Multi-Micro-Sensor Platform for Monitoring Toxic Algal Blooms and Pollution in Coastal Marine Waters: Transducer Integration in Micro-Technology

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Abstract

Multi-Micro-Sensor Platform for Monitoring Toxic Algal Blooms and Pollution in Coastal Marine Waters: Transducer Integration in Micro-Technology †

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Abstract: This work presents the design of a multisensor platform for the in situ monitoring of physico-chemical parameters in seawater. As a result, we propose an 8.5 × 8.5 mm^2 silicon chip that integrates a MOSFET and two ISFETs (Metal Oxide Semiconductor and Ion-Sensitive Field-Effect Transistor) and four microelectrodes (two Ag electrodes and two Pt electrodes). The device allows measurements to be taken in liquid phase of temperature, pH, nitrate concentrations and conductivity. These silicon transducers could be integrated with conditioning electronics to achieve an autonomous environmental sensor device.

Keywords: ISFET sensor; multisensory; in situ

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1. Introduction

Knowledge of our oceans is limited, in particular by the lack of local measurement data, but also by the lack of global data that could help in our understanding of the relationship between biological variations and associated physico-chemical parameters. New methods of measurement and data processing have emerged, in particular with the explosion of deep learning and the use of satellite imagery for the extrapolation of surface measurements [1]. A large number of in situ measurement solutions have also been deployed, by increasing the number of measurement campaigns to cover large areas. However, these approaches are limited by cost and human effort. For example, autonomous measurement devices such as seabird probes [2] are efficient but expensive and require expert operators to deploy.

In this paper, we propose a system that combines integration and robustness for marine environments, allowing high-frequency and long-term measurements.

2. Materials and Methods

Our FET-based transducers were integrated into the 8.5 × 8.5 mm^2 platform developed in silicon technology (Figure 1). Two IS-FETs (Figure 1, mark A) were designed to perform pH and ion-concentration measurements. To achieve these IS-FETs, we deposited specific fluoropolysiloxane-based ion-sensitive layers by drop-casting to deal with nitrate NO_{3-} ion analysis. A MOSFET reference device (mark B) was also integrated for temperature-drift compensation. Finally, two silver/silver chloride (Ag/AgCl) pseudo-reference microelectrodes and two platinum (Pt) microelectrodes were also integrated (mark C). The Ag/AgCl electrodes were used as reference electrodes for the IS-FET gate voltage in the liquid phase, and the Pt electrodes were used for conductivity analysis and for impedance spectroscopy in the liquid phase. The chip characteristics were measured with a parameter analyzer (HP 4142B).

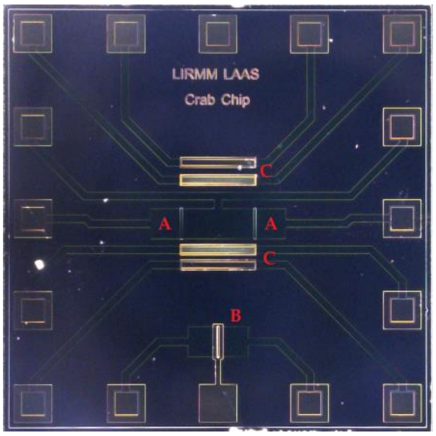

Figure 1. Crab-chip with (A) ISFETs, (B) MOSFET, and (C) electrodes.

3. Results and Discussion

The first results validated the fabrication process. We measured a MOSFET threshold voltage of 0.6 V, as expected. The Mos-FET also had the expected temperature sensitivity of 0.22 mV/°C (Figure 2). This is very important because having a high sensitivity to temperature will allow the MOSFET to be used as a thermal compensator for pH measurements.

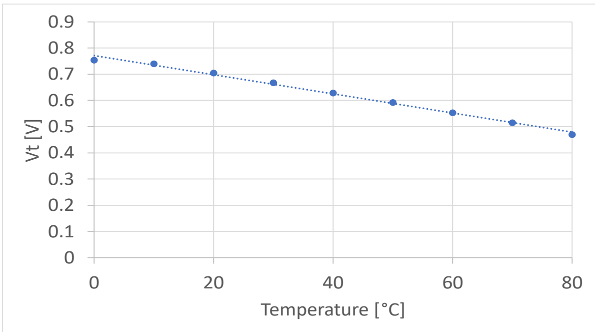

Figure 2. Temperature measurement with a MOSFET.

For the IS-FET, we obtained a pH sensitivity of 46 mV per pH unit [3] (Figure 3). The curve for detecting the variation in nitrate concentration in a solution (Figure 4) gave a sensitivity estimated to 50 mV/pNO3. In addition, these measurements were replicated on the same components, but also on components from other production series, or from the same series. These sensitivities will allow the easy detection of pH or nitrate in an aqueous solution, so that variations in these chemicals can be monitored.

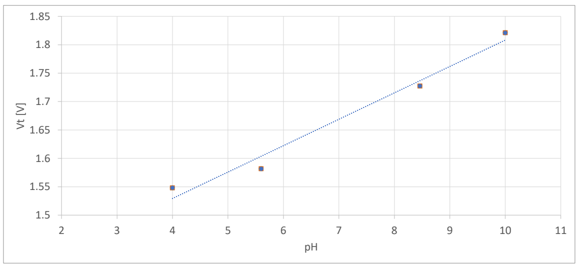

Figure 3. pH measurement with an ISFET.

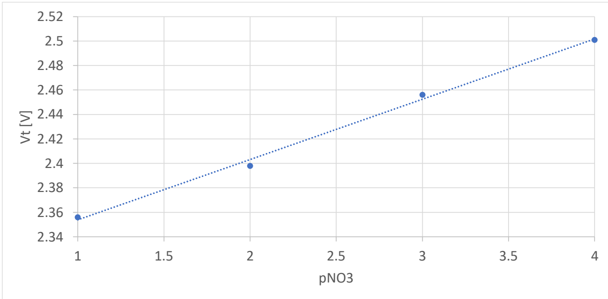

Figure 4. Measurement of nitrate concentration.

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