Immunoglobulin G sensor by means of lossy mode resonances induced by a nanostructured polymeric thin-film deposited on a tapered optical fiber

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Abstract

A novel approach to detect type G immunoglobulins (IgGs) has been developed, based on the combination of two ways of improving sensitivity applied to a simple optical structure. The first one is the fact of tapering the optical fiber, which permits to access the evanescent field of the light propagating through the waveguide and increases the detection surface. The second one is the use of a novel technology known as lossy mode resonances (LMRs) [1,2], which have proved to present higher versatility in some characteristics than surface plasmon resonances (SPRs) [3]. Due to this, although SPRs are normally used to detect biological reactions, LMRs can also address this topic.

To this purpose, a 30 mm uncladded segment of a 200/225 μm core/cladding diameter optical fiber (FT200EMT, Thorlabs Inc.) was tapered by a system designed by Nadetech Innovations S.L. until a waist diameter of 100 μm and a waist length of 10 mm were reached. This tapered uncladded multimode fiber (T-UMF) was subjected to a sputtering process (Quorum Technologies Inc.), in order to deposit a silver mirror on its tip, so that a simple reflective set-up could be prepared. The materials used for the thin-film fabrication were poly(allylamine hydrochloride) (PAH) and the polyanions poly(acrylic acid) (PAA) and poly(styrene sulfonate) (PSS), all from Sigma-Aldrich. These three substances were chosen since they have reported to generate LMRs by using the layer-by-layer electrostatic self-assembly technique (LbL-ESA), which is described elsewhere [4]. Apart from that, both anti-IgGs and IgGs, extracted from goat serum, were also obtained from Sigma-Aldrich.

Fig. 1 shows the equipment used to follow both construction and detection processes. First of all, an AQ4303-B (ANDO Inc.) white light source launched the optical power to an optical 2x1 bifurcator. The light was introduced in the T-UMF and then reflected by the metallic mirror, at the same time it was modulated by the chemical substances being adsorbed during the process. Finally, the different spectra were captured by a spectrometer from 400 to 1000 nm (Ocean Optics Inc.) and then processed.

As it can be observed in Fig. 2 a and b, a $[PAH/PAA]_{20}$ matrix was needed to locate the LMR at 600 nm. Here, a typical behavior of a LMR is observed. Low losses are registered until the LMR starts to be visible at bilayer 15. From then on, the resonance presents a red-shift to higher wavelengths as the nanocoating thickness increases. Then, a $[PAH / PSS]_5$ polymeric matrix was deposited by LbL onto the previous one, in order to create an adequate environment for the deposition of the anti-IgGs, according to [5]. The end of the construction finished when the LMR reached the middle of the monitoring window, this means 700 nm (bilayer 25). The goal for doing this was to center the LMR in a position where the further displacements could be better monitorized wherever the resonance shifted.

The next step was to register the LMR displacement when adsorbing the anti-IgGs layer and the further shifts when detecting the different IgG concentrations. In this sense, Fig. 3 is provided, where the mentioned biological processes are presented, as a wavelength displacement while time passes. First, the substrate deposited by the previous paragraph was subjected to a 6 μg/ml solution of anti-goat IgG in PBS during 4 hours, so that the anti-IgGs were deposited onto the substrate at room temperature. As it is presented in Fig. 3, the LMR shifted around 14 nm to the right, from 735 to 749nm. Then, 3 different IgG concentrations were detected by immersing the resulting biosensor in 1.4, 4.2 and 12.5 μg/ml PBS-IgGs solutions, obtaining shifts to 747, 752 and 757 nm respectively. The reason for this behaviour is a change of the effective refractive index due to the adsorption of the biological compounds, which makes the LMR shift from one position to other.

All things considered, a simple fiber-optic IgG biosensor has been developed by studying the behavior of a LMR induced by a polymeric thin-film deposited onto a tapered optical fiber. The effect of tapering the optical structure leads to a higher detection surface and it gives also an easy access to the evanescent field of the light propagating through it. This results in an improvement of the sensor properties when detecting IgGs concentrations.

References
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Figures

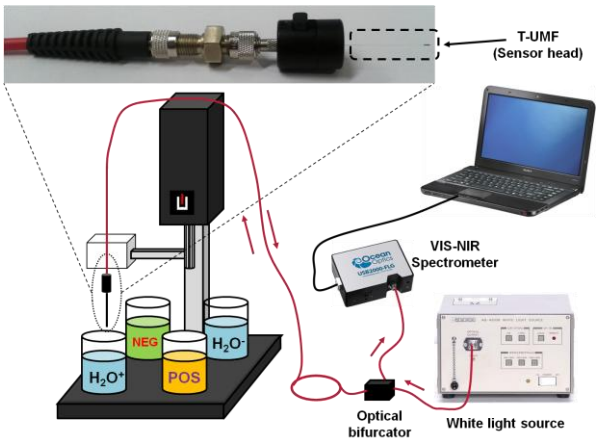

Fig. 1. Set-up prepared to monitorize both the construction and the detection processes.

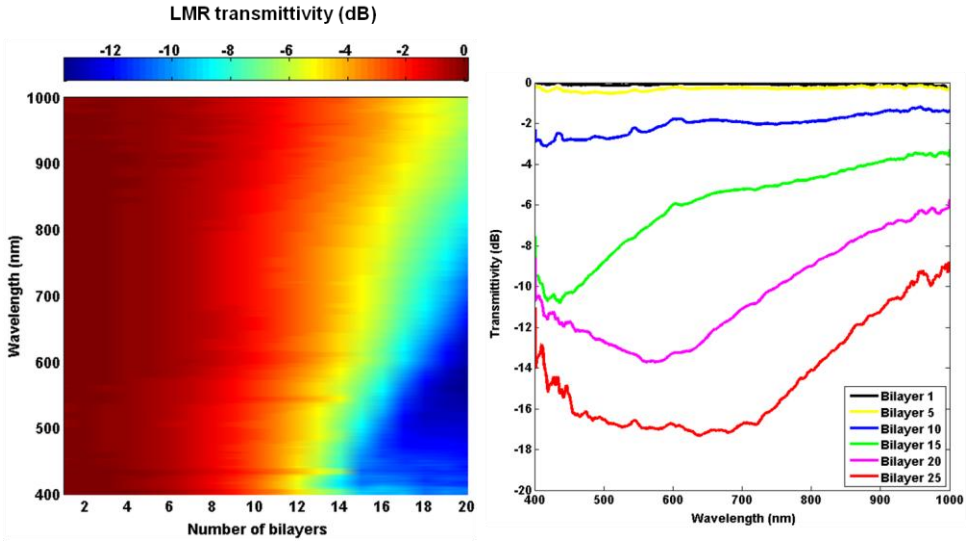

Fig. 2. (a) LMR evolution as the thin-film thickness increases. (b) LMR profile at different bilayers.

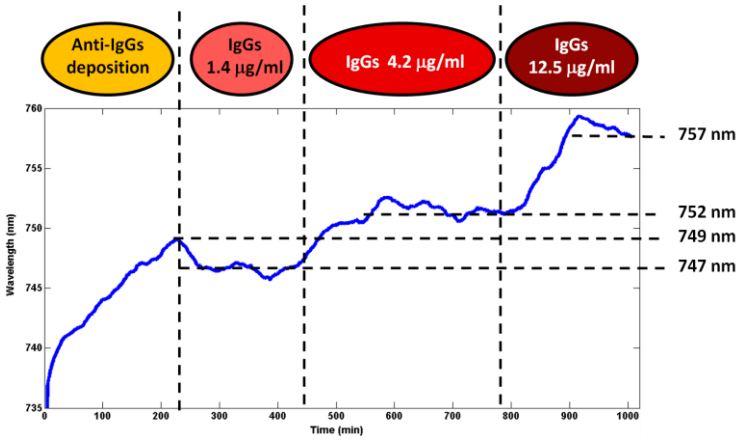

Fig. 3. Tracking of the minimum of the LMR during the anti-IgGs deposition and the IgGs detection. The vertical dashed lines indicate when the sensor is immersed into the next IgGs solution.