SMGroup

SM Analytical and Bioanalytical Techniques

Editorial

Electroanalysis: Towards a "Laboratory-Free" Approach

Stefano Cinti

Department of Chemical Science and Technology, University of Rome "Tor Vergata", Via dellaRicerca Scientifical, Italy

Article Information

Received date: Oct 17, 2016
Accepted date: Nov 05, 2016
Published date: Nov 10, 2016

***Corresponding author**

Stefano Cinti, Department of Chemical Science and Technology, University of Rome "Tor Vergata", Via dellaRicercaScientifica1, 00133 Rome, Italy; E-mail: stefano.cinti@uniroma2.it

Editorial

Recent trends in the sensor community, indicates that one of the major challenges and opportunities of the field relies on developing smart sensor platforms, which are cheap, efficient, easy-to-use, and capable of minimizing tasks at the end user stage, in comparison to traditionally used methods which require bulky instrumentations and qualified personnel. Electroanalysis is gaining a leader position in the development and commercialization of analytical devices due to its operational simplicity and to its "blindness" towards colored/turbid solutions which have often reduced colorimetric tests application in real matrices analysis. For example, the use of Electroanalysis-based devices has been widely adopted all-over the world by its most known example of an easy-to-use device, the blood glucometer, highlighted its prominent role towards smart and facile self-monitoring (almost 90% of the entire biosensors global market) [1]. Cooperation of diverse disciplines such as chemistry, biology, material science, and engineering, is pushing electroanalytical methods towards the realization of low-cost, remarkable sensitivity and low-requirement devices. Even more, taking advantage of the recent development of Nanomaterials (metallic nanoparticles, conductive polymers, carbonaceous, i.e. graphene, nanotubes, carbon black), electroanalysis took advantage of the easy manipulation and the unique chemical-physical properties of these cutting-edge materials, to greatly improve the electroanalytical performance [2-6]. Furthermore, electroanalysis has also exploited the advantage of those some materials widely used in everyday life. Paper, tattoo, gloves, contact lenses, all of these apparently inconsistent with the composition of an electroanalytical device, allowed electroanalysis moving towards a "laboratory-free" experience, (Figure 1).The need to develop methods that can readily perform rapid on-site analyses, made the screen-printed technology (also known as thick film technology) the most favorable approach to achieve this goal by using electroanalysis [7-9]. The ability to be easily mass producible, allows the employment of Screen-Printed Electrodes (SPEs) as one-shot sensors. SPEs own high adaptability: customizing shape, dimension, conductive-ink material, and substrate, allow for selective and finely calibrated electrodes to be fabricated for specific target analytes. Besides these manufacture-customizable features, SPEs, as well as each kind of electrode, are suitable to surface modification. Surface modification helps miniaturization to increase analytical performances of sensors such as sensitivity, selectivity, reproducibility, accuracy, and more. Also, it leads to an extremely high versatility offering specific and low-cost solutions to the electroanalytical sensing scenario. In this respect, the recent emergence of nanomaterials and nanotechnology has opened new horizons in designing integrated electroanalytical systems [10]. Advances in materials science have allowed developing new generations of nano/bio/modified electrodes. (Figure 1).

The Group headed by Professor Joseph Wang developed a plenty of diverse intriguing e-platform, exploiting such diverse substrates in sensor development. They printed electrodes almost

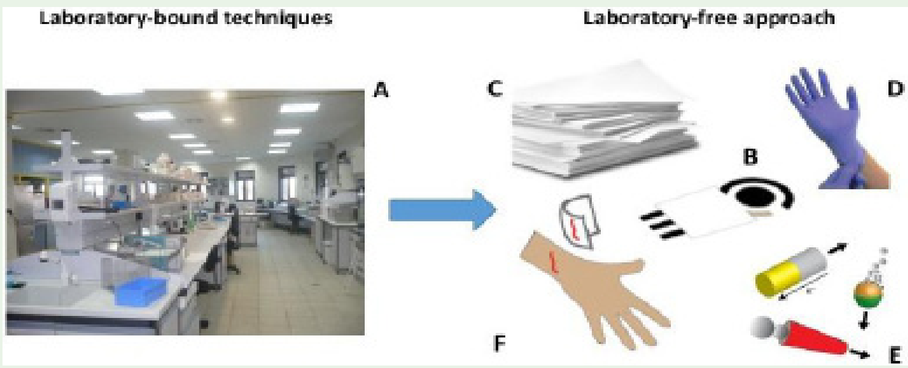

Figure 1: (A) Laboratory, (B) Screen-printed electrode, (C) Office paper, (D) Glove, (E) Nanomotors and Nanomachines, and (F) Transferrable tattoo.

OPEN ACCESS
ISSN: 2573-3729

everywhere. They fabricated SPEs onto neoprene wetsuit making people able to surveil water discovering pollutants maybe deriving from illegal actions [11]. Then, inspired to CSI (TV series), they realized the forensic finger. By printing a three-electrode configured SPE on a glove they were able to readily reveal gunshot residues directly in a hypothetic crime scene [12]. Moreover, they printed electrodes onto removable tattoos obtaining proof-of-concept devices for the healthcare as in the monitoring of loss zinc in sweat during sport activity [13], non-invasive monitoring of alcohol consumption in practical settings and the glucose level for diabetic patients during the day [14], avoiding invasive blood sampling but just by analyzing electrophoretic induced glucose [15].The wearable platforms are ideal for continuous measurements, i.e. during sleeping. Although the high possibility of realizing platform on the most diverse materials, reducing the person/device distance, is representing an effective breakthrough in electroanalytical sensors development, many others research group, led by the Whiteside's one, started a decade ago to exploit the potentiality of one of the oldest material the humankind knows. Paper. Which paper? Whatever? [16].

As for the electrochemical glucose strips, a widespread paper example are represented by the colorimetric pregnancy test (it represents the second most sold biosensors on the market). The most used paper is the chromatographic one (Whatman No.1). It allows to store the reagents, filter the sample, and make a reaction happen, flowing the detectable product toward the test area. By exploiting the exceptional properties and the low-cost of paper, many groups decided to realize colorimetric and, then, electrochemical readout device capable of detecting many targets, i.e. sugar, protein, ions, heavy metals, pesticide, contaminants [17-22]. The effectiveness of specific kind of paper, for instance common filter paper, is the ability to load all the reagents and allowing the sample to be filtered from the interfering species, i.e. cells in the blood, particulate in surface waters, microorganism in seawater. The developed colorimetric strip test, even if simple to use, low-cost, easily transportable, cannot avoid suffering from widely known issues related to real sample, i.e. color, turbidity. Yet, aimed to overcome these operational drawbacks, electroanalytical platforms are being highly coupled with paper, in order to develop alternative (and cheaper) devices. As reported by Whitesides group, only the use of paper instead of plastic in the realization of glucose strips can reduce the cost for the single device from the current $ 0.5/1 to $ 0.015 [23]. Moreover, the use of office paper instead of chromatographic one might reduce the fabrication cost until of 96%.

Recent trend also includes moving from "classic" substrates to "active" substrate, by the use of self-propelled micro/nanomachines for sensing, which consist moving the receptor around the sample, the dimension of those machines ranges from nano to micrometers, and can be fabricated using a wide variety of polymers, metals and semiconductors [24-26]. In terms of application they are still at a proof-of-concept stage of tiny object demonstrating capabilities to autonomously perform different tasks: transporting cargo, destroying cells, remediate pollution. They could allow us to just "sit and see" the final product of a detection, remediation or, as in the movie, surgical event. In this direction, the integration of microengines within electroanalysis platforms was recently reported, using microengines for accelerated destruction of nerve agents, coupled to a SPE for the detection of the non-hazardous remediated product. The use of microenginesoperation leads to a 15-fold increased sensitivity towards organophosphate pesticide detection, compared to a non-engineered SPE [27]. This combined platform represents an attractive alternative for built-in mixing in electroanalysis. Still a challenge for this approach relies on a possible the electrical noise generated by the contact between the nanomotors and the electrode surface.

It is clear how electrochemical sensor and biosensors can be really enhanced both respect to the analytical performances and respect to the gain which every end-user is going to achieve. The above mentioned concept of a "laboratory-free" approach, supported by the need to develop decentralized on-site measurements, is being certainly facilitated by the development of all the previous cited technology, both in the electrochemical and optical fields of operation, allowing to realize method easily applicable in those regions presenting limited resources, i.e. chemicals, laboratory, equipment, safety, experienced personnel. The electroanalytical approaches due to their inherent simplicity in experimental set-up and instrumentations could be considered relevant and impressive tools in lowering time and complexity of an analysis. Wearable, implantable, sustainable, and autonomous, represent the innovation over the realization of smart platforms. However, the real need, in spite of the novelty contained in these new applied materials and interfaces, concerns the analysis of real matrices, i.e. clinical, environmental, food that should be rationally treated. So, the principal need is the establishment of smart and versatile devices able to measure the target(s) molecule(s) also in a very "crowded" matrix guarantying everyone reliable tools. Electrochemistry coupled to the (nano) engineering of surface can represents the answer.

References

1. Turner AP. Biosensors: Sense and sensibility. Chem. Soc. Rev. 2013; 42: 3184-3196.
2. Arduini F, Cinti S, Scognamiglio V, Moscone D. Nanomaterials in electrochemical biosensors for pesticide detection: advances and challenges in food analysis. Microchim. Acta. 2016; 183: 2063-2083.
3. Wang J. Nanomaterial-based electrochemical biosensors. Analyst. 2005; 130: 421-426.
4. Chen A, Chatterjee S. Nanomaterials based electrochemical sensors for biomedical applications. Chem. Soc. Rev. 2013; 42: 5425-5438.
5. Hernández-Santos D, González-García MB, García AC. Metal-nanoparticles based electro-analysis. Electroanal. 2002; 14: 1225-1235.
6. Cinti S, Arduini F. Graphene-based screen-printed electrochemical (bio) sensors and their applications: Efforts and criticisms. Biosens. Bioelectron. 2016.
7. Renedo OD, Alonso-Lomillo MA, Martínez MA. Recent developments in the field of screen-printed electrodes and the irrelated applications. Talanta. 2007; 73: 202-219.
8. Albareda-Sirvent M, Merkoci A, Alegret, S. Configurations used in the design of screen-printed enzymatic biosensors. A review. Sens. Actuators, B. 2000; 69: 153-163.
9. Metters JP, Kadara RO, Banks CE. New directions in screen printed electroanalytical sensors: an overview of recent developments. Analyst. 2011; 136: 1067-1076.
10. Alkire RC, Gogotsi Y, Simon P. Nanostructured materials in electrochemistry. A. Eftekhari (Ed.). John Wiley & Sons. 2008.
11. Malzahn K, Windmiller JR, Valdés-Ramírez G, Schöning MJ, Wang J. Wearable electrochemical sensors for in situ analysis in marine environments. Analyst. 2011; 136: 2912-2917.

12. Bandodkar AJ, O'Mahony AM, Ramírez J, Samek IA, Anderson SM, Windmiller JR, et al. Solid-state Forensic Finger sensor for integrated sampling and detection of gunshot residue and explosives: towards 'Lab-on-a-finger'. Analyst. 2013; 138: 5288-5295.

13. Kim J, de Araujo WR, Samek IA, Bandodkar AJ, Jia W, Brunetti B, et al. Wearable temporary tattoo sensor for real-time trace metal monitoring in human sweat. Electrochem. Commun. 2015; 51: 41-45.

14. Kim J, Jeerapan I, Imani S, Cho TN, Bandodkar A, Cinti S, et al. Non-invasive Alcohol Monitoring Using a Wearable Tattoo-Based Iontophoretic-Biosensing System. ACS Sens. 2016; 1: 1011-1019.

15. Bandodkar AJ, Jia W, Yardımcı C, Wang X, Ramirez J, Wang J. Tattoo-based noninvasive glucose monitoring: a proof-of-concept study. Anal. Chem. 2014; 87: 394-398.

16. Yetisen AK, Akram MS, Lowe CR. Paper-based microfluidic point-of-care diagnostic devices. Lab Chip. 2013; 13: 2210-2251.

17. Maxwell EJ, Mazzeo AD, Whitesides GM. Paper-based electroanalytical devices for accessible diagnostic testing. MRS bull. 2013; 38: 309-314.

18. Lankelma J, Nie Z, Carrilho E, Whitesides GM. Paper-based analytical device for electrochemical flow-injection analysis of glucose in urine. Anal. Chem. 2012; 84: 4147-4152.

19. Wang CC, Hennek JW, Ainla A, Kumar AA, Lan WJ, Im J, et al. A Paper-Based "Pop-up" Electrochemical Device for Analysis of Beta-Hydroxybutyrate. Anal. Chem. 2016; 88: 6326-6333.

20. Dungchai W, Chailapakul O, Henry CS. Electrochemical detection for paper-based microfluidics. Anal. Chem. 2009; 81: 5821-5826.

21. Rattanarat P, Dungchai W, Cate D, Volckens J, Chailapakul O, Henry CS. Multilayer paper-based device for colorimetric and electrochemical quantification of metals. Anal. Chem. 2014; 86: 3555-3562.

22. Cinti S, Talarico D, Palleschi G, Moscone D, Arduini F. Novel reagentless paper-based screen-printed electrochemical sensor to detect phosphate. Anal.Chim.Acta. 2016; 919: 78-84.

23. Nie Z, Deiss F, Liu X, Akbulut O, Whitesides GM. Integration of paper-based microfluidic devices with commercial electrochemical readers. Lab Chip. 2010; 10: 3163-3169.

24. Wang J, Gao W. Nano/micro-scale motors: biomedical opportunities and challenges. ACS nano. 2012; 6: 5745-5751.

25. Wang J. Cargo-to wing synthetic nanomachines: towards active transport in microchip devices. Lab Chip. 2012; 12: 1944-1950.

26. Wang W, Duan W, Ahmed S, Mallouk TE, Sen A. Small power: Autonomous nano-and micromotors propelled by self-generated gradients. Nano Today. 2013; 8: 531-554.

27. Cinti S, Valdés-Ramírez G, Gao W, Li J, Palleschi G, Wang J. Microengine-assisted electrochemical measurements at printable sensor strips. Chem. Commun. 2015; 51: 8668-8671.