Microstructural and Electrical Analyses of Oxygen Diffusion into Iridium Metal Gates

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Iridium is used as gate metal for GaN-based $In_{0,17}Al_{0,83}N$/AlN barrier High Electron Mobility Transistors (HEMTs) 0. Before annealing, a high oxygen concentration confined at the Ir/InAlN interface is detected, but neither an aluminum nor an indium oxide interfacial layer has been formed. In this work we investigate the annealing-induced diffusion of the oxygen-rich interlayer and its electrical effects on the device. No stable iridium oxide forms – instead oxygen is able to diffuse out of the interlayer into the iridium gate metal, thus the interlayer is reduced. Above 700 °C a homogeneous oxygen concentration is observed in the iridium layer, whereas at 500 °C oxygen is distributed inhomogeneously. This behavior is also verified electrically.

The diffusion length of oxygen in evaporated iridium is only in the order of 1 nm for 2 minutes annealing at 500 °C 0. Therefore, oxygen cannot diffuse efficiently in dense iridium at that temperature, so that oxygen diffusion, enhanced by crystal defects and grain boundaries, is assumed. Annealing at 700 °C increases the diffusion length to about 100 nm 0 and allows homogenous diffusion of oxygen into iridium, leading to the most complete removal of the oxygen interlayer, as seen from the C-V-measurements. Additionally, the analysis of the microstructure proves that the thickness of the InAlN/AlN barrier does not change after annealing and metal does not diffuse into the barrier. That confirms the already proven robustness of InAlN.

The rapid thermal annealing was performed for 2 minutes at 400 °C, 500 °C and 700 °C. Two samples with different gate metals (iridium and nickel) are analyzed in order to investigate the dependence on the metal. High-Resolution Transmission Electron Microscopy (HRTEM) gives detailed analysis of the microstructure at the different interfaces. Electron Energy Loss Spectroscopy (EELS) shows the two-dimensional element distribution in the samples. I-V- and C-V-measurements are used to determine the electrical properties.

References

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