Growth of III-Nitrides by MBE

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This talk addresses the heteroepitaxial and homoepitaxial growth of GaN and its alloys with AlN by molecular beam epitaxy (MBE). Plasma-assisted MBE, which involves the activation of molecular nitrogen in a RF or in an ECR-assisted microwave plasma source, as well gas source MBE, in which active nitrogen is produced by catalytic decomposition of ammonia at the surface of the substrate, will be discussed. The kinetics of growth in these two methods of nitrogen activation was found to be different. In the plasma method smooth films are produced under group-III rich conditions of growth, while during growth with ammonia smooth films are obtained under nitrogen rich conditions of growth.

The growth of GaN films along polar and non-polar directions was investigated. Films with the Ga-polarity and N-polarity were grown on (0001) sapphire substrates, coated first with a high temperature AlN-buffer or a low temperature GaN-buffer respectively. The growth of GaN along a non-polar direction was investigated by depositing the films on the R-plane (1-102) of sapphire. In this plane GaN grows with the A-plane (11-20) parallel to the substrate and thus the c-axis of GaN is in the plane of growth. We find that the growth mode in the polar and non-polar directions is different. Specifically, films grown in the non-polar direction have significantly higher domain sizes, suggesting that GaN growth in this direction leads to better wetting and thus 2D-growth. We theorize that the difference in the growth mode along polar and non-polar directions is the result of the dipolar nature of the GaN molecule.

Homoepitaxial growth of GaN was investigated by studying the deposition by MBE of such films on 4-5 micron thick GaN templates, grown by the hydride vapor phase epitaxy (HVPE) method. Atomic force microscopy (AFM) images of these relatively thin HVPE GaN templates are indicative of step flow growth with step height of one monolayer and terraces about 200nm wide. These GaN HVPE films are unintentionally n-type doped with room temperature carrier concentration $2\mathrm{x}10^{17}$ cm^{-3} and electron mobility of 700 cm^2/V.s. Homoepitaxial growth by MBE on these GaN templates indicates that the epitaxial GaN film replicates the underlined HVPE film.

AlGaN films were grown using the plasma-assisted MBE method. It was found that the composition of the films is not uniquely defined by the ratio of Al/Ga flux in the gas phase, but it also depends on the total Al+Ga flux. Specifically, we find that the sticking coefficient of Ga varies from about one to almost zero as the total flux varies from nitrogen to group-III rich conditions of growth. AlGaN alloys grown by this method were found to spontaneously undergo superlattice ordering along the [0001] direction, which is also the direction of growth. Films grown under nitrogen rich conditions have a superlattice structure with two-monolayer periodicity, while those grown under group-III rich conditions have a superlattice structure with twelve- and fourteen-monolayer periodicities. The degree of long-range order was found to depend on the polarity of the films and it is stronger for films having the N-polarity.

The optical and electronic properties of the GaN, AlN and AlGaN films as well as the application of these materials for the fabrication of high reflectivity Distributed Bragg Reflectors (DBRs) to be used in resonant cavity UV-emitters will be discussed.