NOVEL SYMMETRY IN THE HETEROEPITAXIAL GROWTH OF GALLIUM NITRIDE ON MAGNESIUM ALUMINATE SUBSTRATES

T. George, W. T. Pike and P. Chang-Chien
Center for Space Microelectronics Technology, Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena, CA 91109, USA.

M. A. Khan and J. W. Yang
APA Optics inc., 2950 N. E. 84th Lane, Blaine, MN 55449, USA.

Recently, the group-Hi nitrides, especially GaN, have attracted considerable interest due to their wide, direct band-gaps, allowing the potential fabrication of blue-ultraviolet optoelectronic devices from these materials. GaN is typically grown epitaxially on basal-plane sapphire substrates. In this orientation, the lattice mismatch is about 14%. The high concentration of crystalline defects observed in epitaxial GaN layers grown on sapphire can be attributed to this mismatch. Therefore a critical area of investigation is the growth on more closely lattice-matched substrates.

The present study deals with the growth of GaN by metalorganic-chemical-vapor deposition on (11 1) and (100)-oriented magnesium aluminate ($MgAl_2O_4$) substrates with a lattice mismatch of about 10%. Normally on other cubic materials (e.g. GaAs, Si), from symmetry constraints the wurtzite phase of GaN is grown on (11 1), and the zincblende phase on (100) substrate orientations, However, the present transmission-electron-microscopy study shows the GaN to be wurtzite in nature for both substrate orientations, On the (11 1)-oriented substrate the epitaxial relationship is the following: $(0001)_{GaN} \parallel (1\,11)_{MgAl_2O_4}$ and $[11\bar{2}0]_{GaN} \parallel [1\bar{1}0]_{MgAl_2O_4}$. On the (100)-oriented substrate, although the wurtzite phase of GaN is formed, growth is on the ($\bar{1}011$) plane, with the growth direction being between [$\bar{2}021$] and $[\bar{3}032]$. Thus the epitaxial relationship for this orientation is $(\bar{1}011)_{GaN}$ II $(100)_{MgAl_2O_4}$ and the $[11\bar{2}0]_{GaN}$ nearly parallel to $[01\ 1]_{MgAl_2O_4}$. This choice of growth orientation has nearly four-fold symmetry making it compatible with the symmetry of the [100]-axis of $MgAl_2O_4$. Four rotation domains are hence possible for the nitride, although we observe only two such perpendicular domains. We attribute this reduced number to a possible low-angle miscut in the substrate. For both substrate orientations, the GaN epitaxial layers exhibit good crystallinity comparable to state-of-the-art GaN/sapphire growth. The dependence of the orientation relationship and the formation of crystalline defects on interracial bonding for this novel growth orientation is discussed.