

CONTACTLESS DIFFERENTIAL CONDUCTIVITY DETECTION

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ABSTRACT

We propose a new technique, contactless differential conductivity detection (CDCD,) to improve the detection limit of contactless conductivity detection for capillary and microchannel electrophoresis. By exploiting a 3-electrode differential configuration, CDCD greatly reduces the dominant noise source in contactless conductivity detection: temperature fluctuations within the measurement system. This will be a particularly important feature for high-conductivity samples, which are most susceptible to thermal noise. The reduced sensitivity of CDCD to temperature fluctuations and its potential suitability for low-power operation will also make this an excellent candidate for field-portable and point-of-application uses where optical detection strategies may be more difficult to implement.

INTRODUCTION

Contactless conductivity detection (CCD) is applied in microfluidic electrophoresis experiments for ease of use, or when an optical signal is not readily available from the analyte of interest. In this class of techniques, the application of a voltage to an electrode outside of the capillary or microfluidic channel causes a current that is measured at a separate electrode nearby. This technique not as sensitive as optical techniques however, and concentration limits of detection are on the order of 300 nmol/L [1].¹

DESIGN

The CDCD device can be summarized as follows, as seen in Figure 1. An electrophoresis microchannel is contacted on its exterior by 3 electrodes spaced approximately 1 mm apart, and separated from each other and from the outside environment by ground planes. A sinusoidal voltage (typically ~ 10 kHz) is applied to the center electrode. The two outer electrodes are capacitively coupled to the center electrode through the microchannel. The conductivity of the analyte solution inside the capillary controls the magnitude of the electrical current supplied to the outer electrodes. The current at each electrode then passes through a transimpedance amplifier and the resulting voltage is fed to a gain balancing circuit. This balancing circuit is used to equalize the amplitudes of the voltage signals to the transimpedance

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amplifiers before subtraction at the differential inputs of a lock-in amplifier. Since the two outer electrodes are capacitively coupled through the fluid analyte, the current is modulated by the conductivity of whichever analyte component is located in the channel between the electrodes at that point in the separation. Since this detectors senses conductivity simultaneously at two adjacent points along the microchannel, global changes in the conductivity of the fluid in the channel (e.g. due to temperature fluctuations) are cancelled by the differential nature of the detector. It also has the effect of canceling many other extraneous noise sources (including mechanical, and electromagnetic interferences).

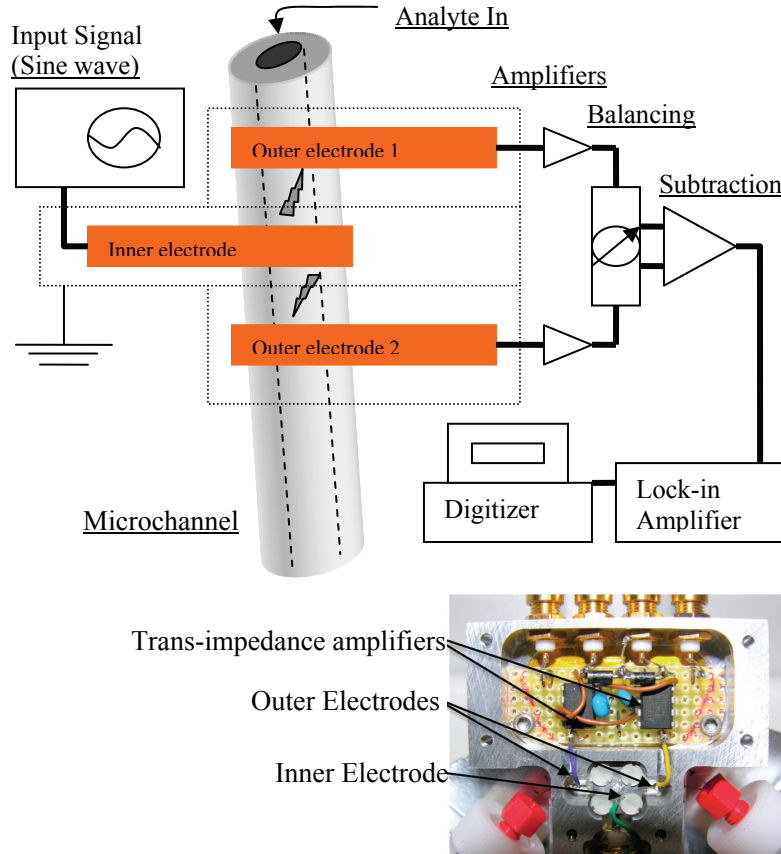


Figure 1. CDCD schematic (top), and photograph of the actual detector (bottom)

EXPERIMENTAL

The CDCD detector head was custom fabricated from aluminum, and is shown in figure 1. The transimpedance amplifiers were placed in direct proximity to the outer electrodes. The amplifier gain for outer electrode two was adjustable for optimal signal balancing. The output of the amplifiers was fed into the differential input of a lock-in amplifier. The differential signal was transferred digitally to a microcomputer for storage.

RESULTS AND DISCUSSION

Initial characterization of CDCD was carried out using a capillary electrophoresis system. Figure 2 is an electropherogram showing the CDCD detection of 4 cations at 20 $\mu\text{mol/L}$ each. The separations were carried out in 12.5 mmol/L Alanine-Acetate buffer at 333 V/cm (1.9 μA) with a 27.6 Pa*sec injection, and a 50 μm x 60 cm (30 cm effective) silica microchannel. Based on these results, the current generation detector has a limit of detection of ~ 300 nmol/L which is comparable to current state-of-the-art contactless conductivity detectors [1]. Further optimization of the detector will provide a viable, robust detection strategy, eliminating some of the challenges of conductivity detection.

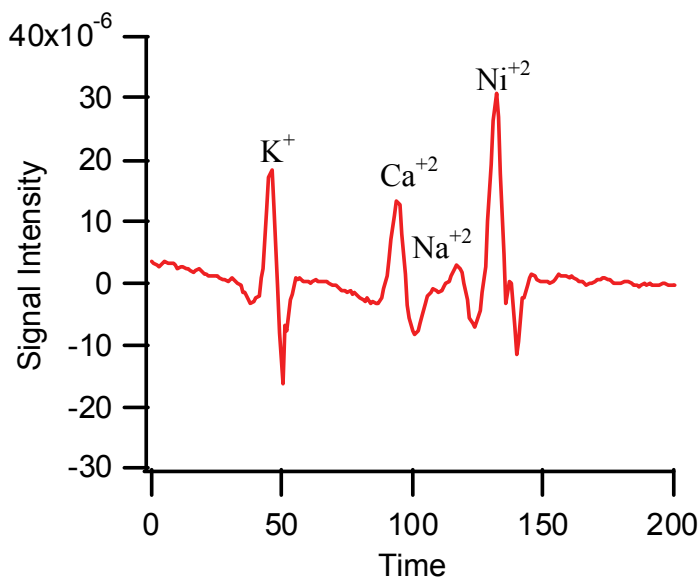


Figure 2. CDCD electropherogram.

CONCLUSION

A new detection modality for capillary and microchannel electrophoresis, contactless differential conductivity detection, has been developed. Separation of several small inorganic ions has been demonstrated with detection limits comparable to existing methods. The new method will resist noise from temperature fluctuations, thus enabling examination of high conductivity analytes.

REFERENCES

- [1] P. A. Kubáň, C. J. Evenhuis, M. Macka, P. R. Haddad, P. C. Hauser, Comparison of different contactless conductivity detectors for the determination of small inorganic ions by capillary electrophoresis, *Electroanalysis*, 2008, 18, 1289-1296