Multiplexing of a plasmonic fluidic sensor with a hydrogel-based transducer

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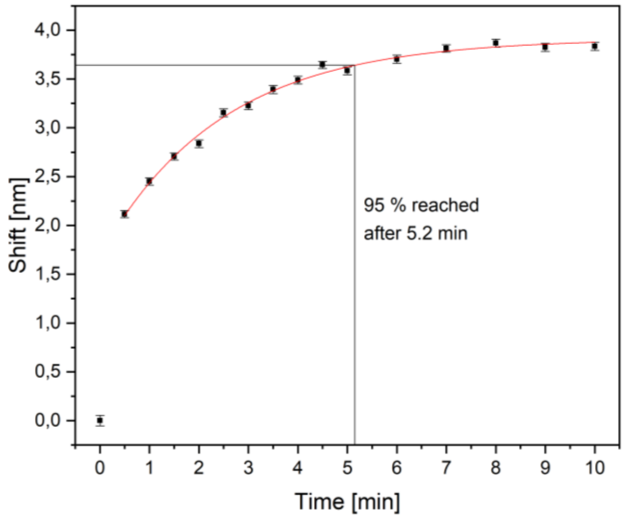
Motivation:

For inline process monitoring in biotechnology, water treatment, process industries, food production or the pharmaceutical industry submersible sensors for the determination of measurement parameters in fluids such as pH, sugar or ethanol concentration, and temperature face a huge demand. A general aim is to apply such sensors for a fast and inline measurement of these parameters. The challenges in this context are found in the integration / immobilization of hydrogels on optical (plasmonically) active sensor substrates and a robust interrogation of the optical properties of such substrates. The cooperation between the Institute of Solid State Electronics (IFE) at TU Dresden and the Fraunhofer Institute for ceramic technologies and systems (IKTS) aims at the development of such a holistic sensor system to be applied in fluids.

Current state of the art:

Conventional laboratory-based chemical analytics achieves high sensitivity e.g. in concentration measurements, but demands high effort concerning hardware, personnel and time. The use of plasmonic sensor substrates with hydrogels as transducers aims at the opposite: cheap and robust chemical sensors ready for process integration. In previous works a demonstrator for the optical interrogation of plasmonic surfaces was developed which allows to detect changes of the refractive index in an analyte [1]. This refractive index change is induced by the swelling behaviour of an analyte-sensitive hydrogel attached to the sensor surface. This approach is promising as very thin hydrogel layers in the range of 100 nm can be used which in turn lead to a fast response of such sensors. Previous members of the research training group were able to show the immobilization of hydrogels on the plasmonic transducer layer, the reduction of the hydrogel layer and a sizeable decrease of the sensor response time to ~ 5 min [2].



Time-resolved response (plasmon resonance shift) of an ethanol-sensitive hydrogel immobilized on a plasmonic transducer

Scientific aims and project goals:

Based on the abovementioned results a deeper understanding and control of the optical sensor effect should be achieved. One particular aim is to determine different measurands on one sensor substrate in parallel (multiplexing). This will lead to a better fit between the sensor technology and the demands of real-world applications, e.g. in breweries. On the other hand, cross sensitivities of different hydrogels may be controlled and eliminated with this approach. In sum, an important step towards industrial application of hydrogel-based sensors is envisaged in this project which includes the following tasks:

- Parallel immobilization of pH- and ethanol-sensitive hydrogels on a plasmonic sensor surface
- Test of different glucose-sensitive hydrogels on the plasmonic transducer, identification and immobilization of the most promising one
- Optimization of lateral structuring as well as further reduction of the hydrogel layer to ~ 1µm in order to increase sensor sensitivity and decrease sensor response time (a microcontact printer can be used at Fh IKTS for this task)
- Design of a measurement setup for a direct and robust contact between the liquid analyte and the sensor surface which allows integration of a temperature sensor and simultaneous readout of pH, ethanol and glucose concentrations (multiplexing)
- Investigation of the cross sensitivities and degradation of the hydrogels in use
- Design and demonstration of measurement protocol which allows to eliminate cross sensitivities
- Determination of the sensitivity limits and response times as well as demonstration of the simultaneous measurement of the respective parameters in real-world media (e.g. mash)

[1] R. Wuchrer, S. Amrehn, L. Liu, T. Wagner, T. Härtling: A compact readout platform for spectral-optical sensors, J. Sens. Sens. Syst., JSSS, 5 (2016), 157–163, doi:10.5194/jsss-5-157-2016.

[2] C. Kroh, R. Wuchrer, M. Günther, T. Härtling, G. Gerlach: Evaluation of the pH-sensitive swelling of a hydrogel by means of a plasmonic sensor substrate, J. Sens. Sens. Syst., 7 (2018), 51–55, https://doi.org/10.5194/jsss-7-51-2018.