Extended defects and electrical properties in MOVPE-grown GaN

M. E. Twigg, A. E. Wickenden, D. D. Koleske, R. L. Henry, M. Fatemi, J. C. Culbertson, J. A. Freitas, Jr., and S. Binari
Naval Research Laboratory
Electronics Science and Technology Division
Washington DC 20375

Due to the absence of homoepitaxial substrates, GaN films must be grown heteroepitaxially, usually on sapphire or SiC substrates. Differences in bonding and crystal structure, however, result in large densities of extended defects in heteroepitaxial GaN. Several research groups have shown how to reduce the density of extended defects in GaN, especially for GaN grown on sapphire, which is the most abundant substrate. By increasing the reactor pressure and reducing the MOVPE deposition rate, grain nucleation is retarded, resulting in larger GaN grains. Grain size may also be increased by reducing the alkyl flow. We have found that larger grain size results in a lower dislocation density and that the grain size must be significantly larger than 1~micron to insure a dislocation density in the low 10^{9}/cm^{2} range and carrier mobilites greater than 400~cm^{2}/Vs.

An additional difficulty in MOVPE growth of GaN is the need for a two-step growth process in which GaN growth is preceded by the growth of an AlN nucleation layer (NL). For growth on sapphire, a 10~nm NL is deposited at a significantly lower temperature (600-800^{o}C) than the GaN layer (1000-1100^{o}C). For growth on SiC, a 100 nm NL is grown at a temperature similar to that of the GaN layer. For the NL growth on sapphire, the AlN NL structure strongly influences the conductivity of the subsequent GaN growth. XTEM observations indicate that the NLs for more conductive (1~ohm-cm) films are smaller-grained (2~nm), whereas the NLs for more highly resistive (1^{10}~ohm-cm) films are larger-grained (10~nm). For the case of sapphire substrates, oxygen, which can act as a shallow donor in GaN, may diffuse into the AlN NL and find its way into the HT GaN film. The implication is that larger grain size in the NL corresponds to a smaller density of threading dislocations and grain boundaries. Extended defects such as these are known to serve as paths for enhanced diffusion. Our approach is therefore to choose growth conditions which enhance NL grain size and thereby maintain the highly resistive GaN layers that are needed for power device and optical detector applications.