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Deep-probe Biosensing Using Metal-clad Waveguides

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Peak-type operation of metal-clad waveguide sensors provides a probing depth into the sample volume of infinity, unlike conventional waveguide sensors, probing depth ~200 nm. Thus, the deep-probe sensor is applicable for detection of micron-sized biological objects.

A typical optical waveguide sensor is based upon monitoring the resonance angle at which light is coupled into the waveguide. Hence, the in-coupled light intensity versus illumination angle gives rise to a peak-type sensorgram. As opposed to this, the metal-clad waveguide is used in reflection mode, see Fig. 1, just as the well-known surface-plasmon resonance biosensor. Hence, in this case the sensorgram typically consists of a dip in reflectance versus illumination angle, giving rise to a dip-type sensorgram, see Fig 2.

What is common for all these conventional biosensor techniques is that the resonance angles of the sensorgrams are quite far from the cut-off angle at the film-sample interface, which is the main reason for the limited probing depth. If, however, an ultra-thin layer of high-loss metal (large imaginary part of the permittivity) is used as a metal cladding, the sensorgram changes completely to a peak-type, in which the peak angle is exactly identical to the critical angle at the film-sample interface, see Fig 3. This causes the probing depth of the evanescent field to increase to infinity. Moreover, the sensitivity increases to unity, which is also approximately 5 times larger than for ordinary waveguide sensors [Ref 1]. The high probing depth for metal-clad waveguides operated in peak-type mode widens the field of application to cover detection of micron-scale biological objects including bacteria and whole cells.

Thus, metal-clad waveguide sensors facilitates two different operation modes depending on the metal used, dip-type and peak-type operation which are optimal for different sensing purposes such as refractive index measurements, detection of micron-scale objects or to measure thin adlayers on the sensor surface. The work to be presented will focus on application of both types of metal-clad waveguide sensors for specific detection purposes and will also include experimental results with various metal-clad waveguide configurations.

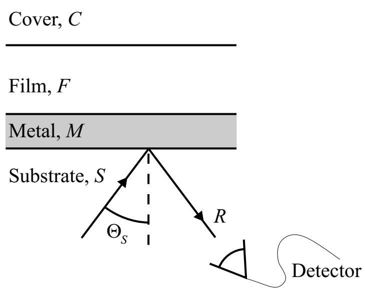

Fig.1: Metal-clad waveguide sensor configuration

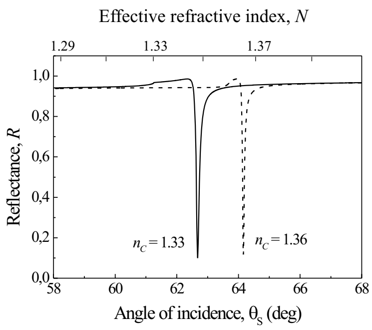

Fig.2: Dip-type sensorgrams of a conventional metal-clad waveguide configuration: glass, 50 nm gold, 300 nm SiO_2 and samples n_C = *1.33* & n_C = *1.36.*

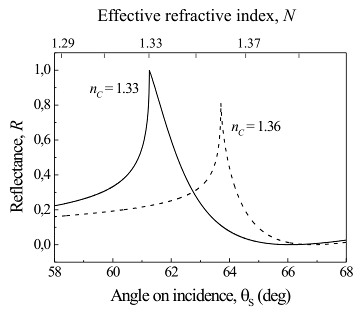

Fig.3: Peak-type metal-clad sensorgrams for a 5 nm titanium-clad waveguide, $\varepsilon = -3.9 + i12.2$*: Glass, 5 nm Ti, 250 nm SiO_2 and samples* n_C = *1.33* & n_C = *1.36.*

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2. N. Skivesen, R. Horvath & H.C. Pedersen, "Optimization of metal-clad waveguide sensors", accepted for publication in Sensors & actuators B.
3. N. Skivesen, R. Horvath & H.C. Pedersen, "Peak-type and dip-type metal-clad waveguide sensing", accepted for publication in Optics Letters.