PhD Proposal

Title: Development of polymer-based photonic crystals for volatile organic compounds (VOC) sensing

Laboratory and research group : INL, Nanophotonics
Location: INL UMR CNRS 5270 – INSA de Lyon

Keywords: Clean room processes, photonic crystal, sensors, optical characterizations

Profile: Physics/Material Science, Optics/Photonics.

Subject:

Background, Context:

Air quality is a major public health issue that can range from discomfort to real pathology. Volatile Organic Compounds (VOC) constitute one of the major class of air pollutants and are essentially generated by the combustion of hydrocarbons from human activities. VOC are organic materials (benzene, toluene, chloroform etc) in the state of gas or vapor under normal conditions of temperature and pressure. VOC of anthropogenic origin are considered to be highly harmful to health; thus VOC detection and sensing techniques are needed for many applications (environmental monitoring, manufacturing process).

In this context, it becomes crucial to provide new tools for air quality analysis. For gas sensing, several approach have already been explored but the production cost, their high operating temperature, limit crucially their range of applicability. In the Nanophotonics group of INL, we focus on optical sensors especially photonic crystals because they offer a versatile and powerful platform to control light at the nanoscale. Indeed, the sensitivity of photonic crystal resonance to refractive index and geometry of the nanostructure[2] (figure 1) associated with the sensitive properties of polymers to VOC[1] is expected to lead to enhanced properties of the VOC sensor. Our objectives are thus the development and the experimental proof-of-concept of a polymer-based photonic crystal sensor showing higher sensitivity and selectivity to different VOC, compared to standard detection techniques (mass spectroscopy[3]).

Research subject, work plan:

The topic focusses on the realization and demonstration of polymer-based photonic crystal sensors. This PhD thesis is thus strongly oriented towards experimental work, although the photonic concepts developed within the Nanophotonic group of INL will be greatly explored to design new and efficient kind of sensors. It will be organized around the following 3 aspects:

- **Device conception:**

The device design will be based on the photonic concepts developed within the Nanophotonics team (Bound States in the continuum, Bloch Surface Waves, “2.5D” etc). Numerical simulations (RCWA, FDTD) will allow designing the photonic crystal sensors with the desired properties in terms of sensitivity and sensibility to the presence of VOC.

- **Device fabrication:**

The fabrication of the photonic devices will require several clean-room nanotechnology processes. A particular attention will be done on low-cost technological production such as nano-imprint and laser interference lithography, allowing the realization of the structures on large surfaces. It will be performed using the Nanolyon facilities at INL laboratory. During his/her work, the PhD student should acquire a deep expertise of nanofabrication processes, as well as a good experience in structural characterization techniques such as scanning electron microscopy.

- **Development of an optical characterizations setup:**

The optical characterization of the photonic devices will be performed using a dedicated setup. The development of such a setup is part of the PhD project. The desired setup should enable micro-reflectivity/micro-transmission measurements over an extended spectral range in the visible and near infrared (300-1100nm); a real-time monitoring of the device responses for the kinetic study of vapor/polymer interaction processes is also expected.

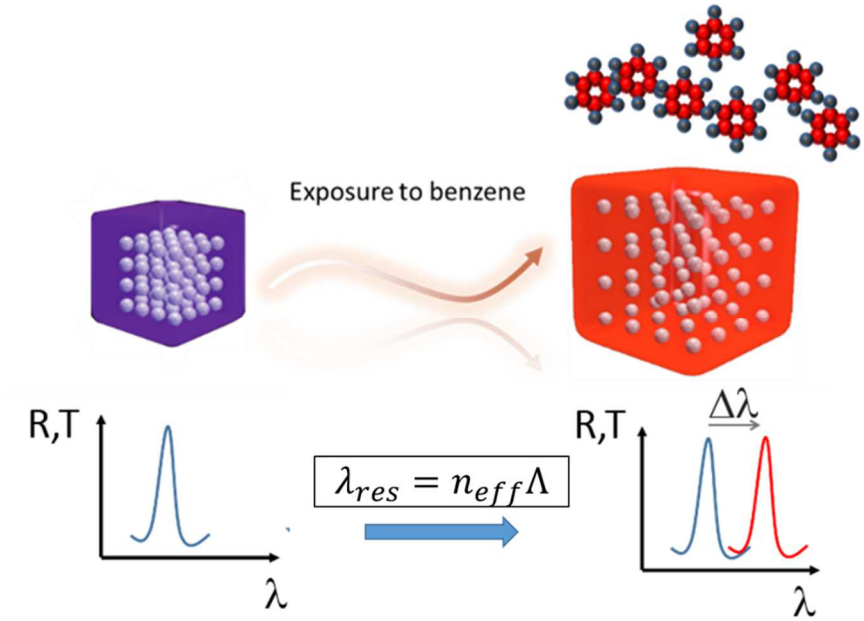

Fig 1. Sketch of the sensing principle: a polymer-based photonic crystal – PhC – (periodic arrangement of dielectric materials) swells upon exposure to VOC (Benzene for example), leading to a change of its geometric parameters. The monitoring of the resonance wavelength shift allows following the PhC deformation and determining the VOC concentration.

Candidate profile:

The candidate should have a solid background in physics and/or optics and should be specifically interested in nanophotonics and nanotechnologies with a strong taste for experimental work. Experimental fabrication skills will be considered as a strong advantage. Knowledge in the area of chemistry would be an asset.

References:

1. Papanu, J. S., et *al*. (1990). Swelling of poly (methyl methacrylate) thin films in low molecular weight alcohols. Journal of applied polymer science, 39(4), 803-823
2. Fenzl, C., et *al*. (2014). Photonic crystals for chemical sensing and biosensing. Angewandte Chemie International Edition, 53(13), 3318-3335.
3. Cooks, R. G., Ouyang, Z., Takats, Z., & Wiseman, J. M. (2006). Ambient mass spectrometry. Science, 311(5767), 1566-1570.

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