MEMS in GaN

Peter Benkart, Ulrich Heinle, Mike Kunze, Ingo Daumiller and Ertugrul Sönmez
GaN-MEMS Overview

GaN-MEMS sensor

- sensing elements in pressure sensors
- proximity sensor with sub-micron resolution

Advantages of GaN-MEMS
- high measurement signal
- functionality shown until 300°C (more can be expected)
- electronic devices are possible on one chip

GaN-MEMS actuator

- varaktors and switches for RF power applications
- actuator/resonator for biomedical analysis

Advantages of GaN-MEMS
- low driving voltages and power dissipation
- compact and variable design is possible
- suitable for harsh environments
GaN-MEMS Process Overview

new wafer

Si-substrate

side view
top view
GaN-MEMS Process Overview

structuring the active layers

sensing element

mechanical part of the cantilever

Si-substrate

side view
top view
GaN-MEMS Process Overview

- deposition of contacts and passivation
- passivation
- ohmic and schottky contacts

Si-substrate

side view

top view
GaN-MEMS Process Overview

Si-substrate

wiring

electric wires and contact pads

side view       top view
GaN-MEMS Process Overview

- Structuring the substrate
- Freestanding cantilever
- Silicon frame for mechanical stability

Side view

Top view
Sensor signal vs time of a cantilever

cantilever with a length of 750µm and a width of 200µm at room temperature
Sensor signal at high temperature

- RT
- 100°C
- 200°C
- 300°C

Relative sensor signal (%) vs. deflection (µm)

beam bent upwards

Hotplate
GaN is a polar material and lateral stress changes the polarization field

Theory predicts the change of the lattice constants by manipulating the polarization field. It should function as actuator.
GaN actuator beam

Actuation with square wave voltages of different frequencies

Beam length: 800µm
Beam width: 200µm
Amplitude: ~3,2µm
Actuators

Capacity

Si-frame

Actuator

RF-contact

Initial position ($C_{\text{min}}$)

sideview

lower electrode actuated ($C_{\text{max}}$)
GaN-MEMS varaktor in action

Square wave driving voltage (1Hz und 2Hz)
Capacity variation

Varactor capacity vs driving voltage of a GaN-MEMS varactor

Capacity (fF)

Driving voltage (V)
Conclusion

The piezoelectric effect in GaN opens the possibility for sensors with high signals on one hand.

On the other hand, turning the sensor principle upside down, the same material system functions as actuator.

This effect allows not only the applications discussed before, but also new fields of application where sensor and actuator are needed in combination.