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2003

Development of a gallium-nitride HEMT for W-CDMA base stations (Fujitsu)

~ Discrete Semiconductor/Others ~

GaN crystal has a high potential as a high frequency high output device by its characteristics of a large band gap, high melting point, high physical strength, high dielectric breakdown voltage, high thermal conductivity, high saturation speed of electrons, and low dielectric constant. Since the success of InGaN/GaN blue LED in 1993, the GaN based crystal technology made great progress, and the development of GaN based high frequency power devices also became accelerated.
GaN has lower electron mobility in bulk than Si and GaAs, but in AlGaN / GaN HEMT structure, two-dimensional electron gas channel is generated and electron mobility is high. In addition, due to the effect of piezoelectric polarization and spontaneous polarization generated between AlGaN and GaN, a two-dimensional gas concentration which is ten times higher than that of GaAs HEMT can be obtained. For this reason, GaN HEMT was most actively developed.

Major problem in the development of GaN HEMT was a phenomenon in which the gate withstand voltage was lower than the theoretical prediction, the gate leakage current was large, and the output current was reduced by the trapping of traveling electrons inside the element (current collapse). Kikkawa et al. of Fujitsu proposed a surface charge control structure HEMT in 2001, introducing a GaN layer doped with n-type impurities on the surface portion of the HEMT structure. Since Al, which is easily oxidized, does not exist on the semiconductor surface, generation of surface traps can be prevented. The trap in the GaN layer was also controlled by the crystal growth method to suppress the current collapse phenomenon, and they succeeded in the development of the GaN HEMT with output of 170W at 2.2GHz in 2004. A 250W W-CDMA signal was obtained with a push-pull type amplifier using the two chips in parallel.

The development of GaN HEMT towards higher frequency and higher power output continues vigorously both in Japan and abroad.
In March 2010, Mitsubishi Electric began sample shipment of C-band (3.7~4.2GHz) GaN HEMT high power amplifier (output power 100W) for satellite installation. There are many reports on the devices from X band to millimeter wave band from domestic and overseas, and expectation for this device is great.
Since the breakdown field strength of GaN is about ten times that of Si, high withstand voltage can be secured even if the thickness of the drift layer is thin and the doping concentration is made high. Therefore, there is a possibility that ultra-low ON-resistance switching devices can be realized. Enhancement type HEMT is important for power supply circuits. Mizutani et al. of Nagoya University

developed HEMT equipped with InGaN cap layer on AlGaN layer, and Kanamura et al. of Fujitsu developed MIS structure HEMT. International Rectifier released an enhancement type GaN HEMT DC-DC converter in February 2010.

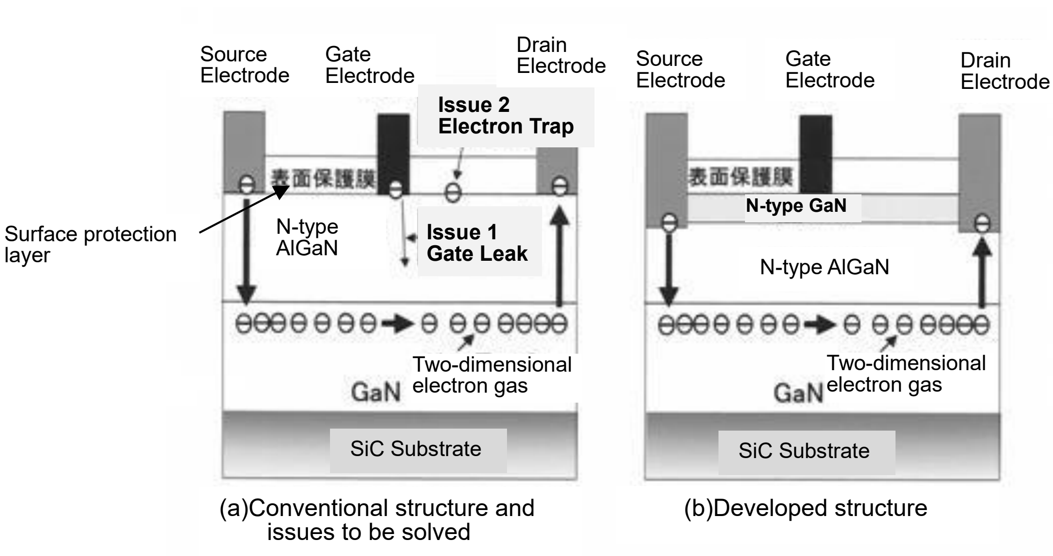

Fig. 1 HEMT with surface charge control structure introduced

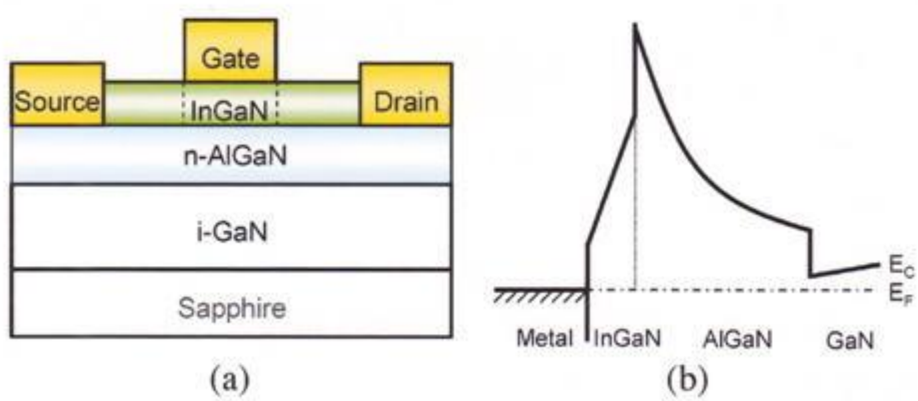

Fig. 2 Enhancement type HEMT with InGaN cap layer introduced [2]

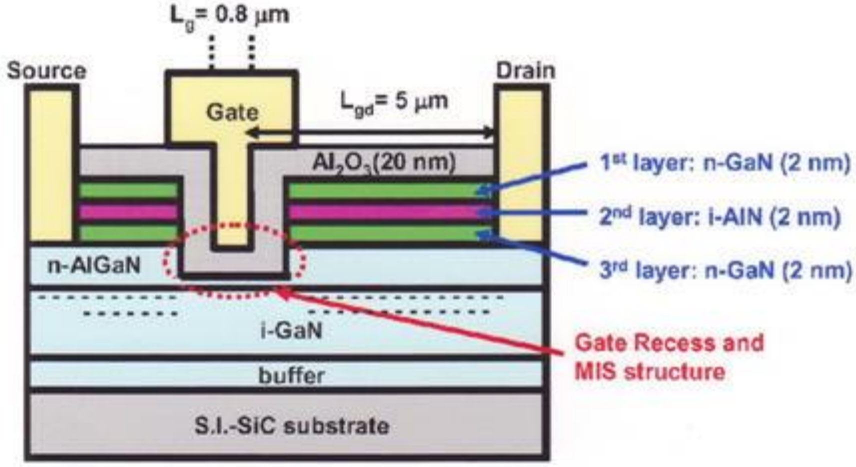

Fig.3 Enhancement type HEMT using High-K gate dielectric film [3]

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[2] T. Mizutani, M. Ito, S. Kishimoto, & F. Nakamura, "AlGaN/GaN HEMTs with thin InGaN cap layer for normally off operation", IEEE Electron Device Letters, Vol. 28, No. 7, pp. 549-551, (July 2007)

[3] M. Kanamura, T. Ohki, T. Kikkawa, K, Imanishi, T. Imada, A. Yamada, & N. Hara, "Enhancement-mode GaN MIS-HEMTs with n-GaN/ i-AlN/ n-GaN triple cap layer and high-κ gate dielectrics", IEEE Electron Device Letters, Vol. 31, No. 3, pp. 189-191, (March 2010)

[4] International Rectifier New Product Release Info. (Feb. 23, 2010) http://www.irf.com/press-room/press-releases/nr100223

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