Miniaturized optical chemical sensing and biosensing using functional dyes and dye-doped nanoparticles

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We are a junior group located at the Universität Leipzig and working in the field of miniaturized optical, mainly fluorescent, chemical sensors, biosensors and bioassays. Miniaturization of analytical methods into dedicated small-scale platforms offers many advantages: Better portability (near patient, near environment), environmentally friendly (using less resources), and due to the unique physics on the micro- and nanoscale they allow novel ways of chemical and biological analysis.

One area of research is the development of nanoparticles and other nanoprobes for optical chemical and biological sensing and analysis. So far we created polymer nanoprobes for pH, temperature, atmospheric gases, carbohydrates and proteins for various applications from fundamental research, aerodynamics, cell culture or environmental analysis. These employed a wide variety of dyes from functionalized xanthenes, porphyrins, perylenes, ruthenium and europium complexes to fullerenes inside polymeric matrices such as polystyrenes, polyethyleneglycols, polyvinylbutyrals (PVB) or (organo-) silicas among others depending on the particular needs and challenges of the application. Often the dye serves as primary response element to the analyte of interest whereas the surrounding polymer acts as matrix for analyte interaction and a shield from undesired influences and degradation. Displayed in Fig. 1 left are spherical perylene-doped PVB nanobeads first created in our lab that are non-cytotoxic and may serve as nanoprobes, tracers or carriers inside living cells. Functional fluorescent dye-doped nanoparticles with pH, oxygen and temperature sensing ability will also be shown.

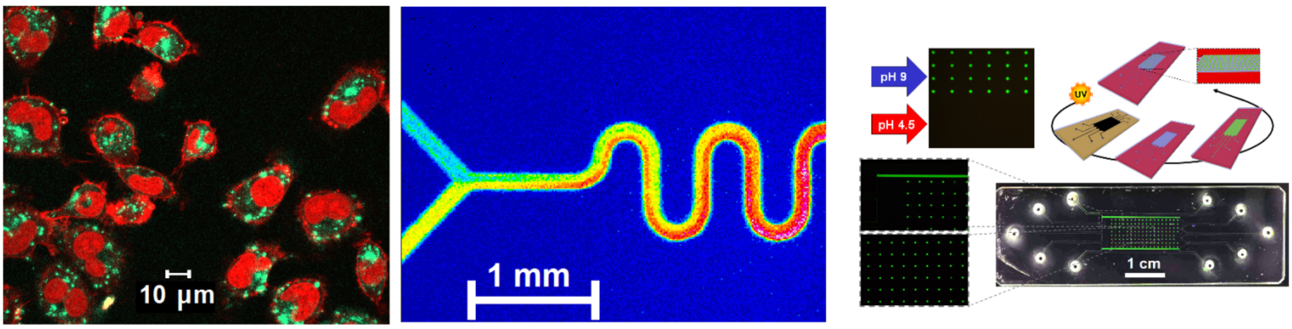

Fig. 1: left: Highly fluorescent dye-doped polyvinylbutyral nanoparticles (green) inside live human cancer cells, middle: microreaction platform with an integrated biosensor, real-time monitoring of glucose oxidation (false-colored fluorescence image) via an integrated porphyrin dye-doped fluorescent sensor, right: pH sensing fluorescent polymer microarray inside a microfluidic electrophoresis chip.

Another interesting aspect using functional dyes is the integration of fluorescent chemical sensors and biosensors into chemical microchip ("lab on a chip") platforms. Such microchips allow for continuous spatial "imaging" on-line analyte monitor in very small dimensions avoiding elaborate off-line analysis steps. We integrated dye-doped fluorescent sensor layers into microfluidic reactors containing serpentine mixers via a combination of wet etching and spin coating and demonstrated its performance using chemical reactions. Modification of the sensing layers employing glucose oxidase allowed for real-time glucose monitoring in microreactors with oxygen transduction (Fig. 1 middle). Such microreactor systems with integrated sensors are of great interest in chemical synthesis as well as in biotechnology.

Microstructures containing fluorescent xanthene dye probes and dye-doped nanoparticles were created in microfluidics via a photopolymerisation method, multi-step liquid phase lithography, and used for integration of optical pH microsensors (Fig. 1 right). Such microchips are of particular interest for the combination of chemical sensing with electrophoretic or chromatographic separations.