M2 Internship offer:

Bio-inspired and sustainable photonic sensors

Scientific context:

Photonic devices offer a great range of properties that are highly interesting for (bio)molecular sensing, as they can support resonances that are sensitive to their environment, while offering compatibility with physiological solutions and great possibilities for compact biomolecular screening using array-based sensing techniques. However, a lot of sensors used for biomolecular analysis tend to be single-use, and end up incinerated or in landfills, in order to avoid cross-contamination. This means that "standard" photonic sensors that are based on silicon technologies have a very high environmental impact due to their fabrication, with respect to their ultra-short life time. In order to reduce this environmental impact, alternative materials and technological processes can be envisaged. At INL, we propose to explore a new strategy based on nanoimprint lithography, a technique that consists in applying a mold on a soft material to directly pattern the reliefs of the desired devices into the material layer. Our choice of materials goes towards bio-sourced and biodegradable polymers, e.g., chitosan, an abundant biopolymer that can be extracted from seafood wastes. Here, the challenge lies in the fact that polymers are materials with a low refractive index, which usually results in poor photonic properties when considering the "standard" concepts of silicon-based photonics. Hence, alternative photonic concepts have to be proposed in order to obtain resonant devices with a high sensitivity, which could be applied as sensors.
Inspiration from natural structures is a route towards achieving this goal. Numerous animal or vegetal species presenting optical properties such as coloration or iridescence can be observed in nature (feathers, insect wings, leaves or petals…); these optical properties are due to a one, two or three-dimensional structuration of matter at submicronic scale [1], leading to optical resonances. In this internship, we propose to use such a natural structure as a mold to fabricate a photonic device in chitosan, and to study its properties for sensing.

Objectives of the internship:

The proposed internship will follow two main objectives. The first objective consists in identifying a natural structure with promising properties, using a methodology that will combine bibliographic studies on natural photonic structures and numerical simulations of their chitosan-replicated counterparts. The second objective is the experimental replication and study of the chosen natural structure. For this purpose, we will use a two-step replication process that is currently under development at INL (replication of the natural structure into a PDMS mold, followed by imprint of the PDMS mold into the chitosan layer). The optical resonances of the chitosan devices will then be studied using micro-reflectivity measurements, in air but also in various aqueous solutions to evaluate their potential for sensing.

Scientific impact and applications:

Although the optical properties of natural nanostructures have already been widely studied, and the underlying light-matter interactions are well-understood, their experimental mirroring is a real challenge that still requires to set up highly-complex designs and technological processes in order to obtain the targeted performances. Hence, the development of alternative original processes enabling, at the same time, to simplify the technological fabrication and to replicate the exceptional optical properties that can be observed in nature, will constitute a major scientific advance in the area of bio-inspired photonics. This could pave new ways for the implementation of bio-inspired nanostructures in several domains of application. Additionally, the demonstration of such nanostructures in sustainable materials will be a crucial milestone for the future developments of eco-friendly photonic devices.

Integration @INL:
The proposed internship will be conducted in the i-Lum team at INL, in close partnership with the DSE team for their expertise on chitosan-based devices. The experimental work will be conducted using Nanolyon facilities.

Training period:
The expected training period (4-6 month) will be from February/March to July/August 2025.

Supervision / Contact:
Céline Chevalier : celine.chevalier@insa-lyon.fr
Cécile Jamois: cecile.jamois@insa-lyon.fr
Xavier Letartre : xavier.letartre@ec-lyon.fr

[1] G. Jacucci, et al., Light Management with Natural Materials: From Whiteness to Transparency, Adv. Mater. 2021, 2001215