DOI 10.5162/EUROSENSORSXXXVI/OT6.260

Characterization of an Integrated Pt Counter Electrode on GaN/AlGaN-ISFET Wheatstone Bridge pH-sensors

A. Hinz[1], *G. Steingelb*[1], *C. Habben*[1], *S. Figge*[1], *M. Eickhoff*[1]
[1]*Institute of Solid State Physics and MAPEX Center for Materials and Processes, University Bremen, Germany*

ahinz@uni-bremen.de

Summary:
GaN/AlGaN high electron mobility transistors (HEMT) were used as a pH-sensors, employing a Wheatstone bridge design in order to reduce parasitic effects on the sensor response. A Pt counter electrode was patterned directly on the sensor to achieve a more compact design and showed good operation characteristics. However, the signal stability was worse compared to an external counter electrode. In addition, we investigated the effect of different pH-sensitive gate layers, such as TiO_2 and Ta_2O_5, as well as the compensation of temperature effects and light-induced drift in the Wheatstone design.

Keywords: GaN/AlGaN, ISFET, Wheatstone Bridge, Heterostructure, pH-sensor

Introduction

Ion-sensitive field effect transistors (ISFETs) have attracted high research interest since their discovery by Bergveld in 1970 [1]. GaN/AlGaN HEMT structures have been demonstrated to exhibit excellent pH-sensor characteristics, such as a high, linear response, chemically inert surface and thus a small chemically induced drift [2]. However, these ISFETs also respond to other environmental parameters such as temperature or light and exhibit related signal drifts [3].

To reduce these effects, a Wheatstone bridge design was fabricated, consisting of one sensitive ISFET with the GaN gate exposed to the electrolyte FETs for which the gate was passivated by a 500 nm thick layer of sputter-deposited Al_2O_3. Thus, the latter ones do not show a pH response but are still affected by parasitic parameters. In addition, a Pt counter electrode was also processed on the chip to reduce the overall size of the sensor.

Methods

The Wheatstone bridges were fabricated on commercial wafers AlGaN/GaN HEMT structures (150 nm GaN/ 20 nm $Al_{0.25}Ga_{0.75}N$/ 3 nm GaN on HR-Si substrate, 2DEG charge density of > 8e12 cm^{-2} and mobility of > 1800 cm^2/Vs, supplied by soitec) with standard photolithographic methods. Heterostructures with and without 3 nm GaN cap were compared. A sketch of the sensor is depicted in Fig. 1.

The sensors were glued on a printed circuit board and the contacts were wire bonded to the board. For measurement in electrolyte the contacts were covered with silicone glue. The measurements were performed with a three-electrode setup in a temperature-controlled beaker. The used electrolyte was phosphate-buffered saline (PBS 0.05 mM). For the pH-measurements titrations with diluted HCl were performed.

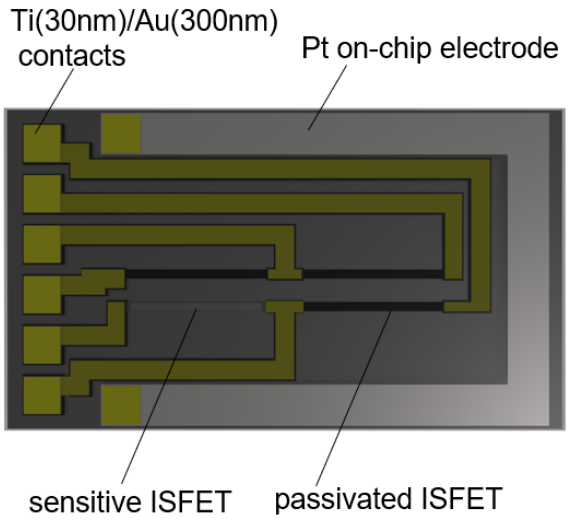

Fig. 1 Schematic of the device. The dimensions are 6 mm in length and 3.5 mm in width.

(1)

Results

To compare the on-chip electrode with an external counter electrode, pH-measurements with the sensitive ISFET only were performed. The drain-source current I_{DS} was regulated constant with the gate-source voltage V_{GS}. In Fig. 2. the measurement an external counter electrode is shown, Fig. 3 displays the results for the on-chip electrode. The sensors with an on-chip electrode exhibit a higher noise level, most likely due to the smaller distance to the gate, thus leading to a higher leakage current as it is also visible in the transfer characteristics.

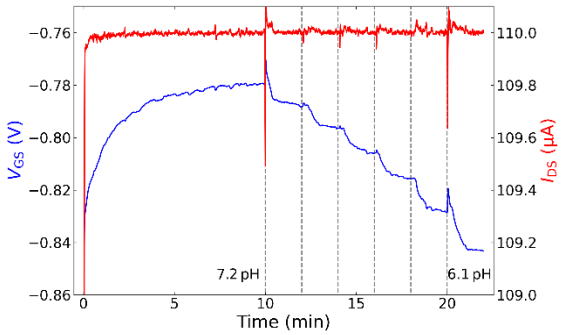

Fig. 2 pH-measurement with external counter electrode.

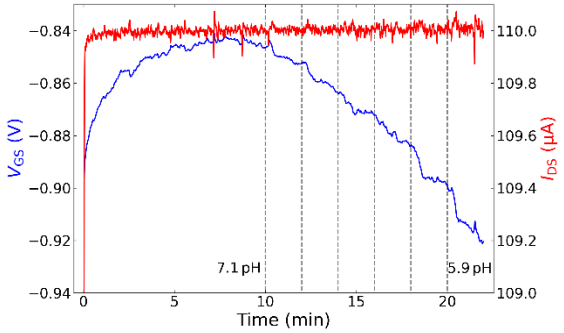

Fig. 3 pH-measurement with on-chip counter electrode.

A measurement with the on-chip electrode in the Wheatstone bridge configuration is depicted in Fig. 4. The bridge sensitivity of ≈ 2.5 mV/pH is similar to values reported in [4] (2.3 mV/pH).

Furthermore, temperature-dependent measurements were performed to analyse the compensation effects of the bridge and a significant reduction from 55 mV/°C to 7mV/°C. was found. Also, ultrathin coatings of the sensitive gate area with TiO_2 and Ta_2O_5 realized by Atomic Layer Deposition were carried out and their effect on the sensor performance was studied.

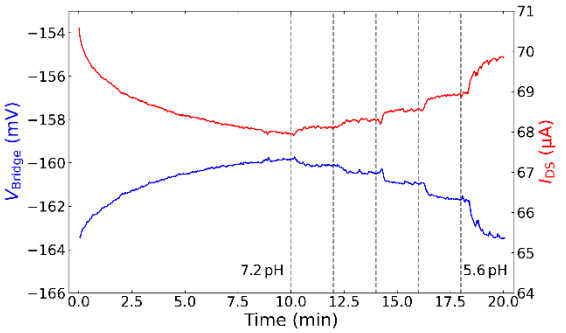

Fig. 4 pH-measurement in the Wheatstone Bridge configuration.

Perspective

The intention is to have a small and compact sensor. To add an on-chip reference electrode in addition would reduce the size of the sensor. Also, a combination of two different gate dielectrics on two sensitive ISFETs with differential read-out is a promising approach in that direction.

(1)

References

[1] P. Bergveld, Development of an Ion-Sensitive Solid-State Device for Neurophysiological Measurements, *IEEE Transactions on Biomedical Engineering* BME-17, 70-71 (1970); doi: 10.1109/TBME.1970.4502688

[2] G. Steinhoff, M. Hermann, W.J. Schaff, L.F. Eastman, M. Stutzmann, M. Eickhoff, pH response of GaN surfaces and its application for pH-sensitive field-effect transistors, *Applied Physics Letters* 83, 177-179 (2003); doi: 10.1063/1.1589188

[3] M.T. Hirsch, J.A. Wolk, W. Walukiewicz, E.E. Haller, Persistent photoconductivity in n-type GaN, *Applied Physics Letters* 25, 1098-1100 (1997); doi: 10.1063/1.119738

[4] D. Stock, G. M. Müntze, S. Figge, M. Eickhoff, Ion sensitive AlGaN/GaN field-effect transistors with monolithically integrated wheatstone bridge for temperature- and drift compensation in enzymatic biosensors, *Sensors and Actuators B: Chemical* 263, 20-26 (2018); doi: 10.1016/j.snb.2018.02.068