PYROELECTRONICS AND PYROSENSORS BASED ON AlGaN/GaN HETEROSTRUCTURES

Oliver Ambacher
Walter Schottky Institute, Technical University Munich
Am Coulombwall, D-85748 Garching, Germany
ambacher@wsi.tu-muenchen.de

High field transport in semiconductors that possess high internal spontaneous and piezoelectric polarizations opens up a new field of pyroelectronics and pyrosensors. The pyroelectric character of group-III-nitrides with wurtzite crystal structure yields a novel degree of freedom in designing and tayloring devices for modern micro- and nanoelectronic applications by taking advantage of the strong spontaneous and piezoelectric polarization of these materials [1]. Further more polarization induced surface and interface charges can be used to develop very sensitive but robust sensors for the detection of pressure, toxic gases and polar liquids.

We present both theoretical and experimental studies of pyroelectric AlGaN/GaN based high electron mobility field effects transistors (HEMT´s) that demonstrate these devices to be optimally suited for high power and high frequency applications as well as for various kinds of sensors operating in harsh environments. On the theory side, we have employed first principles calculations to determine gradients in spontaneous and piezoelectric polarization causing bound charges with high sheet concentrations at interfaces and surfaces of AlGaN/GaN based heterostructures. Polarization induced interface charges are predicted to cause two dimensional electron gases with sheet carrier concentrations as high as $2x10^{13}$ cm^{-2} without the need of modulation doping.

Experimentally we have processed undoped and surface passivated, pyroelectric AlGaN/GaN HEMT´s on c-Al_2O_3 and 6H-SiC substrates that show excellent devices characteristics. With gate length down to 150 nm, we have reached an electron transit velocity and intrinsic transit time frequency of $1.3x10^7$ cm/s and 106 GHz, respectively, at room temperature. For large periphery devices a very high power of 11 W/mm were measured at a frequency of 10 GHz, proving that the devices are very suitable for high power high frequency microwave amplifiers [2].

Without any surface passivation the sheet carrier concentration of the polarization induced 2DEGs confined at interfaces of AlGaN/GaN HEMT´s become sensitive to any manipulation of surface charge. These effect is used to build micro-sensors which are able to detect very sensitive e.g small doses of ions, polution by polar liquids or toxic gases [3, 4].

Beside the basic physics of polarization induced charges and 2DEGs in pyroelectric AlGaN/GaN heterostructures we will discuss the fabrication and performance of the high power transistors as well as the future applications of GaN based pyrosensors

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[4] M. Eickhoff, O. Ambacher, G. Krötz and M. Stutzmann, J. Appl. Phys. **90** (2001) 3383.

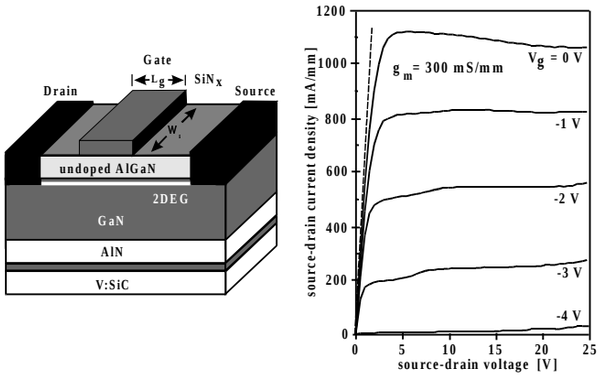

Fig.1: Schematic drawing of an undoped, passivated, pyroelectric AlGaN/GaN based HEMT and the measured current voltage characteristic. Please notice the high current density and transconductance of the device.

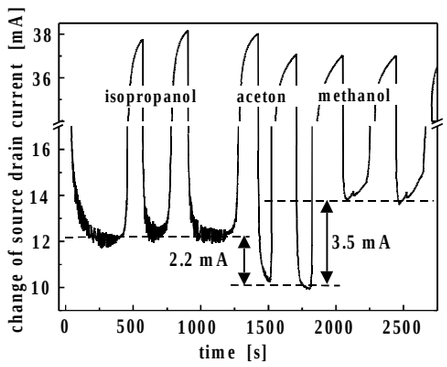

Fig.2: Change of the source drain current of an unpassivated AlGaN/GaN based HEMT, if the gate area of the device is periodically exposed to different polar liquids.

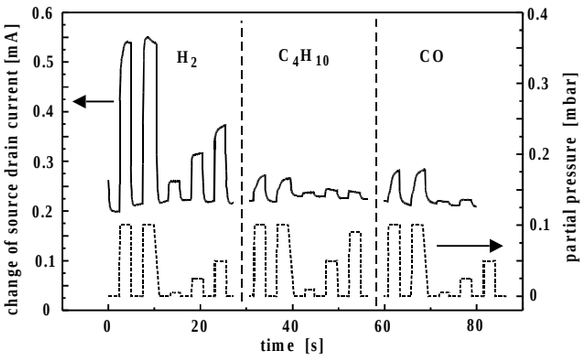

Fig.3: Variation of the source drain current of an unpassivated AlGaN/GaN HEMT, if the platinum gate is periodically exposed to different gases at room temperature.