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P81 - Self-consistent depth profiling of GaN-based high electron mobility transistors

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High energy (MeV) ion microbeams provide unique capabilities to carry out both in-depth and lateral analysis of electronic devices and circuits [1]. However, these studies are scarce because the complex architecture of the devices (including several heterostructures) and their reduced dimensions preclude a reliable characterization in many cases. A self-consistent way to analyse these heterostructures consist in the simultaneous fitting of RBS and PIXE spectra, the so-called total-IBA approach [2], where the mass-depth ambiguity can be reduced and the sensitivity to both light/heavy elements increased. In this work we address the characterization as-processed AlGaN/GaN high electron mobility transistors (HEMTs) under such methodology. HEMTs are key pieces for the implementation of amplifiers working in the microwave range and, therefore, for the development of faster and more extended telecommunications.

RBS and PIXE experiments were carried out in the nuclear microprobe at Lisbon. In order to have an accurate analysis of the layers, the experiments were performed with 2 MeV He+ and 2 MeV H+ beams in consecutive runs. This procedure ensures a good depth resolution of the shallow layers (with He+ ions) but also a direct quantification of the atomic content of the heavy metals forming the contacts (due to the well-separated signals with H+ in the RBS spectra). In addition, the use of He+ and H+ warrants a high sensitivity to low and high energy X-ray lines in PIXE.

The individual parts of the device (wafer, source/drain, and gate) were analyzed and fitted self-consistently with NDF software [2]. The concentration and thickness of the active AlGaN layer was determined in isolated regions of the wafer. The depth-profile of the in-diffused Au/Ni/Al/Ti ohmic contact was extracted in the source/drain, including the detection of the Si3N4 passivant layer. Finally, the thickness of the Schottky Au/Ni gate contact was also quantified. The elemental RBS mapping of shallow Au and N signals at the gate was used to prove the lack of a passivant layer and, taking advantage of the well-separated Au and N energy windows, the 1µm-width gate could be resolved laterally from the near source and drain contacts. The results show that a complete (lateral and in-depth) characterization of such processed devices can be done by IBA and, consequently, be used as a quality control.

[1] Jamieson et al., NIM B 158, (1999) 628. [2] Jeynes et al., NIM B 271, (2012) 107.

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