< FIA Award for Science >

Jaroon Jakmunee

Associate Professor, Department of Chemistry, Faculty of Science, Chiang Mai University, Chiang Mai, Thailand

Born 1970; BS in Chemistry (2nd Honor), Prince of Songkhla University, 1990; PhD in Chemistry, Chiang Mai University, 1997; Thailand Young Scientist Award (Foundation for the Promotion of Science and Technology under the Patronage of His Majesty the King), 2003; Outstanding Younger Researcher, Golden Elephant (Chiang Mai University), 2006; FIA Award for Younger Researchers (Japanese Association for Flow Injection Analysis), 2008; Award for Outstanding Researcher, Golden Elephant (Chiang Mai University), 2010; TRF-CHE-Scopus Researcher Award (Thailand Research Fund), 2012; FIA Award for Science (Japanese Association for Flow Injection Analysis), 2017; Member of Thai Association for Flow-based Analysis; Member of Chemical Society of Thailand; Member of Science Society of Thailand under the Patronage of His Majesty the King.

Development of Cost-effective Flow-based Analysis with Electrochemical Detection

Flow-based Analytical techniques such as flow injection analysis (FIA), sequential injection analysis (SIA), etc. are efficient tools to perform chemical assays. They provide several advantages including high precision and accuracy, fast and high throughput analysis, high automation, low chemical consumption and low waste generation which conform to the green analytical chemistry. Moreover, apart from the commercial instrument available for these techniques, the cost-effective systems can be assembled from low-cost parts/devices which allows for the place of a limited budget. An automatic electrical control injection valve could be constructed from a set of 3-way solenoid valves to be operated as hydrodynamic injection in FIA [1,2]. A simple home-made colorimeter [3-5] potentiometer [1], amperometer [6,7], and data recording system [1,6] were built for use in flow-based analysis.

Based on the electronic timing control of solenoid valves the hydrodynamic sequential injection (HSI) was introduced, which both sample and reagents are aspirated through solenoid valves to fill a defined volumes conduit between 3-way connectors connected in series, forming stacked zones of solutions similar to those in a normal SIA. This system is automatically operated, and offer advantages similar to SIA but with a lower instrumentation cost. The concept was applied for determination of manganese [8], nitrite and nitrate [9], hemoglobin E [10], phosphate and silicate [11], and recently phosphate by microfluidic HSI system [12].

Low-cost microfluidic platform can be built by laser engraving of an acrylic plastic block [12,13] or by soft lithography using poly(dimethylsiloxane) with a master mold made of a printed circuit board [4]. Microfluidic system consumes microliter amounts of reagent solution per analysis. The determination of glutathione [4], Fe(II) and Fe(III) [13], and the use for selective chemical stimulation of neurons and characterization of peptide release [14] were demonstrated.

A down-scaling analytical system based on SIA, namely lab-at-valve (LAV) was also introduced. SI-LAV was made by attaching a device integrating sample processing and detection units on a port of a multiposition selection valve, without taking apart components of a purchased valve. The SI-LAV approach was demonstrated for potentiometric determination of chloride with a simply made chloride ion selective electrode [15], and diphenhydramine hydrochloride and anionic surfactant by on-line solvent extraction with spectrophotometric detection [16,17].

The electrochemical detections (EC) are of interest to be applied in flow system because they provide several advantages such as high sensitivity and selectivity, simple and compact instrumentation, variety of electrode modification, and suitability for use in a miniaturized flow system. The electrochemical reaction/interaction occurs at the solution/electrode interface therefore sensitivity of the method does not depend on path length of the solution as in optical techniques. Moreover, EC did not suffer from colored substances, particulates and refractive index effect (Schlieren effect). In fact, flow-based techniques also enhance performance of the electrochemical detection, the surface of electrode can be easily cleaned and re-newed leading to higher reproducibility, stability, and sensitivity.

FI-gas diffusion system was applied to improve selectivity of conductometry for determination of gas convertible analytes such as for the determination of total protein content in food [18,19], total inorganic nitrogen in soil [20], and dissolved inorganic carbon [21].

SIA with monosegmented flow was employed for solution handling for voltammetric determination of cadmium and lead using a bismuth film working electrode [22]. The further development by incorporating an in-line UV digestion can be used for speciation of free and bound forms of Zn(II), Cd(II), Pb(II) and Cu(II) in water samples [23]. SI-voltammetric method based on screen printed carbon electrode (SPCE) modified with carbon nanotube/Nafion was proposed for sensitive determination of paraquat [24].

FIA with amperometric detection was developed for available phosphorus in soil [2] and further applied for fractionation of phosphorus species [25]. SPCEs modified with various nanomaterials was utilized in FIA for determination of hydrogen peroxide [26], hydroquinone [27], and immunoglobulin G [28].

In addition, natural reagents from plant extract such as Guava leaf [29], Green tea [30], Noni root [31], and Indian almond leaf [32] were exploited for use in flow-based analysis. SI systems for enzyme inhibition test were also developed [33,34].

References

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