CF_4 plasma treatment toward GaN transistor applications

R. M. Chu, C. Suh, M. H. Wong, E. Snow, N. Fichtenbaum, D. Brown, L. McCarthy, S. Keller, F. Wu, J. Speck, and U. K. Mishra

Department of ECE, University of California, Santa Barbra, CA 93106
Department of Materials, University of California, Santa Barbra, CA 93106

CF_4 plasma treatment was found to play a unique role in electrical behaviors of GaN transistors. CF_4 plasma treatment has been demonstrated to shift the threshold voltage of AlGaN/GaN HEMTs (high electron mobility transistors) towards positive bias thus enabling enhancement-mode AlGaN/GaN HEMTs. Additionally, It was also reported that exposure of AlGaN/GaN HEMTs to CF_4 plasma prior to gate metallization could significantly suppress gate leakage. In this paper, we present a study on mechanisms behind the CF_4 plasma treatment of GaN transistors.

Firstly, we investigated etching effect of CF_4 plasma on GaN. It was found that CF_4 plasma etches GaN at slow rate and yields a smooth etched surface. Then GaN MESFETs were employed to study how the CF_4 plasma induces depletion of mobile electrons. Results show that after CF_4 plasma treatment, decrease of electron concentration appears in the near surface region. This suggests CF_4 plasma may introduce acceptors or acceptor-type defects into GaN. Finally, mechanisms of gate leakage reduction were analyzed. It was found that for AlGaN/GaN HEMTs, CF_4 plasma instantaneously reduces the gate leakage current by about 2 orders of magnitude. A more surprising feature is that additional gate leakage caused by Cl_2-based gate-recess etching can be completely removed by CF_4 plasma. TEM and Z-constrast STEM observation suggests the formation of a thin F-containing surface layer on GaN after CF_4 plasma treatment. This surface layer might be correlated with the effective suppression of gate leakage current. Cl_2-based etching combined with CF_4 plasma treatment shows great promise in gate-recessed AlGaN/GaN HEMTs technology.