

Lab-on-a-chip device for soil nutrient measurements

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Abstract. Capillary electrophoresis is known as a fast and easy method for ion analysis. Implemented as lab-on-a-chip costs can be reduced drastically. This allows for commercial applications in soil nitrate. A known issue, however, is the injection variability caused by chip-to-chip differences as well as by samples varying in viscosity and overall ion strength and thus turning quantitative analysis into a challenge. We overcame this by adopting bromide as an internal standard. In order to discriminate bromide from ubiquitous chloride in soil samples we used polyvinylpyrrolidone as a separation additive in our background electrolyte.

Keywords: Lab-on-chip, capillary electrophoresis, microfluidics, precision agriculture

1 Introduction

Fertilizers containing nitrate, phosphate and potassium are indispensable for modern agriculture and necessary to nourish the current world population. The calculated fertilizer demand for the year 2015 alone is around 186.6 million tons. This calculation combines the single amounts of N, P₂O₅ and K₂O and the annual demand is expected to grow beyond 199 million tons by 2019 (F.A.O. 2015).

Although there is an undeniable need for fertilizers in industrial agriculture, production as well as utilization have an enormous ecological and social impact. Furthermore fertilizers are often overused, i.e. applied in quantities that don't increase yield any further a while increasing negative impacts. According to recent estimates about 60% of applied fertilizers are in fact overuse and therefore dispensable. Farmers have a genuine interest to be as resource efficient as possible.

In this paper we present a novel lab-on-a-chip device, which allows for fast and easy measurement of soil nutrients and does not require any laboratory skills. The only remaining requirement is taking samples of the field. The sample is then inserted into the device and measured in an automated manner.

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2 Material and Methods

We developed an easy-to-produce foil chip. The two PET foils have each a 125 μm thickness. Channels were carved out by laser milling resulting in a 50 μm depth resulting in 10% surface variance (5 μm surface errors). The open side channel would theoretically allow for hydrostatic sample leakage but to the highly viscous nature of our buffer this did not occur (Bidulock, 2015)

The channels were carved out of the foil by laser milling. Two PET foils comprising 125 μm each were heat bonded under vacuum. Electrodes for contactless conductivity detection (Zemann, 1998) were fabricated, after bonding, by inkjet printing of conductive ink. A fabricated chip is seen in Figure 1. The chip was introduced in an interchangeable manner in the device containing the fluidic and electronic peripherals. More details about the basic configuration of the proposed platform has been reported by Smolka *et al* (2017).

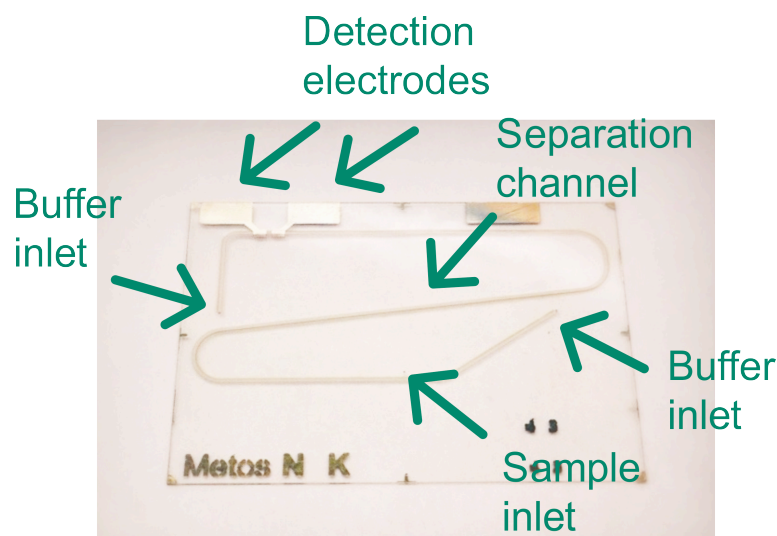


Fig. 1. The new developed chip: a) the separation channel, b) the detection electrodes, c) the buffer inlet and outlet and e) the sample channel.

3 Results

A series of experiments were carried out in the device in order to evaluate its performance. The measured probes consisted of laboratory prepared samples of three analytes i.e. Cl, Br and NO₃ and calcium lactate (present in soil samples due to its use during extraction). The analyte concentrations were cross-checked using an ion chromatographer (Sigma-Aldrich, USA). A single probe measurement is seen in the

electropherogram of Figure 2. Figure 3 reports the measured versus the nominal value of the probes for a range of concentrations, which furthermore exhibits the second order polynomial response of the sensor.

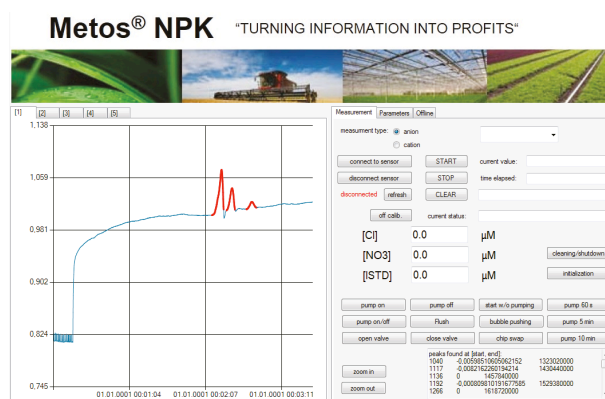


Fig. 2. Measurement of a single probe. The peaks correspond to Cl-, Br- and NO₃- respectively.

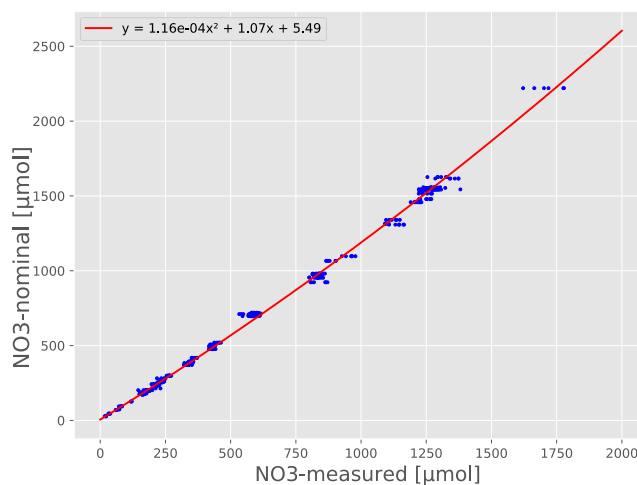


Fig. 3. Measured values versus nominal values of the probes for a range of concentrations.

4 Conclusions

In this paper we have presented the development of a lab-on-a-chip platform for soil nutrient sensing. The device performed with relative errors of the order of 5% in a range of concentrations ranging from 28 – 2220 μM. The response was fitted using a second order polynomial equation.

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