Simple Evanescent Field Sensor for NIR Spectroscopy

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Near-Infrared (NIR) spectroscopy is a powerful tool for chemical analysis in applications ranging from biomedicine to analysis of food products and textiles [1]. However, molar absorptivities in this spectral region are usually weak, so that high-sensitivity measurement devices are required. Optical waveguides provide for highly sensitive attenuated total reflection (ATR) spectroscopy in a robust mass-producible format, and allow for ultra-small sample volume, due to the 100 nm scale extent of the evanescent field, and the potential for lab-on-chip integration. Optical waveguide approaches using chalcogenide glass waveguides [2] and silicon waveguide ring resonators [3] have been applied to the detection of N-methylaniline, which was chosen because it has well a defined absorption peak in the NIR region due to an N-H bond overtone near 1496 nm. Here, we demonstrate the detection of N-methylaniline in hexane using a simple low-cost chemically robust fibre-compatible ion-exchanged silicate glass waveguide, achieving similar or greater sensitivity. Channel waveguides were designed for monomode operation and high sensitivity at a wavelength of 1.5 µm using the finite element method (FEM) and employing an approximate diffusion profile of potassium ions in glass [4] with substrate index of 1.5013 and maximum core index of 1.5105 (Fig. 1a). The waveguides were fabricated by photolithographically patterning stripe openings of 6 µm width in an aluminium film on BK7 glass and then immersing in a KNO_3 melt for 11 hr at 395°C [5]. After ion-exchange the end faces of the glass were polished perpendicular to the waveguides resulting in waveguides of length ~35 mm. Optical waveguide measurements of transmission spectra were made using the apparatus shown in Fig. 1b.

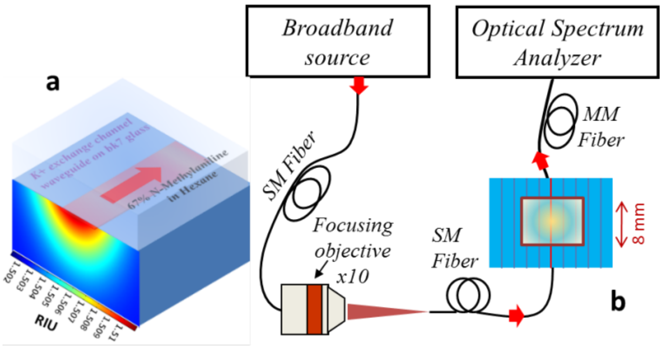

Fig. 1 (a) Schematic of the device with calculated diffusion of K+ in glass using FEM. (b) Experimental apparatus for waveguide transmission spectrum measurements.

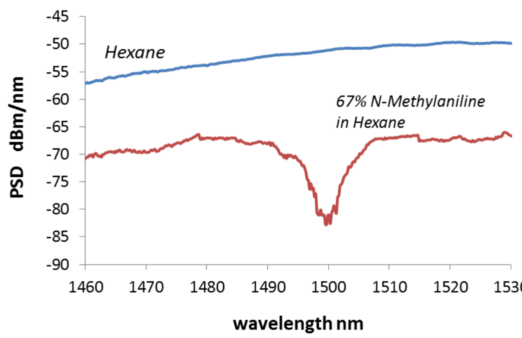

Fig. 2 Waveguide transmission spectra of solvent (hexane) and of 67% N-methylaniline.

A demountable polydimethylsiloxane (PDMS) chamber of length 8 mm was placed on top of the waveguides to contain the liquid analyte and a glass coverslip was placed on top of this chamber to seal it. Light from a supercontinuum source (Fianium SC-600-FC) was directly fibre-coupled into a channel waveguide and the power transmitted through the waveguide was fibre-coupled to an optical spectrum analyser (Yokogawa AQ6370). Measurements were made with pure hexane and with N-methylaniline in hexane in the chamber. Fig. 2 shows the waveguide output power spectral density (PSD) for pure hexane and for 67% N-methylaniline in hexane in the chamber. The N-H bond overtone in the N-methylaniline solution shows strong peak absorption of ~15 dB near 1500 nm, showing promise for future applications using this low-cost chemically-robust material system and simple waveguide approach. It is expected that these sensor chips can be driven by cheap broadband sources, and future work includes nanostructuring for surface field enhancement and application in flow-systems to determine limit of detection for clinically important analytes.

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