Three-dimensional microfabrication for photonics and biomedical applications

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Outline

- Motivation
- Two-photon polymerization
- Resin preparation
- Microstructures fabricated via 2PA polymerization
    - Scaffold for bio applications
    - Birefringent microstructures
    - Conjugated polymer microstructures
- Conclusion

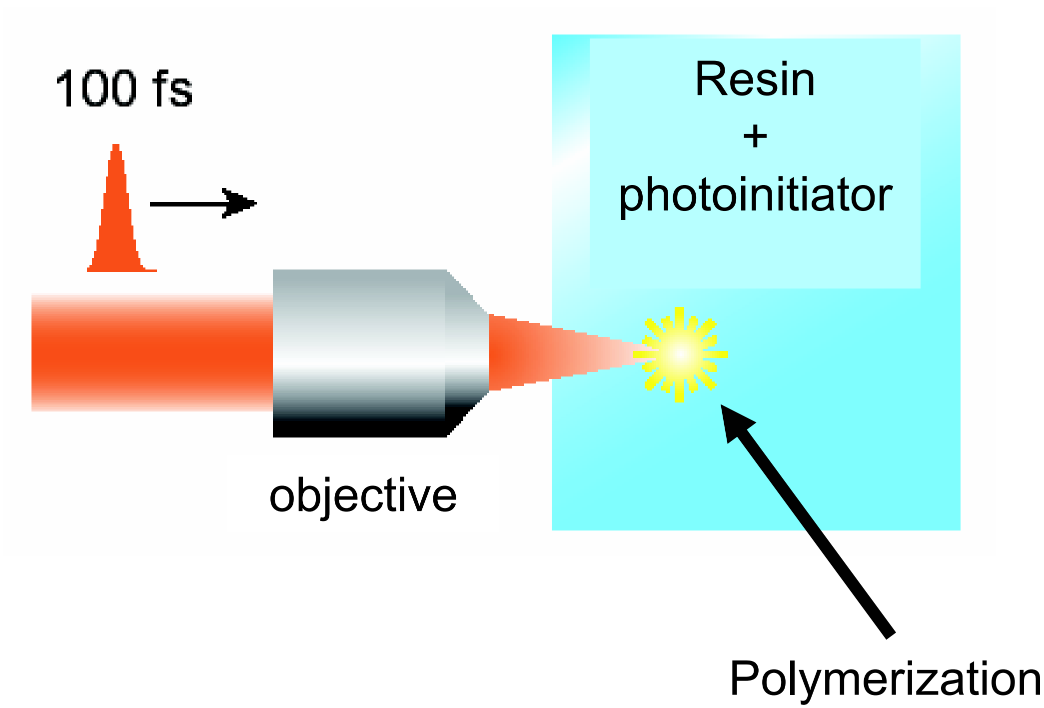
Motivation

Two-photon absorption polymerization have been used to fabricate 3D micromechanical actuators, photonic crystals, optical devices, etc

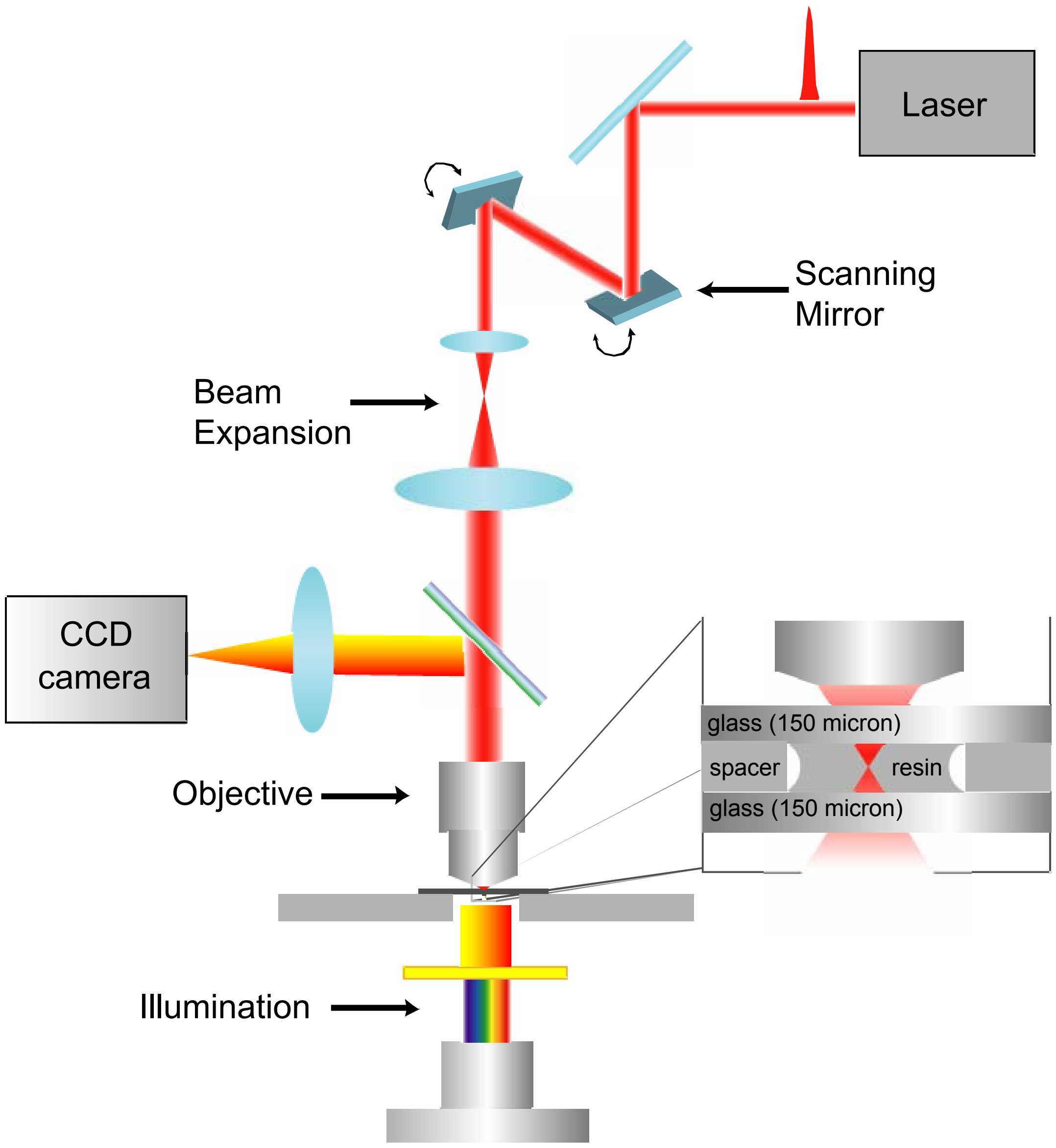
Most of the structures reported until now are passive elements, whose properties cannot be changed by external mean, thus hindering their applications.

In this way, it is desirable to look for new resin formulations containing active components, which still can be polymerized using two-photon absorption.

Microfabrication using two-photon polymerization



Two-photon polymerization setup



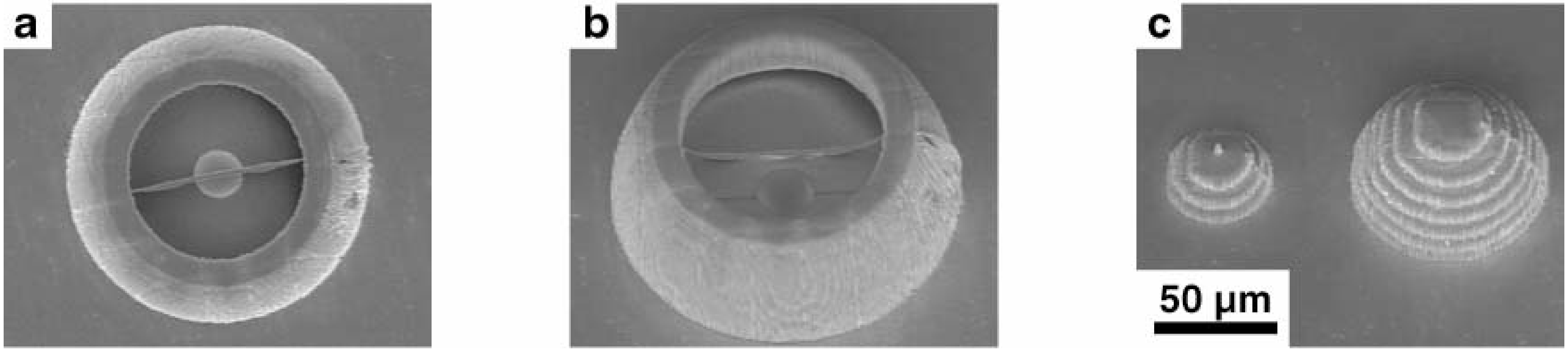
Ti:sapphire laser oscillator

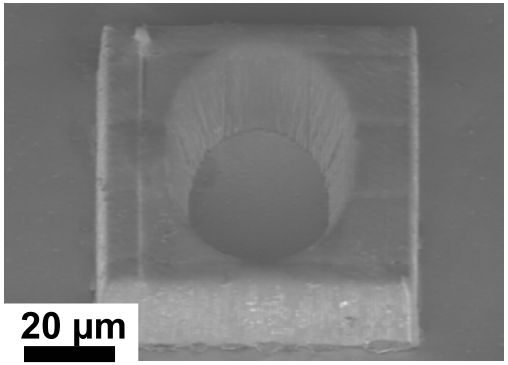
- 130 fs
- 800 nm
- 76 MHz
- 20 mW

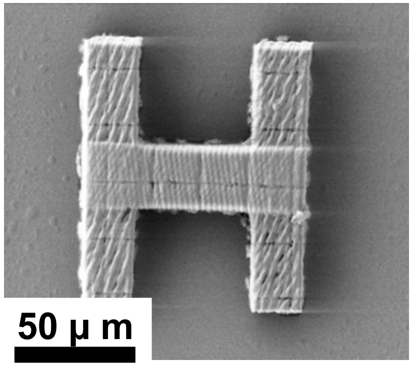
Objective

40 x
0.65 NA

Scanning electron micrograph of microstructures fabricated by 2PA polymerization



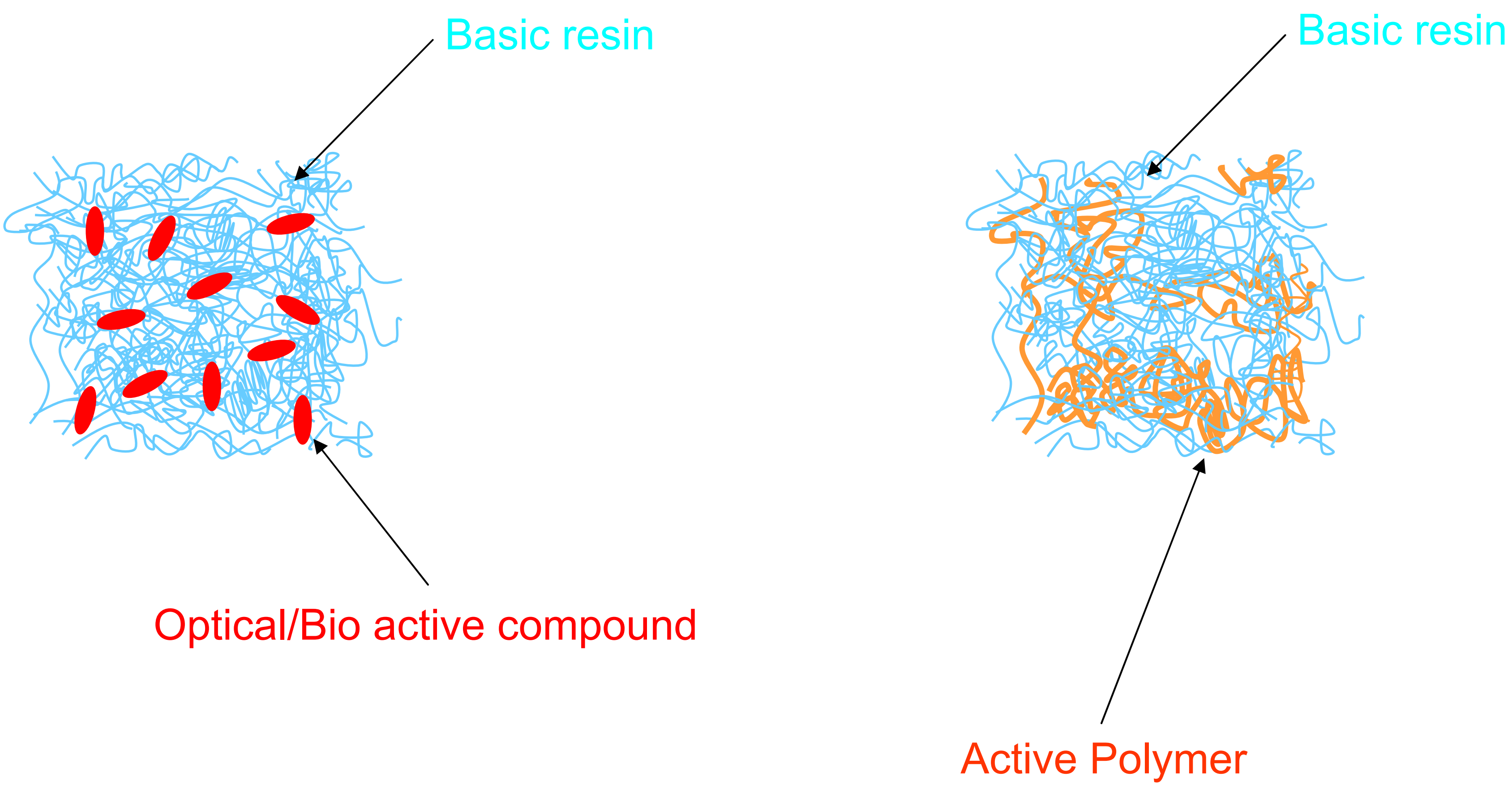




The microstructures show excellent integrity and high definition.

Doping approach

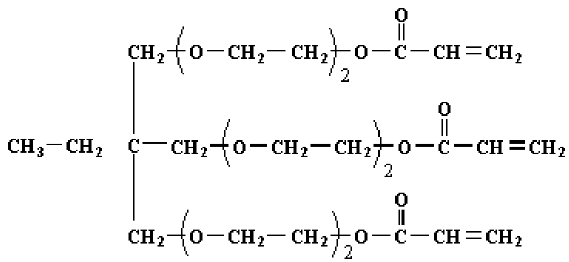
Two guest-host systems



Basic resin composition

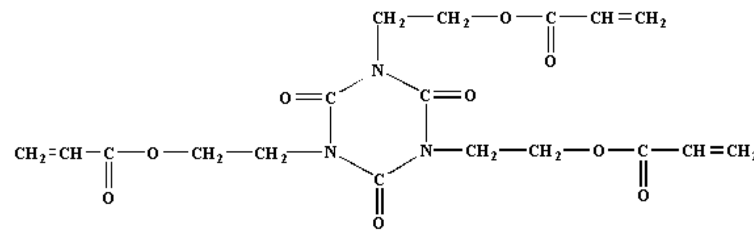
Monomers

SR499



reduces the shrinkage upon polymerization

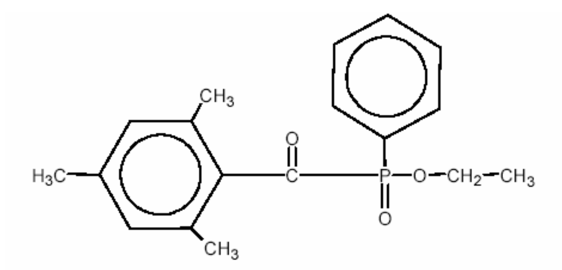
SR368



gives hardness to the polymeric structure

Photoinitiator

Lucirin TPO-L



Microstructures properties

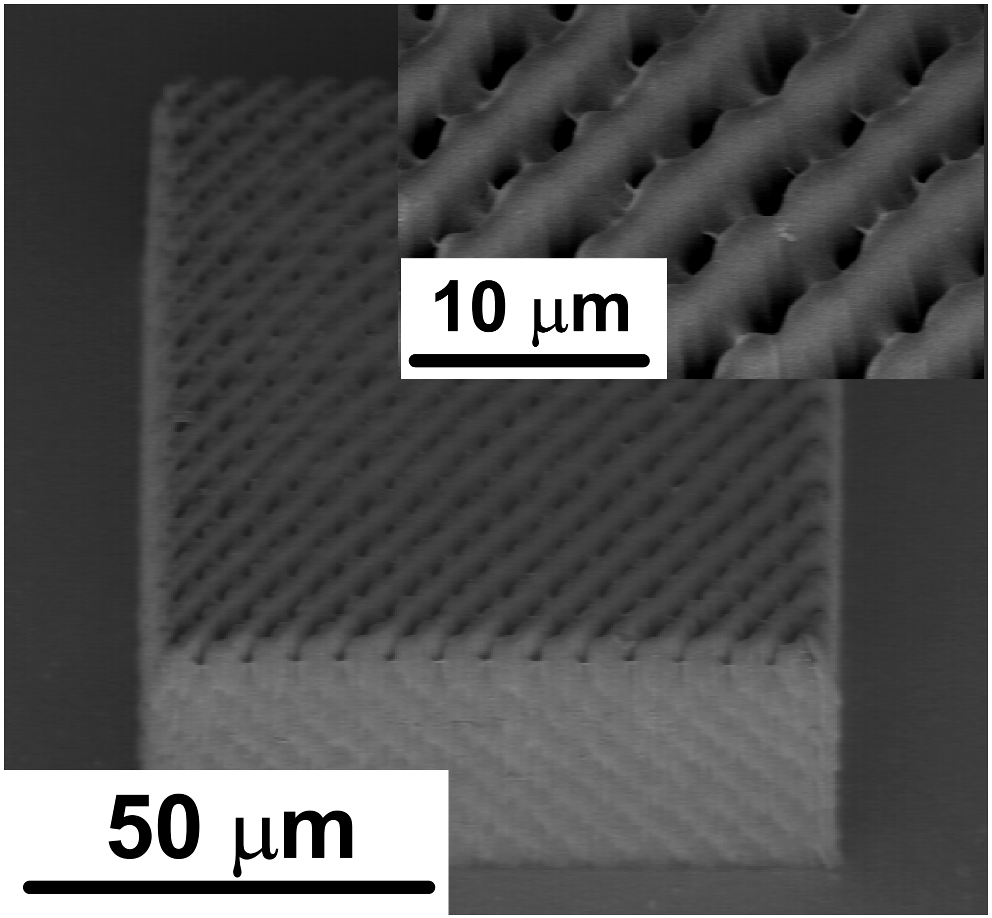
1- Microstructures for bio applications

2- Optically induced birefringence

3- Conjugated polymer microstructure

1- Microstructures for bio applications

3D interconnected microstructure for biological applications (3D scaffold)



→Tailored scaffolds (3D confinement of cells)

tissue engineering

bone reconstruction

growth factors

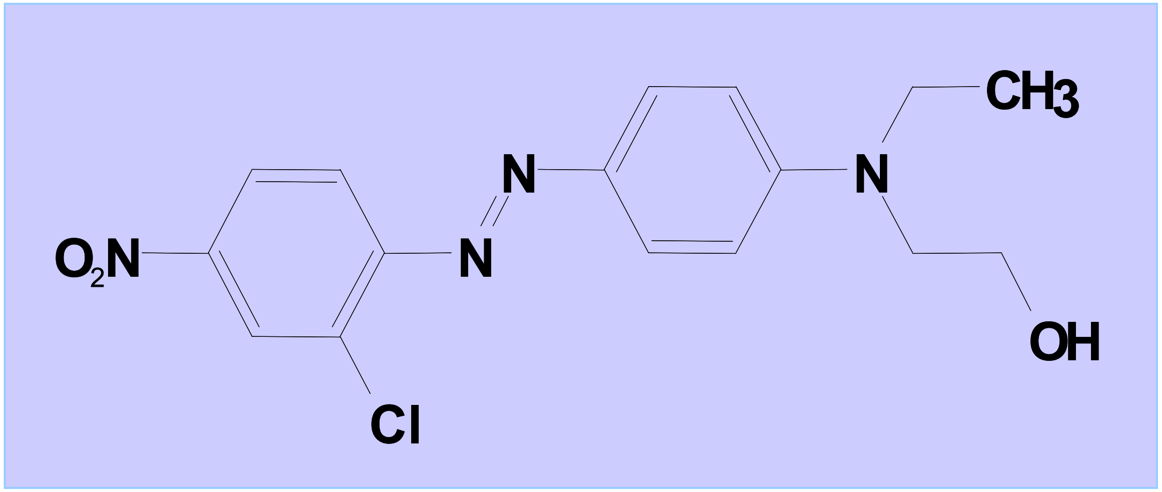
antibiotics

biopolymers

→ 3D cell mechanics studies

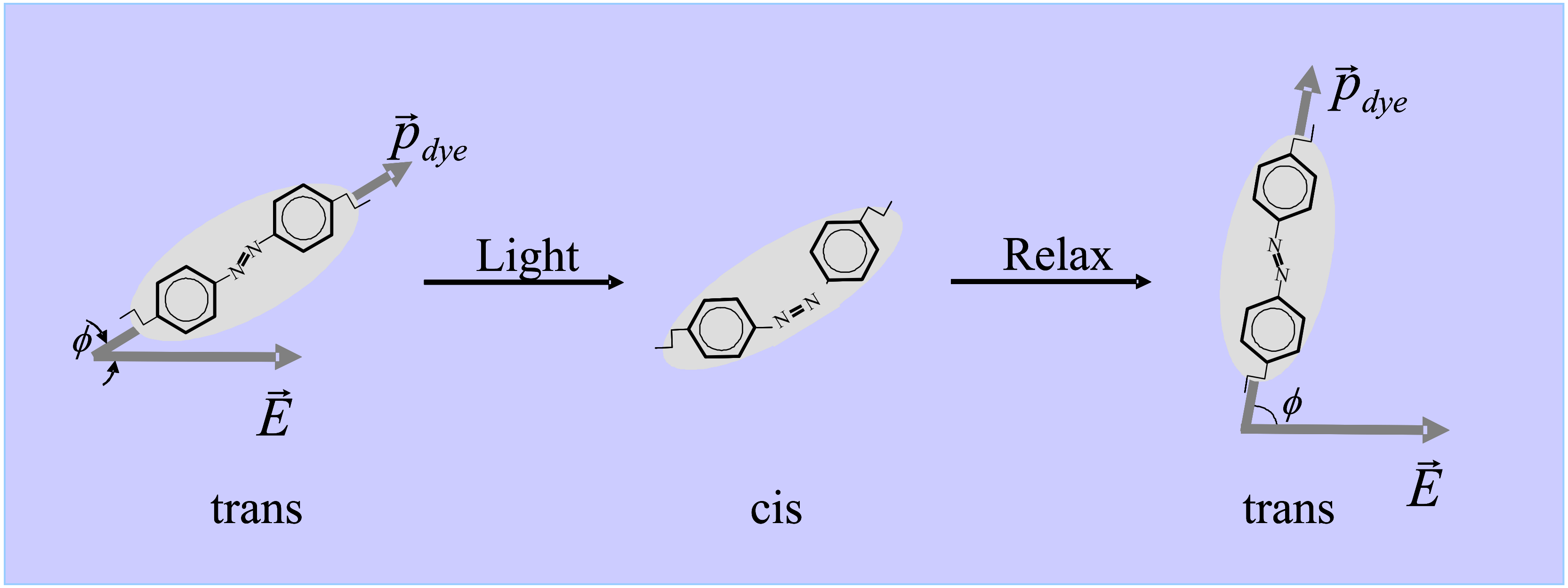
2- Birefringent microstructures

To the resin we add the azodye DR13

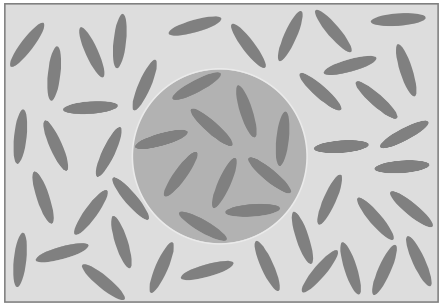


Optically induced birefringence mechanism

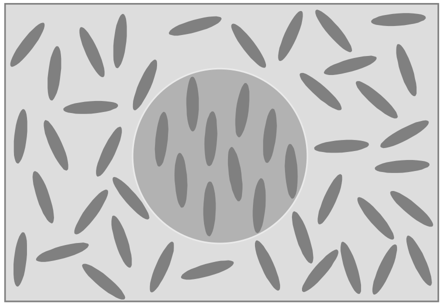
Molecular orientation by excitation with linearly polarized light



Before alignment

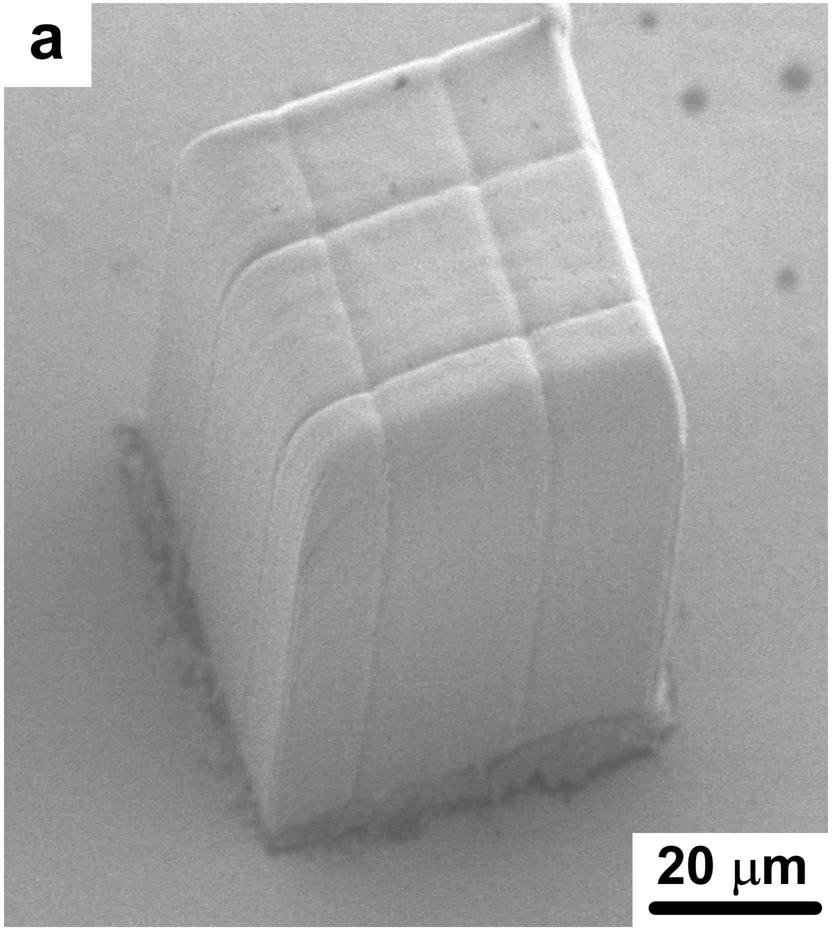


After alignment



Optically Induced birefringence

Microstructure with DR13



Ar+ ion laser irradiation

- 514.5 nm
- one minute
- intensity of 600 mW/cm^2

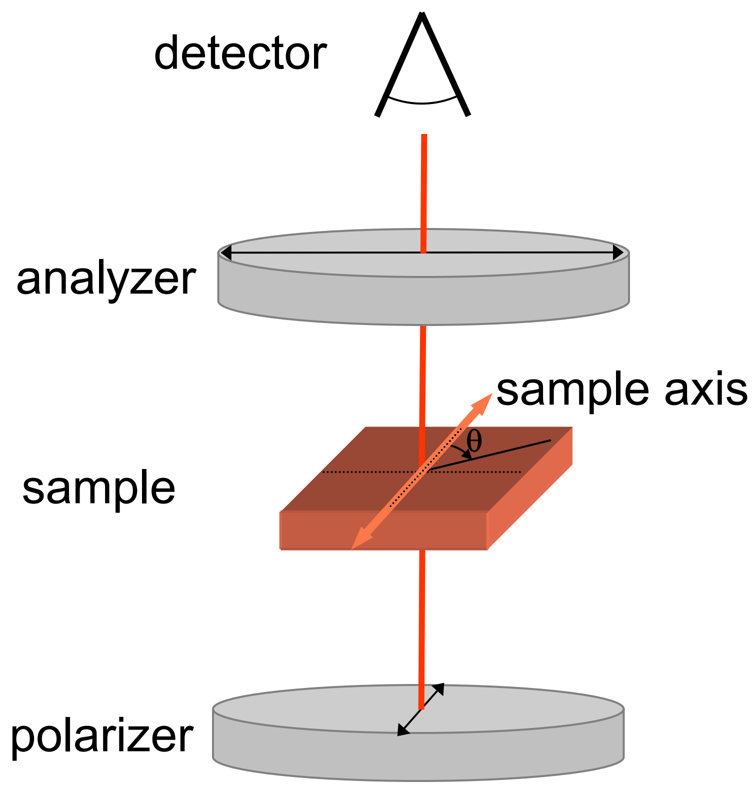
70% SR368 : 30 % SR499

1% DR13

- more stable birefringence
- enough amount of SR499 to reduce microstructure shrinkage

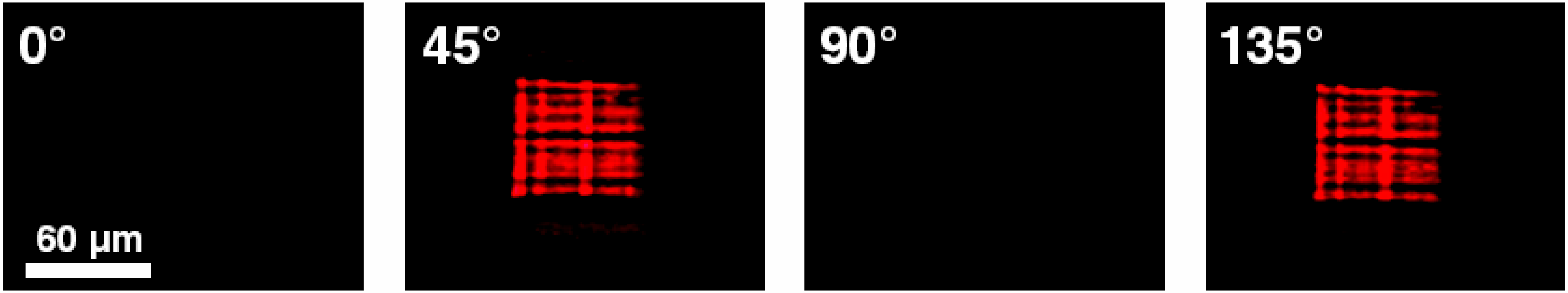
Birefringence in the microstructure

The sample was placed under an optical microscope between crossed polarizers and its angle was varied with respect to the polarizer angle



Birefringence in the microstructure

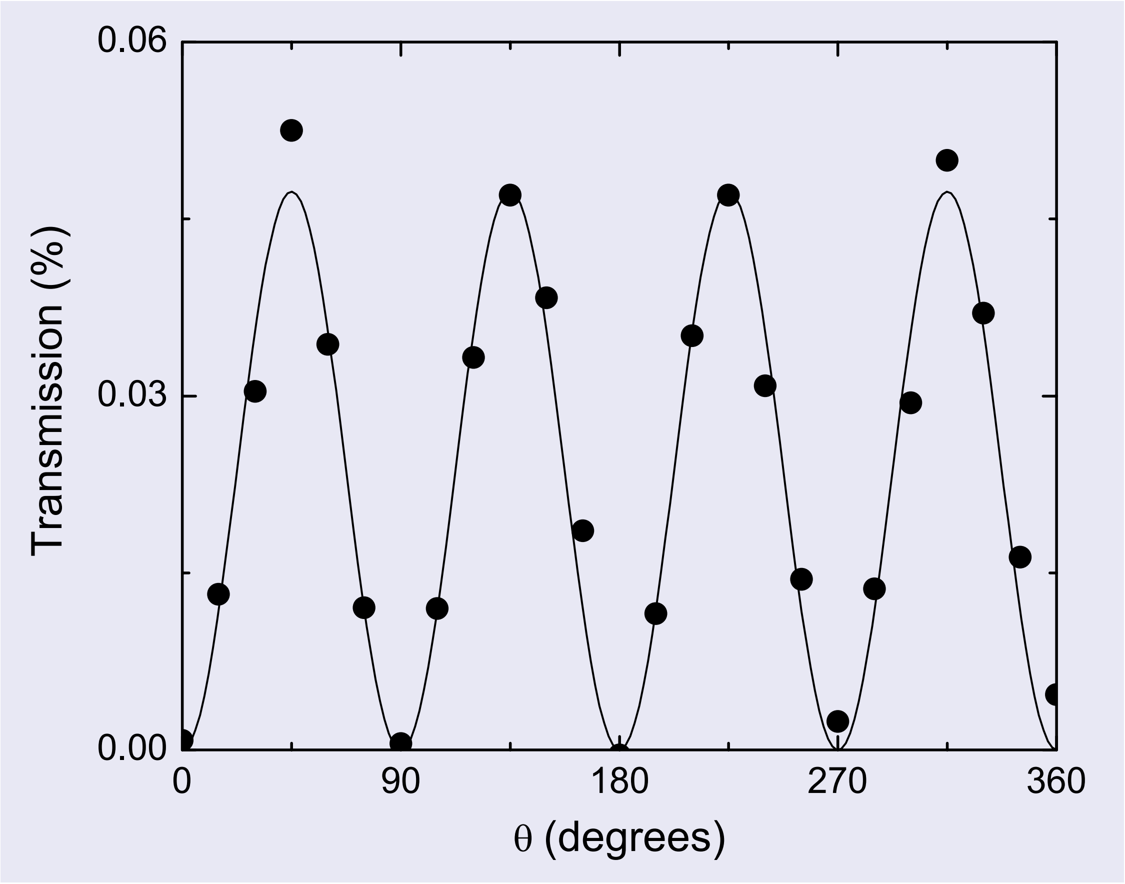
The structure is visible when the angle between the birefringence axis and the polarizer is an odd multiple of 45°



This birefringence can be completely erased by irradiating the sample with circularly polarized light.

Birefringence in the microstructure

Transmitted light through the analyzer as a function of θ, for the previous microstructure.



Sinusoidal behavior typical of the birefringence

$$T = \sin^2\left(\frac{k\Delta n L}{2}\right)\sin^2(2\theta)$$

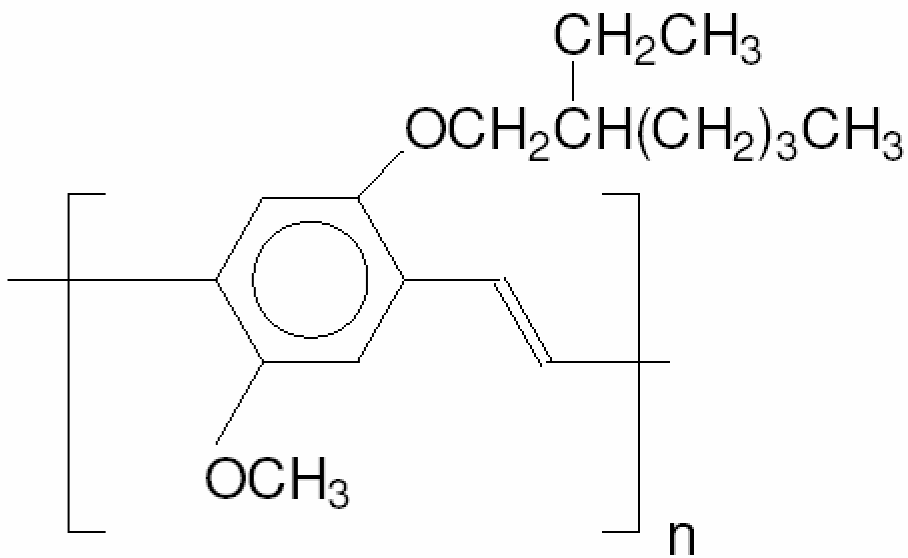
$\Delta n = 5\text{x}10^{-5}$

Applications for birefringent microstructures

- ✓ Waveguides
- ✓ Connector
- ✓ Electro optical devices

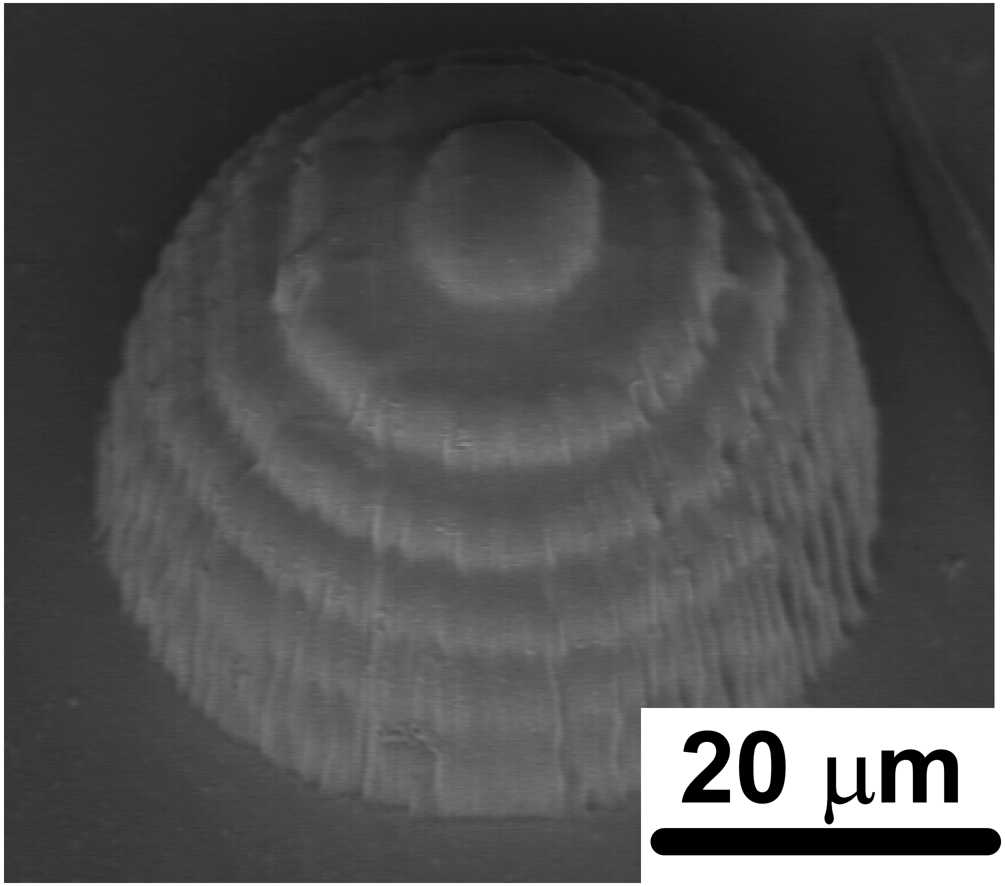
3- Conjugated polymer microstructures

To the resin we add the conjugated Polymer MEH-PPV

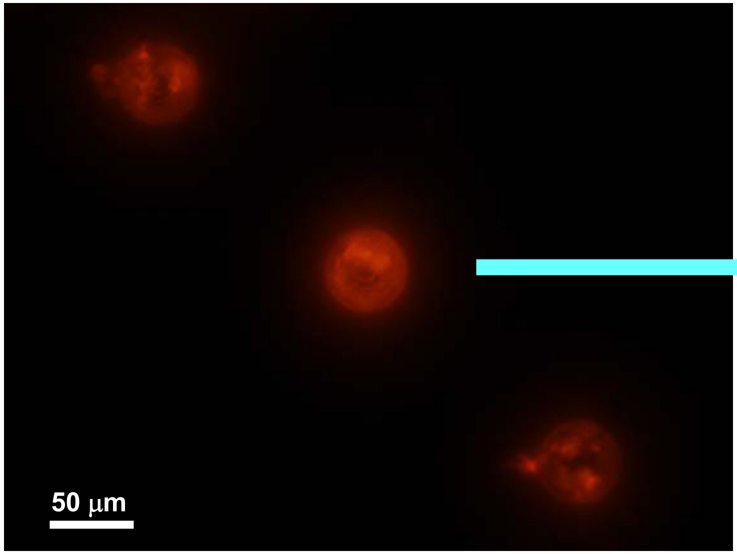


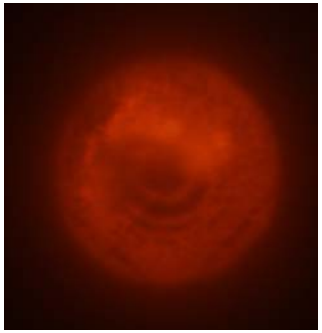
Fluorescence
Electro Luminescent
Conduction

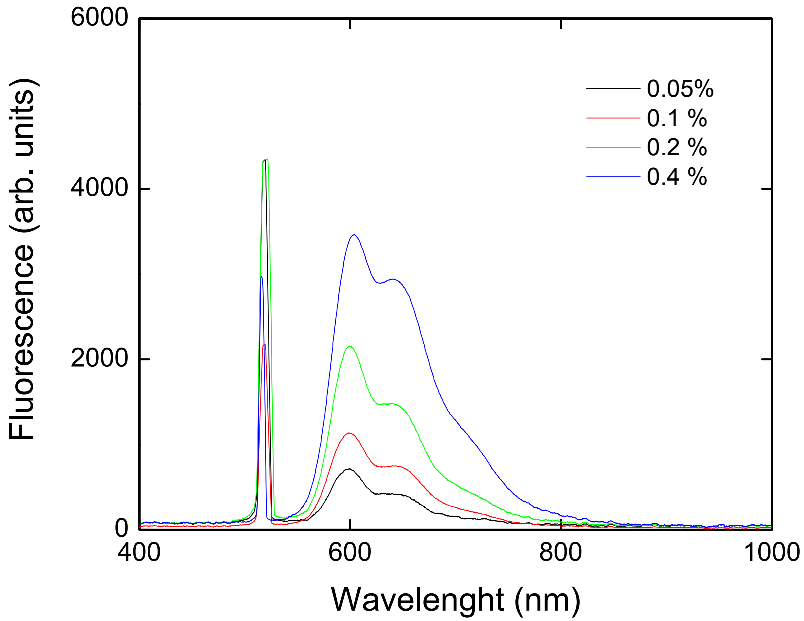
Scanning electron micrograph of microstructures with MEH-PPV



Fluorescence Microscopy







Applications for conjugated polymer microstructures

- ✓ Displays
- ✓ LED
- ✓ Conductive microdevices

Message

fs-laser microfabrication allows designing polymer-based devices for photonics and biomedical application

Acknowledgments

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