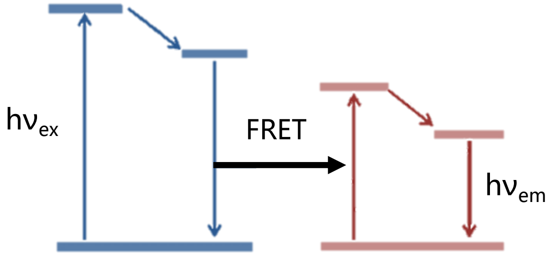


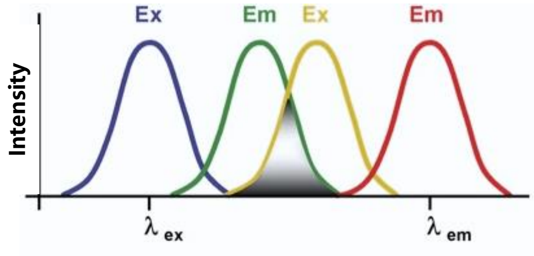
R: rhodamine 590



Förster Resonance Energy Transfer



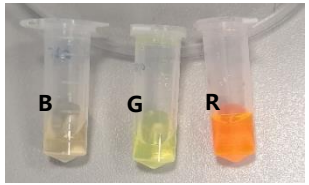




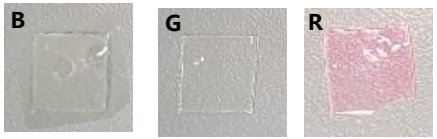
White-light-emitting 3D printed system

Photoluminescent mixtures optimization

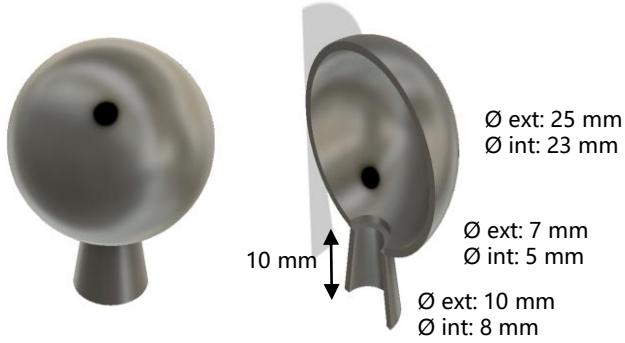
Dye concentration calibration
Single-dye-doped solution made of
BPA + 2% of TPO + 0.01% single dye



Φ_{PL} (%) printed **B = 16%**
Φ_{PL} (%) printed **R = 42%**
Φ_{PL} (%) printed **G = 8%**

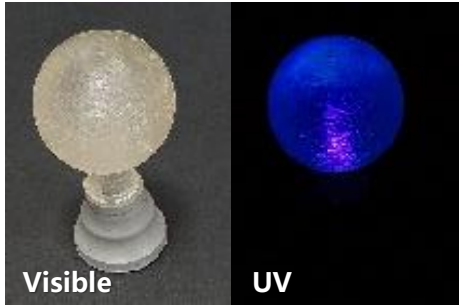


3D Design

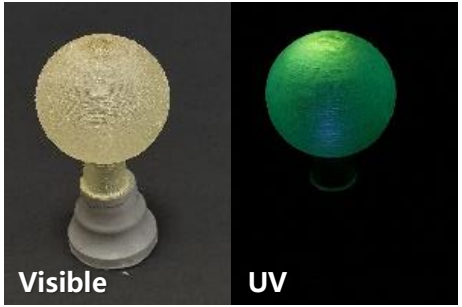


Single-color-emitting 3D printed system

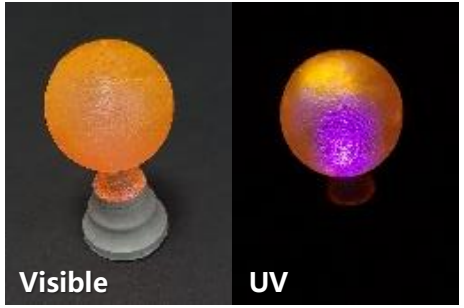
STILBENE-420



COUMARIN-500



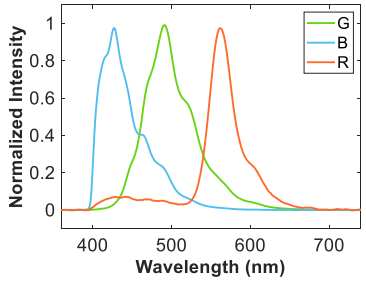
RHODAMINE-590



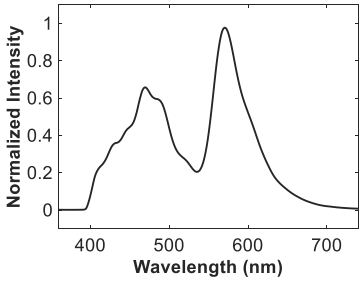
White-light-emitting 3D printed system

White-light-emitting mixture calibration

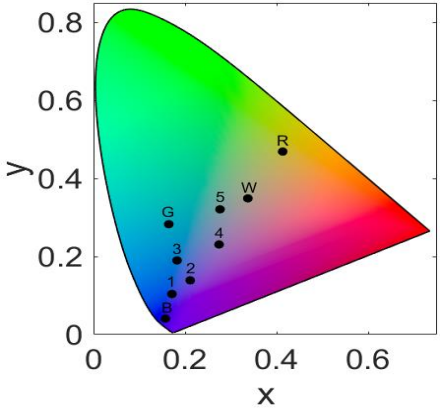
Single-dye PL



White-emitting mix **PL**



CIE 1931 chromaticity diagram



R:G:B molar ratio

1 – 5:10:100
2 – 1:1:10
3 – 1:2:5
4 – 1:1:1
5 – 1:2:2
W – 2:2:1

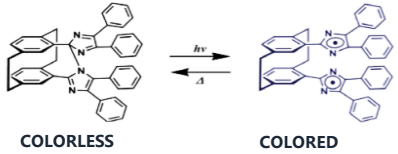
Molar ratio of white emitting system:
R:G:B= 2:2:1

3D printing of white-light-emitting structure

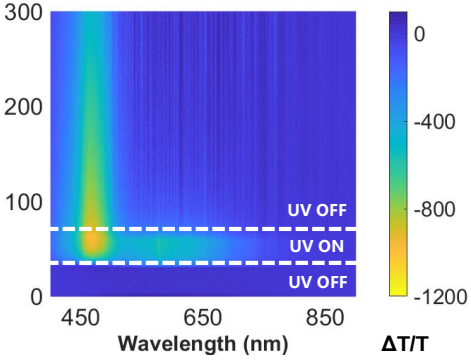
Future work

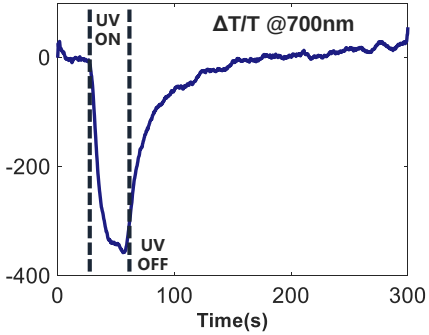
*Development of **light-responsive** 3D printed systems*

Pseudogem-bisDPI[2.2]PC

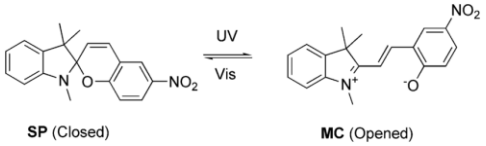


Pump-probe absorption of 3D printed single layer BPA + 1%TPO 5% PC

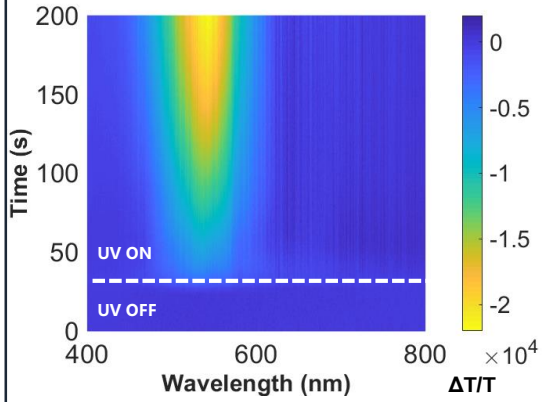


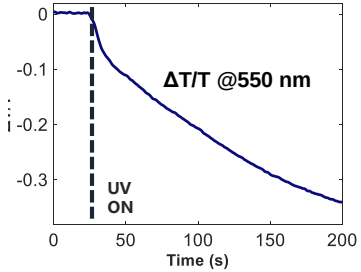


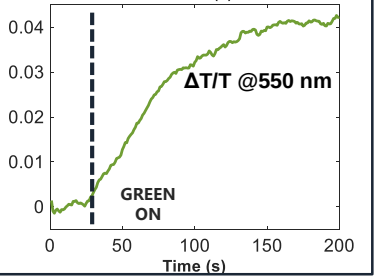
Spiropyran



Pump-probe absorption of 3D printed single layer BPA + 1%TPO 1% Sp







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Thanks for the attention

Francesca D'Elia