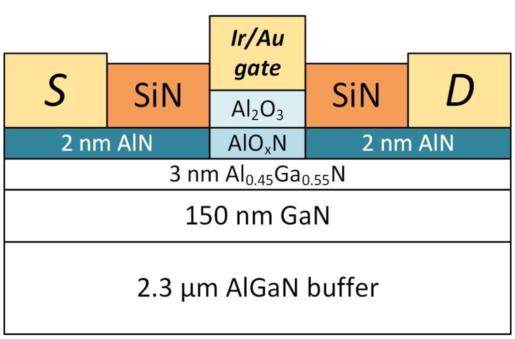
Switching HFETs based on III-N semiconductors

Owing the ever growing demand for energy, today's society is facing a question on more efficient energy consumption. As the most of energy is now used by the electronics (home, offices, and industrial appliances), huge power savings reside in the reduction of energy losses generated during the energy conversion (AC/DC and DC/DC converters). In fact, more than 10% of all electricity is lost in the form of conversion losses, representing over 10 times higher volume than the world's supply of renewable energy. Even partial improvement in the conversion efficiency can therefore have a strong economical impact.

To decrease the conversion losses, highly efficient converters utilizing a new generation of power switching transistor based on SiC or GaN can be employed. Amongst them, GaN offers the highest theoretical figure-of-merits substantially over-performing the state-of-the-art Si switching devices. However, a wider commercialization of the GaN power switching devices is hampered by the technology immaturity and, in particular, absence of a safe and reliable enhancement mode (or normally-off) transistor concept combining high positive and adjustable threshold voltage and high output current. As recently proposed by us, all these issues can be addressed by the integration of a metal-oxide-semiconductor (MOS) gate structure with sufficiently high density (~10^{13} cm^{-2}) of negative fixed charge placed close to the oxide/heterostructure interface.

As a member of 7th FP program HipoSwitch, we have developed a novel normally-off transistor based on AlGaN/GaN heterostructure. These devices are intended for integration in the new high-efficiency power converters for power supplies in industrial applications such as telecom base stations. Our technology features the adjustment of the oxide/heterostructure interface charge and thus threshold voltage using plasma-assisted oxidation of the semiconductor surface followed by the oxide deposition using atomic layer deposition technique. In this way, transistors with threshold voltage of 1.6 V and current density of 0.5 A/mm have been achieved. Also, the analysis of the breakdown mechanism in the OFF-state pointed to avalanche effect and related degradation of the device interfaces. Besides publishing the results in the scientific journals, the industrial design was provided to the partners.



Schematic cross-section of the gate structure in our normally-off GaN MOS-HEMT.

Further reading:

D. Gregušová, et al.: Adjustment of threshold voltage in AlN/AlGaN/GaN high-electron mobility transistors by plasma oxidation and Al_2O_3 atomic layer deposition overgrowth. Applied Phys. Lett. 104 (2014) 013506.

J. Kuzmík, et al.: Degradation of AlGaN/GaN high-electron mobility transistors in the current-controlled off-state breakdown. J. Applied Phys. 115 (2014) 164504.

M. Ťapajna et al.: A comprehensive analytical model for threshold voltage calculation in GaN based metal-oxide-semiconductor high-electron-mobility transistors. Applied Phys. Lett. 100 (2012) 113509.