**Gallium Nitride Based Chemical Sensors**

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**Purpose of this work**

The Development of new Anion Selective Potentiometric Sensors based on the Surface Active Gallium Nitride (GaN)

**Terminology**

- **Chemical Sensor** is a device which transforms chemical information (e.g. activity or concentration of a specific compound), into analytical signal, continuously and reversibly

- **Potentiometry** is the field of electroanalytical chemistry in which potential is measured under conditions of zero current flow in order not to disturb the chemical equilibrium of the system

**Potentiometric Ion Selective Electrodes (ISEs)**

- ISEs are used for the direct measurement of ions in solution, through the measured potential difference between the ISE and a reference electrode

- The reference electrode has a well-known and stable potential, independent of the concentration of the ions in the test solution

- The electrometer is a potential measuring device with very high input impedance (>10^12 Ohm)
**ISE Sensing Elements**

- Electrochemically active surfaces (sensing elements) are used for the development of the measured potential in ISEs.
- Solid state sensing elements are ideal for the development of ISEs since they are robust, and can be produced in different shapes and sizes.
- There are only few examples of such solid sensing elements in Anion Selective Sensors (LaF* and Cd-face CdS crystals **)
- These materials can also be used as gate in ISFETs, for the development of selective CHEMFETs.


**GaN as Sensing Element in ISEs**

- III-nitride materials have been of intense research lately.
- GaN has been used as matrix for the pyrolytic detection of certain gases*
- On the surface of the (0001) GaN wurtzite crystal, each gallium atom has three complete bonds to the underlying nitrogen atomic plane.
- These gallium atoms are relatively electropositive, due to the induced polarity of the Ga to the N bond.


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- Thus the gallium atoms of the epitaxial, Ga-face polarity, GaN are expected to interact with anions of the solution.
- In such a case, the formation of a double layer at the GaN/solution interface can be measured, and thus can be the basis for the development of a Chemical sensor.

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**Potential development**

- When a conductive surface is placed in contact with an electrolyte, their electrochemical potential must be the same. If they do not lie at the same energy level, a movement of charged species at the interface is induced.
- When anions are adsorbed, the double layer forming will, by electrostatic repulsion, decrease the density of electron near the surface inside the semiconductor.
- This is reflected in a downward bending of the conduction and valence band towards the interface.
Potential development

Sensor Construction

- The Ga-face GaN (0001) films were grown on Al₂O₃ (0001)
- The wafer was then scribed to pieces approximately 5*5 mm
- A 0.1 mm diameter platinum wire was bonded with indium at the edge of the GaN
- The bonding pad, the sides, as well as the back side were covered with epoxy glue, leaving exposed to the solution only the GaN surface

High resolution AFM image of the GaN surface morphology

pH Response

- The potentiometric response is obtained upon additions of HCl in 0.1mole/lt Tris solution
- The sensor showed considerable sensitivity to pH changes

Preparation of solutions

- In all solution we have used 50ml of nano-pure water
- Aliquots from the 0.1mole/lt solution of each salt were added, in order to prepare solutions of different electrolyte concentration:
  - KCl → K⁺ + Cl⁻
  - KBr → K⁺ + Br⁻
  - KF → K⁺ + F⁻
  - KI → K⁺ + I⁻
**Chart Recording**

- Potentiometric measurements were performed versus an Ag/AgCl reference electrode and the signal was recorded via a personal computer.

**Data analysis**

- *Calibration Curves*: the graphical display of the response variable $V(y)$ (electromotive force) versus the logarithm of the analyte($X$) concentration($x$).

**Anion Response**

- The sensitivity of the sensor is depended on the surface potential generated due to the specific interaction with the active sites within the double layer.
- The selectivity of the sensor can be related to anion lipophilicity.

**Impedance Spectra**

- There is a direct relationship between the anion activity and the capacitance of the GaN-Solution interface.
The double layer capacitance is directly related to the observed potentiometric response.

The signal stability of the sensor over time is excellent, since there is no significant potential drift when the sensor was immersed in electrolyte solution for up to 5 days.

**Conclusions**

- GaN crystal grown on sapphire substrate is shown to be an excellent anion selective sensing element.
- It has been shown that the Ga atoms of the outer surface of that crystal coordinate selectively and reversibly with the anions in solution.
- The interfacial potential as well as the interfacial capacity generated is related to the anion activity in the solution.
- The GaN-based sensor has excellent stability and reversibility, providing the grounds for the development of novel direct anion CHEMFETS and other types of chemical micro-sensors and biosensors.

**Acknowledgments**

This work has been supported by GSRT, Hellenic Ministry of Development, and Intracom S.S. through the PENED project no:01ED 583 "PRONITRO".