In situ microbeam surface X-ray scattering reveals alternating step kinetics during OMVPE of GaN

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The kinetics of atomic incorporation at steps on vicinal surfaces is a fundamental science topic of broad practical importance in the growth of epitaxial films. The stacking sequence of hexagonal close-packed and related crystals such as GaN typically results in steps on vicinal {0001} surfaces that have alternating A and B structures with different growth kinetics [1]. However, because it has been difficult to experimentally identify which step has the A or B structure, until recently it had not been possible to determine which has faster adatom attachment kinetics. Furthermore, it has been proposed that the incorporation of an alloying element such as indium is strongly influenced by the kinetics of attachment at atomic-scale steps on GaN surfaces. Better control of indium incorporation would improve the efficiency of devices such as monolithic white LEDs, including micro-LEDs and mini-LEDs, since the $Ga_{1-x}In_xN$ active material is typically grown on the GaN (0001) surface and the indium fraction x controls the emission wavelength. However, the internal quantum efficiency (IQE) is currently lower for higher indium fractions. Theory [2] suggests that composition inhomogeneities contribute to this behavior.

Our recent in-situ studies of GaN homoepitaxy by organo-metallic vapor phase epitaxy (OMVPE) under step-flow conditions have shown that microbeam surface x-ray scattering can unambiguously determine differences in the attachment kinetics at A and B steps [1]. Analysis of the surface scattering [3] combined with an extension [4] of the classic Burton-Cabrera-Frank (BCF) theory allowed us to obtain the first direct information on step attachment rate constants in this system. I will extend this work to address a topic of significant technological impact, the incorporation of indium during $Ga_{1-x}In_xN$ growth by OMVPE. Our experiments will provide fundamental understanding of the influence of surface step morphology on indium fraction inhomogeneities and allow quantitative modeling of the growth process.

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Invited abstract submitted to 20th International Conference on Crystal Growth and Epitaxy (ICCGE-20), Naples, Italy, 30 July - 4 August 2023