Study and development of plasmonic optical fiber platforms for biochemical and environmental sensing

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This thesis has been conducted in the Advanced Photonic Sensors ERC unit within the Electromagnetism and Telecommunication Department of the Faculty of Engineering at the Université de Mons (UMONS). It focused on biochemical and environmental optical fiber sensors based on plasmonic.

The thesis started with the basic knowledge required to understand the operating principle of the two sensing platforms used in the experimental work: gold-coated tilted fiber Bragg gratings (TFBGs) and gold-coated multicore fiber (MCF) interferometers. Then, the necessary knowledge such as the theory of surface plasmon resonances, the physical mechanism of surface plasmon wave generation and the demodulation techniques were introduced in this thesis. Also, simulation works concerning the study of two platforms were implemented. Finally, the original experimental work based on two gold-coated sensing platforms towards both environmental and biochemical sensing was performed.

This thesis allowed to initiate an environmental application for the first time in our group towards lead ion detection in water by using the gold-coated TFBGs. The demonstrated sensor was able to detect these extremely small targets thanks to a functionalization with the thrombin aptamers on gold layer. The study results showed that the demonstrated TFBG sensor was able to detect the lead ion solution with concentrations from 0.001 ppb to 0.1 ppb. Moreover, FBGs bring their inherent advantages, such as ease-of-fabrication, remote monitoring and label-free.

The next project was focused on the study of the discrimination between bulk and surface refractive index effects by using partially gold-coated TFBGs. The spectral characteristics of partially-coated TFBGs have been experimentally investigated. The bare part and gold-coated part of TFBGs show different sensitivities to bulk (through cut-off mode) and surface (via SPR mode) RI change with the sensitivities of around 21 nm/RIU and 67 nm/RIU, respectively. In HER2 protein biochemical sensing, the demonstrated configuration showed the advantage to identify the environmental perturbation detected by the bare part of the TFBGs. HER2 proteins were detected with a concentration as low as 10^{-8} g/ml.

Finally, in the framework of an international collaboration, the opportunity to work on another original approach arose. An MCF interferometer was studied to build a refractometric sensor without integration of gratings. In our study, we showed that a 10 nm-thick gold-coated MCF interferometer presented a higher sensitivity to SRI for p-polarized light. The insulin bio-sensing was implemented in this study and the sensitivity of demonstrated sensor was obtained with a value of ~8.02 a.u./RIU. As a new all-fibered platform, the gold-coated MCF interferometer can detect both RI change and temperature changes through peak amplitude and wavelength modification. Consequently, it can be considered as a good choice in biochemical sensing. We believe that these first experimental results will pave the way towards other applications and improved performance in the future.