Multi-commutation in spectrometry

Ángel Morales-Rubio, Boaventura Freire dos Reis, Miguel de la Guardia

We review recent developments in manifold components and the introduction of light-emitting-diode technology in spectroscopic detection in order to evaluate the tremendous possibilities offered by multi-commutation for in-field and in-situ measurements, based on the use of multi-pumping and low-voltage, portable batteries, which make possible a dramatic reduction in size, weight and power requirements of spectrometric devices.

Keywords: Light-emitting diode (LED); Manifold; Multi-commutation; Multi-pumping; Portability; Spectrometry; Spectroscopic detection

Ángel Morales-Rubio*, Miguel de la Guardia
Department of Analytical Chemistry, University of Valencia, Edificio Jeroni Muñoz, Moliner Street, 50, 46100 Burjassot (Valencia) Spain

Boaventura Freire dos Reis
Centro de Energia Nuclear na Agricultura, Universidade de Sao Paulo, P.O. Box 96, Piracicaba, 13400-970, Brazil

*Corresponding author.
E-mail: angel.morales@uv.es

1. Introduction

Automation has been one of the most challenging research topics of analytical chemistry since the last quarter of the twentieth century, and generalization of flow-injection-based strategies from 1975 [1] has dramatically modified work in analytical laboratories. It has contributed to improvements in selectivity and repeatability of measurements and has improved both laboratory productivity and the safety and the comfort of operators.

On looking through the development of automation strategies at the end of the 1990s, we concluded that classical flow-injection analysis (FIA) has been overtaken by sequential injection analysis (SIA) [2] and multi-commutation [3], which have dramatically reduced the time of analysis, thus improving sampling throughput, and also minimized reagent consumption and waste generation [4].

We can look at the evolution of the automation strategies as a change from simple mechanization to complete automation of all the steps of the analytical process together with miniaturization of all components so that equipment is truly portable.

Within this framework, we consider the micro total analytical system (μTAS) [5] and the lab-on-a-valve (LOV) [6] as the main approaches to reducing the size of the manifold components and to integrating all sample treatment and measurement steps in a single device.

However, to achieve truly portable automated systems, we are convinced that the recent development in multi-commutation [7–9] based on new propulsion devices (e.g., micropumps [7]), which can improve previous systems based on peristaltic pumps and three way valves [3], or multi-syringes [10]) and light-emitting diodes (LEDs) [8], as the main components of spectrometric detectors, can downscale the power supply to the level of those employed in potentiometry-field measurements. The main purpose of this work is therefore to discuss the main developments in multi-pumping and LED-based multi-commutation strategies, which could permit automation in spectroscopy to take off of for in-field and in-situ control of analysis.

2. The evolution of multi-commutation in the literature

Multi-commutation was devised as a flow-analysis option in 1994 [3]. Fig. 1(a) shows that fewer than 25 papers were published in the twentieth century, so this technique has developed mainly in the past five years. Today, it is a hot topic in automation in analytical chemistry. Three-quarters of all papers on the topic were published in the past four years.

The inset in Fig. 1(b) shows that multi-commutation has been applied in many fields [e.g., spectroscopy (94% of published papers), which includes molecular absorption (44%), chemiluminescence (22%), atomic (13%), molecular fluorescence (10%) and vibrational (5%) as the main detection techniques used]. The use of multi-commutation in the electroanalysis is rarely explored with few new methods in amperometry, potentiometry and voltammetry, with some applications

0165-9936/$ - see front matter © 2009 Elsevier Ltd. All rights reserved. doi:10.1016/j.trac.2009.03.016

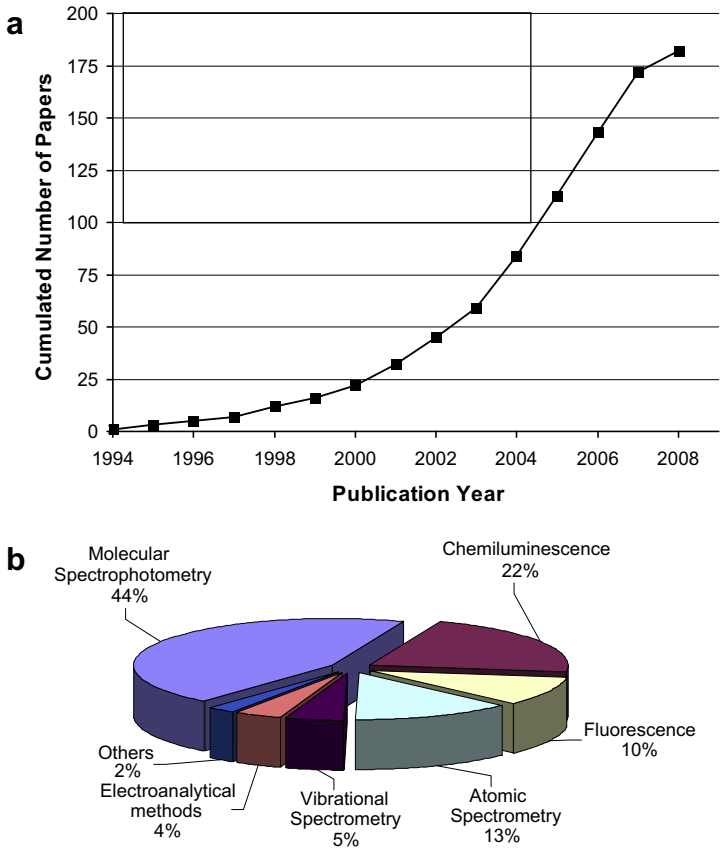

Figure 1. (a) Evolution of the scientific literature about multi-commutation. (b) Distribution of the literature published in this century as a function of the analytical techniques employed.

in enzyme-linked immunosorbent assay (ELISA) and radioactive measurements.

Differences in the development of multi-commutation-based procedures using analytical detectors depend strongly on the fields of expertise of five main research teams, which have published 81% of the literature available on the subject. However, it is clear that multi-commutation principles can be applied in all kinds of measurement and the increasing popularity of the technique and its intrinsic versatility will surely encourage other research groups to explore new possibilities in a near future.

Multi-commutation principles and applications have been reviewed in 14 publications (Table 1), which have described specific aspects of multi-commutation (e.g., multi-syringes [10]), applications in chemiluminescence determination of phosphorus [15], and their use in turbidimetry and nephelometry [17]), or given general reviews on flow analyses that included aspects of multi-commutation [11–23].

In preparing this review, we took into account 166 papers in the Science Direct and Scopus databases for the period 2000–08. We evaluated papers concerning multi-pumping and LED-based methodology in depth in order to provide a good picture of the state of the art of multi-commutation as a tool for developing fully-automated, easily-portable devices.

3. The literature on multi-commutation since 2000

The 166 research papers published in multi-commutation since 2000 appeared in 28 scientific journals.

Fig. 2 clearly shows that two journals (*Analytica Chimica Acta* and *Talanta*) published 55.9% (31.2% and 24.7%, respectively) of the literature in the field in the past eight years. These journals are general publications in analytical chemistry, showing the importance of multi-commutation as a general tool in analysis.

In addition, journals on molecular and atomic spectroscopy have been the main sources of multi-commutation