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Review Article

Inexpensive and versatile measurement tools using purpose-made capillary electrophoresis devices coupled with contactless conductivity detection: A view from the case study in Vietnam

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A B S T R A C T

In this study, the development of purpose-made capillary electrophoresis (CE) devices with capacitively coupled contactless conductivity detection (C^4D) as a simple and inexpensive measurement tool and its applications for water monitoring, food control and pharmaceutical analyses in Vietnam are reviewed. The combination of CE and C^4D, both relying on the control of the movements of ions in an electrical field, can be realizable even with a modest financial budget and limited experimental skills and expertise. Different CE-C^4D configurations, which were designed and developed for various applications were highlighted. Some perspectives for a wider recognition of its potential in Vietnam and for rendering this technique as an analytical tool for the population are discussed.

1. Introduction

Capillary electrophoresis (CE), with its advantageous properties of covering a wide range of accessible analytes, high separation efficiency, short analysis time, low power requirements, limited consumption of chemicals, ease of installation, operation and maintenance, is a particularly interesting candidate for analytical instrumentation. It is inherently much simpler than chromatography for ion separations, as it is achieved by the application of a high voltage and does not require a stationary phase. The separation efficiency is inherently very good, and high plate numbers according to the Van Deemter theory are obtained even with a simple apparatus. The employment of a high voltage as a driving force allows elimination of the use of expensive, complicated and sometimes irreplaceable high-pressure components as in high pressure liquid chromatography (HPLC). However, the sensitivity of the popularly used optical detection in CE of at least 100 times worse than that of the standard UV absorbance detection in HPLC (mainly due to a limited optical path length across the capillary of 50 μm i.d. in general), has rendered it less attractive than the pressure-driven counterpart. In addition, a too small detection volume in CE leads to difficulties in manipulation with any on-column or post-column detection techniques.

The marriage between CE and contactless conductivity detection, whose creation of the detection signal is based on the same property as the CE separation, on the other hand, has offered many advantages over its standard coupling with UV detection. The ions are simply manipulated with voltages applied through electrodes. In principle, any charged species which can be separated in electrophoresis can also be detected with a conductivity detector. This feature is important, as UV absorption is not suitable for most inorganic ions nor is sensitive detection possible for organic ions lacking a strong chromophore. The contactless property allows a measurement without any contact between the electrodes and the solution inside the capillary. The launch of its new configuration in 1998 [1,2], termed capacitively coupled contactless conductivity

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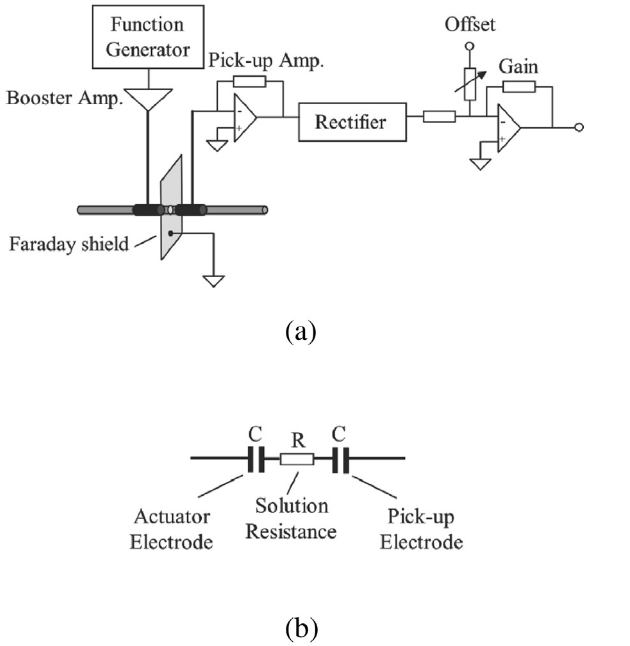

Fig. 1. Schematic drawing of C^4D in an axial arrangement. (a) Schematic drawing of the electronic circuitry; (b) Simplified circuitry.

detection (C^4D) and based on tubular electrodes arranged side by side along the axis of the capillary has led to a full adaptation of this approach for narrow separation channels in CE. With C^4D, the difference between the conductivities of the analytes from that of the background electrolyte (BGE) can be measured without having the electrodes in contact with the sample. Commercial detectors have been available for some time [3,4], but the in-house construction is possible with limited mechanical and electronic facilities [5–7]. In fact, due to the relative simplicity of CE, it is also feasible to build entire instruments relatively easily, which is not possible these days for most methods. Three additional positive features of CE-C^4D that make it even more suitable for versatile and screening analytical purposes are portability for mobile deployment [8–11], customer-oriented CE configuration for adaptation to different financial and expertise situations [12,13], multi-channel setup for concurrent determination of various analytes having different characteristics [14–16]. The employment of CE-C^4D to solve various analytical challenges, notably in environmental monitoring, food control, pharmaceutical and clinical analysis, has been reviewed for several times [17–25]. Both instrument and application aspects of CE-C^4D were addressed exhaustively in these reviews. Instrumental optimization was also proposed therein for performance improvement, for example the employment of high excitation voltage to boost the sensitivity of C^4D, or the removal of some electronic components to minimize power consumption so that the whole system can be operated for several hours with the battery-powered mode. Fundamentals of CE-C^4D can also be found in these reviews.

Herein we highlight the development of in-house-made CE-C^4D devices towards the purpose of analytical instrumentation for non-expert users. This paper can be considered as the view of the authors towards the potential and applicability of CE-C^4D as inexpensive and versatile measurement tools based on the works carried out in Vietnam over 5 years. These works include i) instrument design and development (implemented together with the group of Prof. Peter Hauser – University of Basel, Switzerland), ii) instrument deployment in Vietnam and subsequent instrumental optimizations for adaptation to the operating conditions in Vietnam and iii) methodology developments using the developed instruments. The applications of in-house made CE-C^4D instruments notably for water monitoring, food control and pharmaceutical analysis with the case study in Vietnam are highlighted. The potential of compact CE-C^4D as an analytical tool for the people is also discussed.

2. Instrumentation development

2.1. Capacitively coupled contactless conductivity detection

The basic arrangement of an axial C^4D, which was first introduced independently by Zemann et al. [1] and by da Silva and do

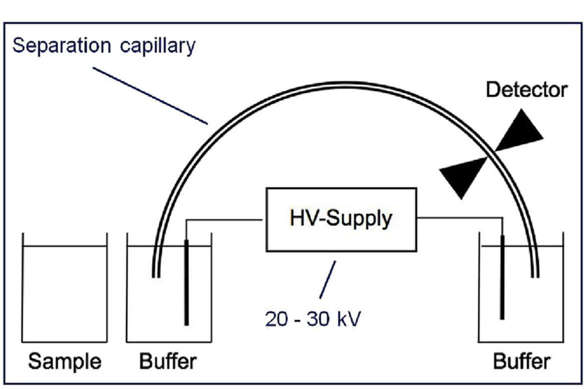

Fig. 2. Arrangement of a basic CE setup.

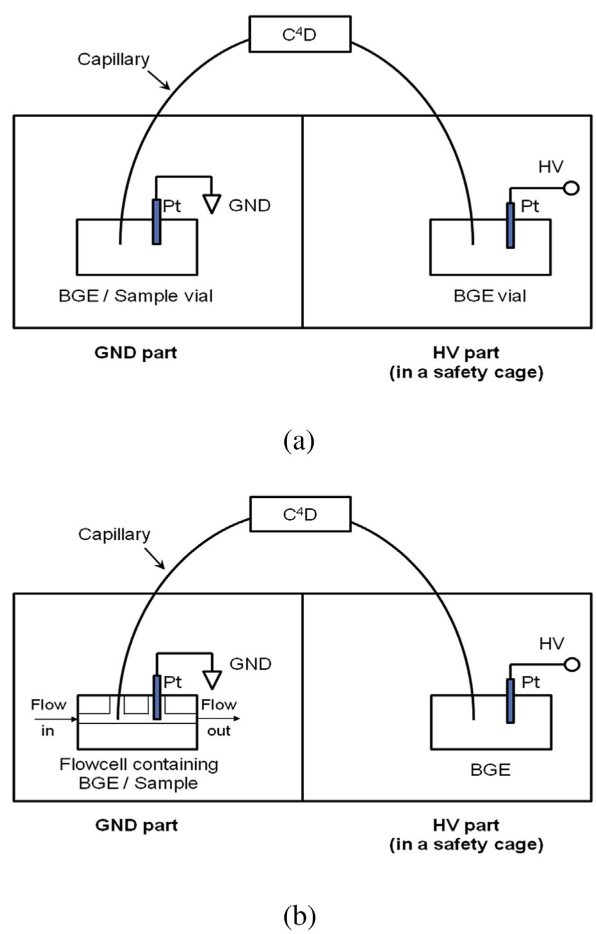

Fig. 3. Schematic drawings of a CE arrangement with a) manual injection mode; b) automated injection mode with extension with a fluidic module. HV: high voltage; GND: ground; BGE: background electrolyte; Pt: Platinum electrode.