

Proc. Eurosensors XXVI, September 9-12, 2012, Kraków, Poland

## A new capacitive sensor based on electrostriction phenomenon. Application for determination of ionic surfactants

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### Abstract

The aim of the work was to develop a new capacitive sensor based on the electrostriction phenomenon observed in membranes deposited on solid electrodes in contact with an electrolyte solution. The functioning of the sensor was checked in determination of ionic surfactants. The sensor was based on self-assembled monolayers (SAM's) of thiol supported on the surface of a gold electrode. Two thiols, 1-octadecanethiol and 1-hexadecanethiol, and two surfactants, anionic sodium dodecyl sulfate and cationic hexadecyltrimethylammonium bromide, were chosen for studies. Different shapes of capacitance-potential curves with hysteresis were revealed. After an addition of a surfactant, the height of hysteresis changed, enabling construction of linear relationship between the hysteresis' height and concentration of surfactant.

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Keywords: capacitive sensor; ionic surfactants; electrostriction;

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### 1. Introduction

The search for new detection methods dedicated to various compounds, both organic and inorganic, remains a challenge to many scientists. The possibility to evaluate a detection technique based on measurement of changes in the capacitance of a thiol layer resulting from the electrostriction phenomenon, may open new perspectives in numerous fields of science. The phenomenon of lipid

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membrane electrostriction, described in literature in 1960's [1], can be used in the electrochemical detection of electrochemically-inactive substances, which are not susceptible to redox processes [2]. The focus of this research was to develop the method in question. Recording capacitance-potential characteristics is a base of this method developed. Interactions between analyzed molecules influence on some of the parameters of the characteristics.

The electrostriction phenomenon can be observed for thiol membrane covalently bound on the surface of a gold electrode. The structure of the long-chain thiol membrane, supported on a gold electrode, with functional groups exposed to the electrolyte solution, is shown in the Fig. 1.

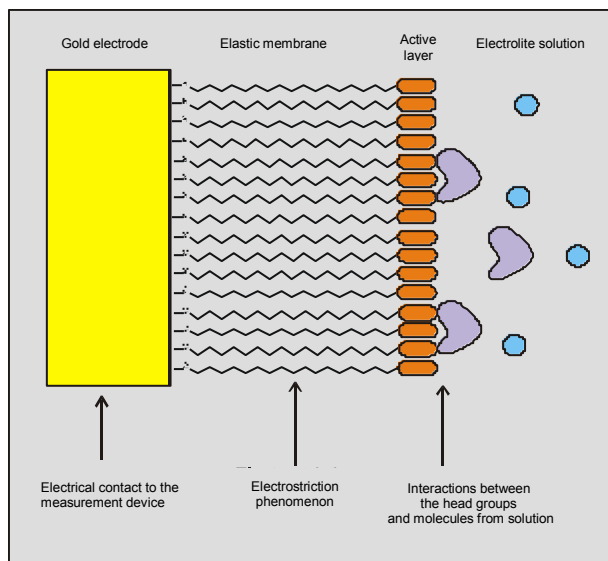


Fig. 1. The structure of the electrode covered by the membrane, contacted with the electrolyte solution.

Electrostriction occurring on the membrane/solution phase boundary leads to changes in value of the measured capacitance as an analytical parameter. Several types of interaction between functional groups of the membrane and components of the electrolyte can be observed (see Fig. 2).

In the studies presented, a sensor was proposed for determination of ionic surfactants. Surfactants are widely used in households, cosmetics, industry and research laboratories [3]. Surfactants and their metabolites are directly after use introduce into environment. Nevertheless, they are not effectively removed from the wastewater treatment [4]. Their continuous presence leads to its toxicosis to aquatic organisms, even at very low concentration levels. As a result, it is important to develop a rapid, sensitive and effective method for trace analysis of surfactants in environmental samples.

The present research was focused on two thiols, 1-octadecanethiol and 1-hexadecanethiol, and two surfactants, anionic sodium dodecyl sulfate and cationic hexadecyltrimethylammonium bromide.

## 2. Electrode preparation

The procedure of gold electrode preparation consisted of cleaning of electrode surface and formation of alkanethiol monolayers.

Different ways of electrode surface preparation were tested: mechanical polishing with alumina slurry, sonication in water and ethanol, voltammetric measurements in KOH and H<sub>2</sub>SO<sub>4</sub> solutions, bathing of

electrode in hot solutions of  $\text{HNO}_3$  and  $\text{KOH}$ . The cleanness of electrode surface was checked using cyclic voltammetry in  $\text{K}_3[\text{Fe}(\text{CN})_6]$  solution. The best results were obtained employing mechanical polishing with alumina slurry followed by cyclic voltammetry in  $\text{KOH}$  and  $\text{H}_2\text{SO}_4$  solutions.

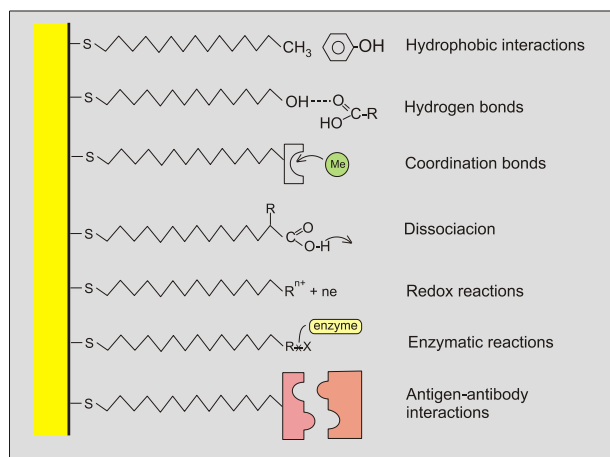


Fig. 2. Different types of interactions between functional groups of the thiol membrane and components of the electrolyte can be observed [2]

The procedure of thiol's chemisorption were optimized taking into account solvent and the time of thioling process. The optimum SEM's were deposited by spontaneous adsorption of thiols from  $3 \text{ mmol}\cdot\text{L}^{-1}$  acetonitrile solution for at least 40 hours.

### 3. Results and discussion

For studied surfactants capacitance-potential curves were recorded. Different shapes of curves with hysteresis were revealed. It was observed that after an addition of a surfactant, the height of hysteresis changed, enabling construction of linear relationship between the hysteresis' height and concentration of surfactant. Exemplary capacitance-potential curves of cationic surfactant and the corresponding calibration curves obtained based on height of hysteresis noticed at different potentials, are shown in Fig.3.

Despite the fact that the gold electrodes were prepared according to the same procedure, the capacitance-potential curves were different, even for the same thiol, surfactant and electrode. However, the widest linear ranges were similar (see Table 1).

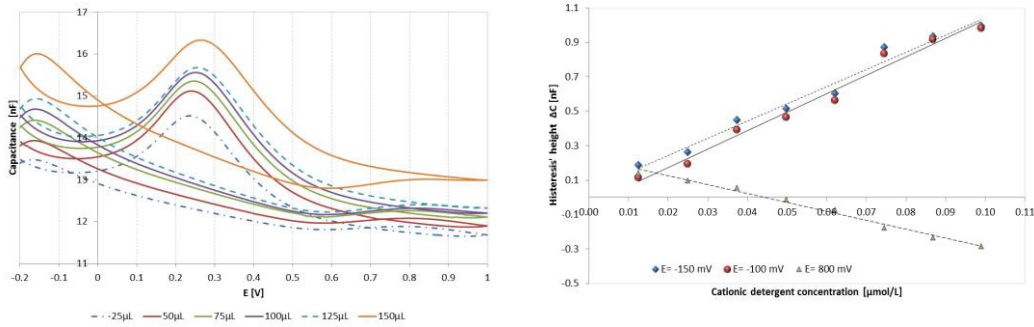


Fig 3. (A) Exemplary capacitance-potential curves recorded for 1-octadecanethiol, supported on a gold electrode, in solution of hexadecyltrimethyl- ammonium bromide (cationic surfactant) of different concentrations; (B) the calibration curves obtained based on changes of capacitance noticed at three different potentials: -150, -100 and 800 mV vs. Ag/AgCl reference electrode

Table 1. The comparison of the widest linear ranges obtained for studied thiols for cationic and anionic surfactants

Surfactant	thiol	Linear range [ $\mu\text{mol}\cdot\text{L}^{-1}$ ]
anionic	$\text{C}_{18}\text{H}_{38}\text{S}$	0.023 – 0.130
	$\text{C}_{16}\text{H}_{34}\text{S}$	0.015 – 0.094
cationic	$\text{C}_{18}\text{H}_{38}\text{S}$	0.012 – 0.099
	$\text{C}_{16}\text{H}_{34}\text{S}$	0.017 – 0.130

## References

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