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Portable Measurement System for Voltammetry and Impedance Spectroscopy. Application for TNT Detection

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Abstract

This paper presents the design of a portable low-cost electronic tongue system that includes an electronic equipment based on a 16 bits microcontroller and a software application that runs on a personal computer. The designed system is able to carry out voltammetry and impedance spectroscopy measurements with different electrodes configurations in a single device, allowing the implementation of both techniques in a convenient and easy way. The designed system has been electrically characterize and has shown good levels of accuracy and reliability. It is composed by an electronic equipment, the electrodes and a software application. This system has been successfully used in various applications in the field of chemical analysis, food quality and environmental. In this communication the results of the application of the designed electronic tongue system to explosive compounds detection are shown

Keywords: Electronnic tongue, explosive deteciotn

1. Introduction

In recent years our research center has developed various electronic tongues systems based on measuring equipments employing different electrochemical techniques. Among them, voltammetry [1] and impedance spectroscopy [2] are highlighted because they have shown excellent results and good future perspectives. In this communication, an electronic tongue system based on both voltammetry and

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impedance spectroscopy is presented. The use of various techniques in the same electronic tongue system is particularly important because the information provided by each technique can be complementary to the other one [3].

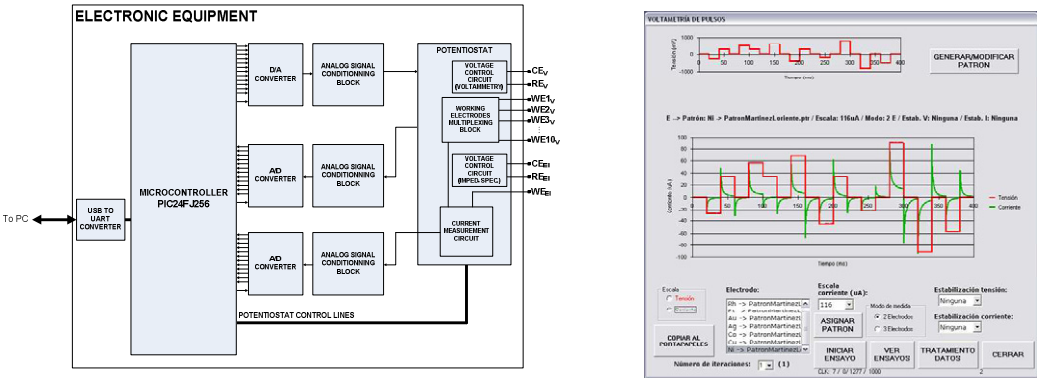
2. Material and Methods

2.1. Electronic tongue system

The electronic tongue system consists on an electronic equipment, a software application and the electrodes (Fig.1).

Fig. 1. Electronic tongue system with the three main parts.

The electronic equipment includes a digital processing block, a mixed signal circuit, an analog block and a potentiostat. Fig. 2-a shows its block diagram.



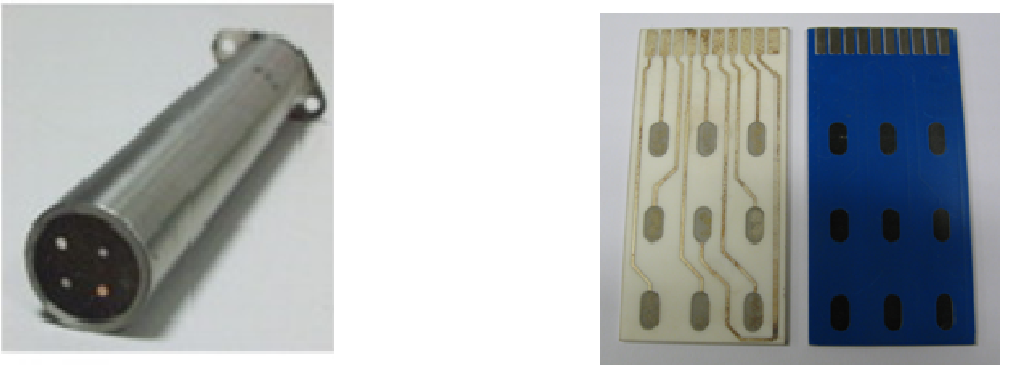
(a) (b)

Fig. 2. (a) Electronic equipment block diagram (b) GUI for pulse voltammetry measurement

The digital processing block consists on USB to UART converter and a 16 bits microcontroller (PIC24FJ256). The microcontroller has been programmed in C and assembler languages using the C30 compiler. The software application has been designed using the development tool Visual Basic 6.0. The

application allows the implementation of the three electrochemical techniques. It includes one form for each technique; the GUI (Graphic User Interface) for pulse voltammetry is shown in Fig. 2-b.

The electronic tongue system is designed to work with different electrodes configuration. The potentiostat can work in two or in three electrodes mode. Impedance spectroscopy measurements are carried out on one working electrode while for voltammetric techniques tests can be done in up to ten working electrodes. The electrodes used are formed by metal wires of different materials enclosed in a metal casing filled with an insulating material (Fig. 3-a), but we have also developed metallic electrodes using thick-film technique where pastes of different materials are deposited on a small board (Fig. 3-b).



(a) (b)

Fig. 3. (a) Electrodes formed by different metallic wires enclosed in a metal casing (b) Metallic electrodes built in a board by Thick-Film technology. Initial stage where electrodes and connection lines are shown (left) and final stage with an insulating protective layer to allow the immersion in liquid samples (right)

2.1. Data processing

Voltammetry measurements consist on sampling the current signal produced at the electrodes when a certain potential is applied to them. The design system collects 1000 current samples per each electrode.

In order to reduce the number of data to be processed a compression algorithm has been developed (Fig. 4). The algorithm establishes a 4^{th} order polynomial approximation for the current signal of each pulse. The coefficients of the polynomial approximation are used instead of the current samples. The effect of the applied algorithm is not only the compression of the data but also the filtering of the current signals. Voltammetry data are used to classify the samples or to quantify their fisicochemical properties by means of multivariate data analysis tools.

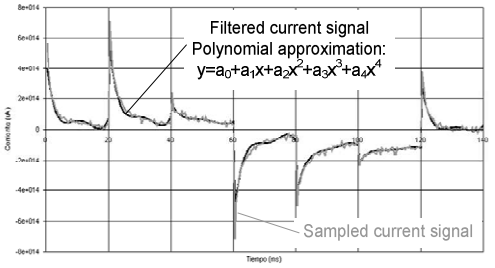


Fig. 4. Data compression algorithm

3. Measurements

This system has been used in several applications. In this work we present the results of an experience where explosive compounds (TNT) in different concentrations are detected and quantified. Various samples with different concentrations (from zero to 5.9·10-6M) of TNT were measured with the voltammetric electronic tongue. The results are shown in a principal component analysis (PCA) plot (Fig. 5). Discrimination of the samples is observed.

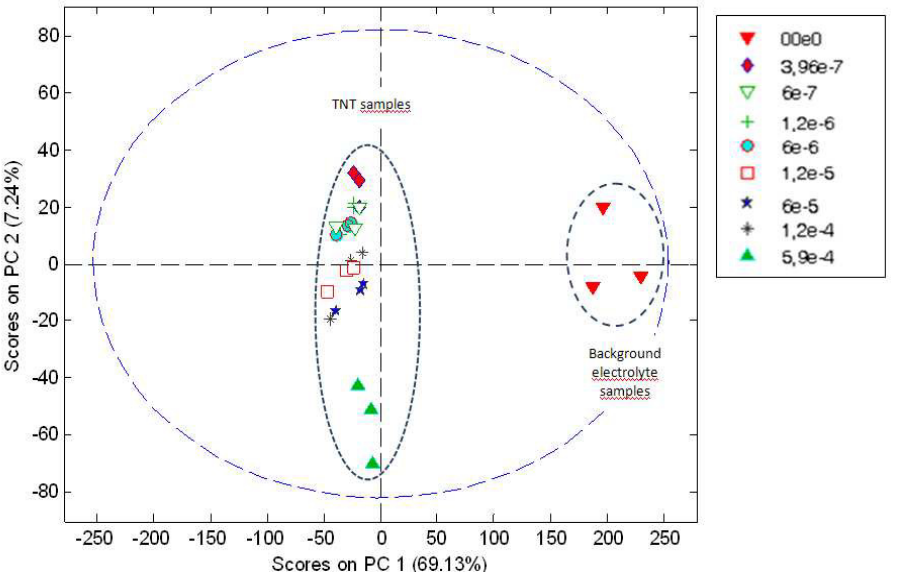


Fig 5. Principal Component Analysis plot obtained from the voltammetry measurements.

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