TopoLight: SOFT MATTER PLATFORM FOR OPTICAL DEVICES VIA ENGINEERING OF NON-LINEAR TOPOLOGICAL STATES OF LIGHT

Deliverables

Project details:	
Call:	H2020-FET Open – 2018 - 2020 - 01
Project name:	TopoLight
Project number:	964770

Deliverable details:	
Work package number and title:	1 Fabrication and basic characterisation of hybrid OLC MCs
Deliverable rel. number and title:	**D1.1 Design of OLC MCs**
Due Date	Month 4
Lead beneficiary:	WAT
Dissemination:	Public
Report coordinator	Wiktor Piecek

This project has received funding from the European Union's Horizon 2020 FET Open research and innovation action under the grant agreement No. 964770 (TopoLight).

Projects of planar microcavities (MCs) of various types and technologies of fabrication.

1. General description:

Microcavities are photonic hybrid organic/liquid-crystal system (OLC) for room temperature Bose-Einstein condensate (BEC) research and applications. The planned study is based on the idea of external electrical control over spin-orbit coupling (SOC) due to artificially engineered fields acting on photons. The project aims create topologically protected states of light: unidirectional flow robust against backscattering and vortex states carrying quantized angular momentum. For this purpose MCs platform combine a strong emissivity with the ease of fabrication, low costs, and scalability and room temperature operation.

2. MC assumptions:

MCs will consist of a two solid substrates equipped with functional layers including Distributed Bragg Reflectors (DBRs) separated with calibrated spacers, forming a cell gap filled with Liquid Crystal (LC) for the anisotropic modulation of light (see Fig.1.) The light modulation is provided with LC director driven by external electric field generated between transparent electrodes deposited over a substrates inner surfaces. Such a cavity needs to incorporate inside the cell gap an emitting layer.

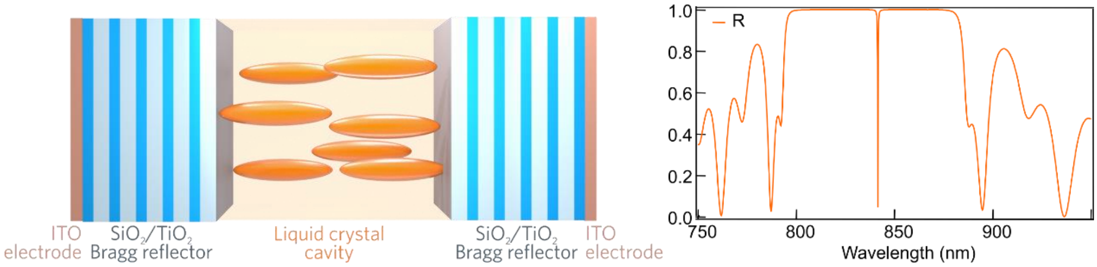

Fig.1. a) A general scheme of LC microcavity. b) Cavity reflection mode of an exemplary OLC MC. (Fig. by M. Król).

The design must address the materials and technologies used for manufacturing the functional MC allowing for:

1. **trapping photons** in a cell gap by using of DBRs (WAT) of an arbitrary reflection band and providing arbitrary planed cavity modes,
2. forming an optically anisotropic LC layer vulnerable for driving with external electric field,
3. the optical axis of LC structure is oriented by using proper LC orienting layers (OL); cell gap filled with OLC is assured by using proper spacers (SP),
4. providing **intra-cavity light emission** by incorporating **emitting** layer (WAT),
5. providing spatial **distribution of an intensity and the direction of the electric field,** by fabrication of electrodes on both sides of MC (WAT),
6. providing an **arbitrary distribution of the LC molecular director** (WAT).

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3. Materials.

As to provide all functionalities mentioned above the following materials have been selected for fabrication of MCs:

1. **Substrates**:
    a. **for testing MCs -** commercial **borosilicate float glass** (thickness of 0.7 and 1.1 mm) for LCD technology (tested),
    b. **for final MCs** – flat – parallel plates of a commercial **quartz glass** (in progress).
2. **Transparent electrodes**: **Indium Tin Oxide** (ITO) (tested),
3. **DBR** – designed (WAT) using a commercial software, vacuum deposited, controlled by ellipsometric and spectroscopic methods.
4. **Ordering layers:**
    a. homogeneously orienting layers HG (tested),
    b. homeotropic orienting layers HT (tested).
5. **Liquid crystal** (WAT):
    a. nematic (tested)**,**
    b. dual frequency nematic (tested).

4. Structures of MCs

The performing MCs will be prepared using quartz glass substrates of thickness of 3.0 mm od size 20.0x27.0 mm (see Fig. 2). Both substrates equipped with all functional layers will be assembled with sealing gasket and separated with the spacers doped to this gasket.

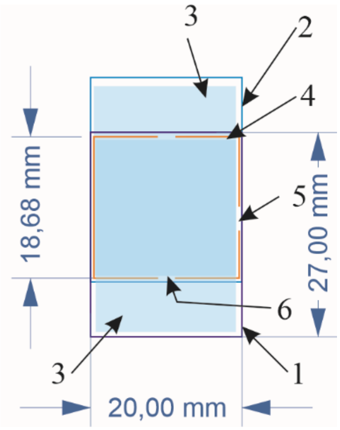

Fig. 2. Top view of the MC. Top (1) and bottom (2) quartz substrate, bottom (3) and top (3) ITO electrodes, sealing gasket (4), inlet for vacuum filling of the cell gap with LC (5) and inlet for filling with capillary action in the air (6). The DBRs an the rest of functional layers but ITO transparent electrodes are not displayed. The whole structure of the MC is shown in the Fig.3.

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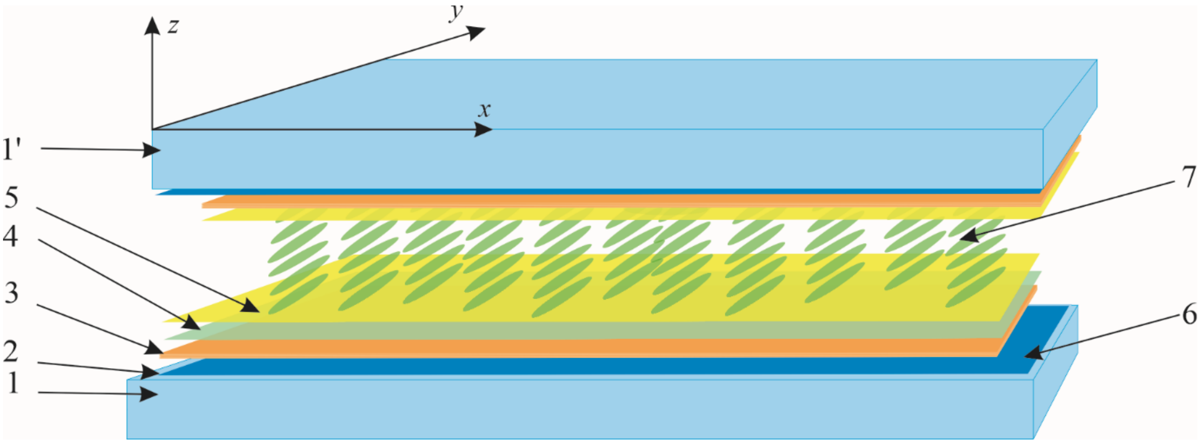

Fig.3. The MC with all functional layers and LC.

1. Bottom substrate and top substrate (1')
2. ITO transparent electrode
3. DBR
4. Emitting layer
5. Orienting layer
6. Contact to transparent ITO electrode
7. LC molecules

Depending on the needed structure of LC inside of the MC the transparent electrodes as well as rubbing direction can be patterned with using of technologies mentioned below.

The cell gap can be assured by using of hard glass micro-balls (micro-rods) spacers distributed in sealing gasket and/or within a cell gap. (tested).

Technologies:

For preparation of MCs a several technologies have been chosen and tested.

1. Substrates preparation.
   a. Cutting and beveling:
      i. The **commercial float glass** substrates (already available at WAT) are subject of cutting and beveling (tested).
      ii. quartz substrates are formatted on demand by a provider (delivery in 4 weeks) (in progress).
   b. Washing: cleaning in organic solvent followed by deionized water ultrasonic cleaning in deionized water. At final stage drying and heating for removing of residual water. No storage. Substrates passed to vacuum technologies immediately (tested).

   The above technologies are ready and tested.
2. **Vacuum technologies** of inorganic layers deposition of ITO, SiO2 and DBR – tested.
3. The technology of **patterning** of ITO transparent electrodes for testing cells was tested. The projects of masks and dedicated holders are in progress.
4. Emitting layer deposition and further steps of technology tested .
5. **Ordering layer deposition** polyimides and photo-orienting materials by spincoating from solvents – ready and tested. Technologies of further **thermal processing** of orienting layers are tested. **Photo-orientation** technology has been tested using display like dummy samples.

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6. The **patterning** of ordering layers to obtain 2D and 3D structures of LC - tested.
7. The patterning by illumination from with a resolution of c.a. 5 um is under construction. Expected tests in 3 months.
8. Cells assembling will be dome by the deposition of the sealing glue doped with proper spacers at the substrate's perimeter and approaching (finally pressing) the other substrate (at the reverse orientation) under optical control (in progress).
9. Filling of MC with dedicated LC will be done in special chamber in air by capillary action or in vacuum. After cell filling with LC it is finally sealed with special glue and wired with using of a ultrasonic soldering unit and special, low temperature alloy (tested).

5. Final remarks

As mentioned above the materials and technologies for MCs are tested.
Due to the delay of the quartz substrates of a size 20x27 mm the testing and fabrication of MCs of a final size is delayed. As a substitution of this a bunch of testing substrates on float display glass have been fabricated and tested. They are ready to send to IBM for MeLPPP deposition (January 2022).

Wiktor Piecek

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