High quality graphene/AlGaN/GaN diodes as key building-blocks for high frequency vertical transistors

F. Giannazzo[1]*, G. Greco[1], E. Schilirò[1], R. Lo Nigro[1], I. Deretzis[1], A. La Magna[1], F. Roccaforte[1], F. Iucolano[2], S. Ravesi[2], P. Prystawko[3], P. Kruszewski[3], M. Leszczyński[3], E. Frayssinet[4], A. Michon[4], Y. Cordier[4]

[1] *CNR-IMM, Strada VIII, 5, Zona Industriale, 95121 Catania, Italy*
[2] *STMicroelectronics, Stradale Primosole 50, 95121 Catania, Italy*
[3] *TopGaN, Prymasa TysiÄclecia 98 01-424 Warsaw, Poland*
[4] *CNRS-CRHEA, Rue Bernard Gregory, 06560 Valbonne, France*

Contact@E-mail: filippo.giannazzo@imm.cnr.it

Vertical hot electrons transistors (HETs), relying on the ballistic transit of hot carriers through a monolayer graphene (Gr) base, are potentially able to operate at very high frequencies, in the THz range [1,2]. However, proper choice of the emitter-base and base-collector barrier materials is necessary to achieve the theoretical device performances. The emitter structure is especially important for an efficient injection of hot electrons in the Gr base, which is required for practical applications of HETs. Recently, epitaxial $Al_xGa_{1-x}N$ layers (x=0.2 – 1) on GaN proved to be excellent emitter-base barriers for Gr base HETs [3-5]. Furthermore the high density (10^{13} cm^{-2}) 2DEG present at the AlGaN/GaN interface works as a very efficient hot electrons emitter.

In this work, we focus on the fabrication, structural and electrical characterization, and simulation of Gr junctions with MOCVD grown AlGaN barrier layers of different thickness (from ~5 nm to ~20 nm) and Al content (from ~65% to ~20%) on GaN wafers.

A high n-type doping (~10^{13} cm^{-2}) of Gr in contact with AlGaN was evaluated from Raman spectroscopy and electrical measurements on top-gated FET structures. This doping was ascribed to a Fermi level pinning effect from AlGaN surface states, as confirmed also by DFT calculations of the energy band-structure for this heterojunction.

Current-voltage characterization of the Gr/AlGaN/GaN diodes at variable temperature indicated different current injection mechanisms from the emitter to the base, depending on the AlGaN barrier thickness and Al content, i.e. thermionic emission above the barrier or Fowler-Nordheim tunnelling through the triangular barrier (see schematic in Fig.1a and b). Finally, a Gr HET demonstrator with very promising performances in terms of on-state current and ON/OFF current ratio was fabricated using a thin Al_2O_3 films deposited on Gr by atomic layer deposition as a base-collector barrier.

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References

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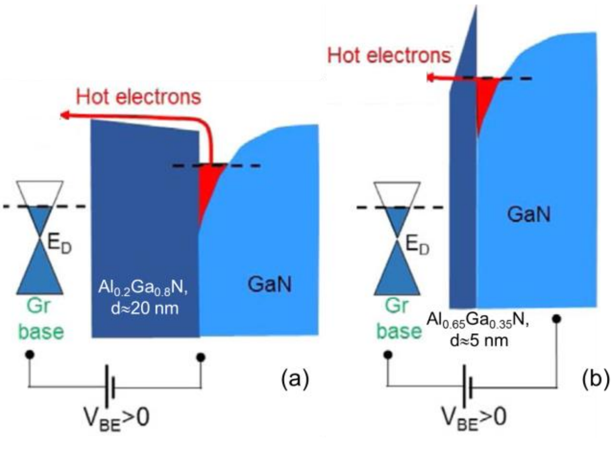

Figure 1: Illustration of hot electrons injection mechanisms through graphene/AlGaN/GaN heterojunctions with different AlGaN thickness and Al content.