The Potential of Nanostructured Electrode Materials in Analytical Sciences: A Short Commentary

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ABSTRACT

Nanostructured materials are often employed in electrode manufacturing in order to enhance charge transfer kinetics as well as improve operational conditions in energy storage and electroanalytical devices. Considering the impact of modifying electrode surface with conductive nanostructured elements and the applicability of these modifications in pharmaceutical, biomedical, food, chemical and other sciences, this commentary is intended to briefly discuss the general characteristics and parameters underlying the uses of these devices, as well as foment the importance of nanostructured composites for analytical and electronic applications.

Keywords: Electroanalysis; Electrocatalysis; Kinetics; Thermodynamics; Electrode Modification.

OVERVIEW

The development of new approaches towards electrode manufacturing is a growing trend in electronic and bioelectronics [1,2]. These devices, which house the main component of an electroanalytic operational system, may be modified with several composites in order to achieve a desired behavior, which may be either capacitive or resistive in the most straight forward applications [3]. Considering the widespread use and nature of solid electrodes, their highly capacitive behavior in fluidic systems is often explored in analytical chemistry in order to promote analyte preconcentration, as well as understand electrode-solution interface features.

Although highly capacitive in nature due to double layer formation upon contact to electrolyte containing liquids, solid electrodes whose use is intended in sensing and biosensing technologies should also display lower charger transfer resistance [3]. This feature is largely pursued by materials scientists due to the influence of electron kinetics on device performance [3,4]. Moreover, when electrode materials showcase chemical affinity to oxidation or reduction products of analytes, a phenomenon known as electrode fouling may take place, which may hinder faradaic current output mid-analysis [5,6]. In this sense, many researchers focus on developing disposable low-cost electrodes whose surface is easily renewed [7]. Considering that most electroanalytical methods are conceived upon the premise that redox processes promote faradaic currents, therefore a stress must be applied in the system in order to render the thermodynamics of redox processes feasible.

In this context, analytical tools such as chronoamperometry and voltammetry make use of electric potential to promote redox processes whose current is used to determine analyte concentration, impurity, authenticity, etc [8,9,10]. In electroanalysis, the precise monitoring of the kinetics and thermodynamics of redox processes is essential to develop a reliable and reproducible method [3]. Given the representation of faradaic current as reactional kinetics, and the electric potential associated to these processes corresponding to the thermodynamic parameter, the efficiency of a method may be considered optimal if a minimal applied stress, i.e. electric tension applied to the system, is able to promote a massive change in reactional kinetics, i.e. faradaic current associated to redox processes [3]. Henceforth, taking in consideration that chronoamperometric and voltammetric approaches make use

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of electric current as an analytic signal, one can clearly assume that the operation of a method under low electric potentials is highly sought after in electroanalytical development.

Nanostructured Electrode Materials

Considering the importance of operating electroanalytical devices under low potentials and the relevance of achieving best electric current outputs, several research groups have investigated different ways to modify an electrode and obtain electrocatalytic and electromediative effects [3,11,12]. In this sense, distinct composites and electrode materials have been assessed as modifiers, being the most reported those matrixes whose low cost and versatility allow their use in different devices, e.g. carbon graphite [13]. Moreover, surface modification is often discussed as one of the major alterations which electrodes may undergo, being this approach the most reported in scientific literature. In this sense, the modified electrode surface promotes a thermodynamically feasible charge transfer under low electric potentials, and if the electrode material is appropriately conductive, the current output will be quickly delivered to the transducer [3,13,14].

Literature reports on electrode surface modifications with organic, inorganic and biological components are widespread in electroanalytical sciences, however, most of these approaches make use of a similar electrocatalytic system, represented by nanostructured materials [13,14,15]. Although variable in terms of morphology and architecture, nanostructured systems such as transition metal oxides have in common the electron-accepting properties of Lewis acids, what enhances the thermodynamic feasibility of redox processes at electrode surface [3]. Despite some strenuous preparation procedures and time-consuming modification protocols such as drop-casting techniques, many modified matrixes are commercially available, such as carbon-transition metal oxide and carbon-transition metal [13,14,15] . Notwithstanding, depending on the analytic system to which these modified electrodes may be applied, reuse can be feasible. Regarding nanostructured electrode modifications applicability in pharmaceutical and chemical industries, several reports evidenced carbon-transition metal oxide electrodes being used in chronoamperometric techniques whose analytic parameters rivalled standard analytical approaches, such as high-performance liquid chromatography [10,13,15]. Moreover, when taking in consideration that liquid chromatography involves the expenditure of many liters of organic solvents, as well as high operational cost and time-consuming analysis, the appeal of electroanalytical tools employing nanostructured electrodes is remarkable. Although the determination of substance concentrations is the first idea considered when nanostructured electrode use in electroanalysis is under the spotlight, their applicability is fairly diverse, being straight forward such as drug determination in pharmaceutical formulations [7,13], authenticity tests in raw mater assessment [5,8], emerging pollutants and industrial effluent monitoring [10], as well as other uses such as in decontamination systems for wastewater treatment [16,17], and operation and process monitoring in food and chemical industry [18]. In this sense, the sheer variety of applications provided by these compounds is noteworthy, and surely many more uses are yet to be unraveled.

CONCLUSION

Therefore, this commentary was intended to briefly discuss the general characteristics and parameters underlying the uses of nanostructured electrode materials, as well as foment the importance of nanostructured composites for analytical and electronic applications. It is safe to say that the use of nanostructured electrodes provides deep advances in electroanalytical area, and their versatility allows the use of these materials in several other fields.

Conflict of Interest

Author declare that there is no conflict of interest.

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