Title: Surface modifications of long-period fiber gratings for biosensing applications

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Date: 2019-09-13

Abstract

The biosensor market is developing fast in recent years mainly due to the growing demand for point-of-care devices and fast detection solutions that may be applied in healthcare, biodefence, environmental monitoring, and food industry. Significant improvements have been made in optical label-free biosensors that provide fast, simple, and accurate analysis. Another advantages, such as small size, low cost, and flexibility, can be obtained by using optical fiber sensors. The main goal of my thesis was to develop simple and reliable surface modification methods and implement them for preparation of long-period fiber grating (LPFG) biosensors for virus detection.

The first part of my thesis describes characterization of the LPFGs used in further work. The LPFGs were tuned to their highest refractive index (RI) sensitivity by chemical etching. The obtained RI sensitivity (~2000 nm/RIU) indicated great potential for label-free biosensing. Additionally, I analyzed the effect of surface drying on the optical response of the LPFG. The results showed that drying between measurements performed in liquid significantly influences the transmission spectrum of the LPFG due to changes in the cladding surface. This indicates that any drying should be avoided because it may cause getting misleading conclusions. Therefore, I designed a flow cell in which the surface drying was limited. It was used in my studies for other measurements with LPFG-based sensors.

Biosensor preparation requires robust methods for bioreceptor immobilization. In my work I tested and described vapor phase silanization methods to introduce proper functional groups that may be used for covalent bonding of protein receptors. Until now, such methods were used for flat glass surfaces, but my work demonstrated that they are also suitable for cylindrical optical fibers. The best procedures were further used for modification of LPFGs with antibodies and other receptors.

The next part is focused on the utilization of sensitive LPFGs and developed surface modification methods for preparation of highly demanded biosensors for virus detection. By application of antibody-modified LPFG biosensors in label-free approach it was possible to detect 5×10^3 PFU/mL of T7 bacteriophage and 1 ng/mL of norovirus virus-like particles in 40-min assay. Moreover, the method of surface regeneration, which may decrease production costs and enable conducting different measurements on the same LPFG sensor, was presented.

In the last experimental part, I used LPFG sensors coated with thin metal oxide overlays. A tantalum oxide thin film was used for sensitivity enhancement of LPFG-based device in both RI sensing and in biosensing. Compared to the bare LPFGs used in this work, the improvement of RI sensitivity was almost sixfold and translated also into better label-free biosensing capabilities. Additionally, thin metal oxide films make it possible to expand application range of LPFG sensors. I demonstrated that indium tin oxide (ITO)-coated LPFG can be used for simultaneous electrochemical and optical measurements in specially prepared combined setup. The ITO overlay served as both working electrode in the electrochemical system and as a coating that enhances the sensitivity of an LPFG to changes of the external RI. The optical response of the sensor was strongly dependent on the voltage applied to the ITO-LPFG working electrode and on the composition of the electrolyte.

All described achievements were finally summarized and put into perspective of future research to understand their input in the biosensing field.