T-009

Hybrid MBE Growth of Crack-Free GaN Layers on Si (110) Substrates

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Two main MBE growth techniques have been used: plasma-assisted MBE (PA-MBE), which utilizes a rf plasma to supply active nitrogen, and ammonia MBE, in which nitrogen is supplied by pyrolysis of NH3 on the sample surface during growth. PA-MBE is typically performed under metal-rich growth conditions, which results in the formation of gallium droplets on the sample surface and a narrow range of conditions for optimal growth. In contrast, high-quality GaN films can be grown by ammonia MBE under an excess nitrogen flux, which in principle should result in improved device uniformity due to the elimination of droplets and wider range of stable growth conditions. A drawback of ammonia MBE, on the other hand, is a serious memory effect of NH3 condensed on the cryo-panels and the vicinity of heaters, which ruins the control of critical growth stages, i.e. the native oxide desorption and the surface reconstruction, and the accurate control of V/III ratio, especially in the initial stage of seed layer growth. In this paper, we demonstrate that the reliable and reproducible growth of GaN on Si (110) substrates is successfully achieved by combining two MBE growth technologies using rf plasma and ammonia and setting a proper growth protocol. Samples were grown in a MBE system equipped with both a nitrogen rf plasma source (SVT) and an ammonia source. The ammonia gas purity was ＞99.9999% and further purified by using a getter filter. The custom-made injector designed to focus the ammonia flux onto the substrate was used for the gas delivery, while aluminum and gallium were provided via conventional effusion cells. The growth sequence to minimize the residual ammonia and subsequent memory effects is the following: (1) Native oxides are desorbed at 750^{o}C (Fig. (a) for [1$\bar{1}$10] and [001] azimuth) (2) 40 nm thick AlN is first grown using nitrogen rf plasma source at 900^{o}C nder the optimized condition to maintain the layer by layer growth of AlN buffer layer and slightly Al-rich condition. (Fig. (b)) (3) After switching to ammonia source, GaN growth is initiated with different V/III ratio and temperature conditions. A streaky RHEED pattern with an appearance of a weak (2×2) reconstruction characteristic of Ga-polarity is observed all along the growth of subsequent GaN layer under optimized conditions. (Fig. (c)) The structural properties as well as dislocation densities as a function of growth conditions have been investigated using symmetrical and asymmetrical x-ray rocking curves. The electrical characteristics as a function of buffer and GaN layer growth conditions as well as the growth sequence will be also discussed. Figure: (a) RHEED pattern after oxide desorption (b) after 40 nm thick AlN growth using nitrogen rf plasma source and (c) after 600 nm thick GaN growth using ammonia source for (upper) [110] and (lower) [001] azimuth.

Keywords: GaN, Si (110), Plasma-assisted MBE, Ammonia MBE

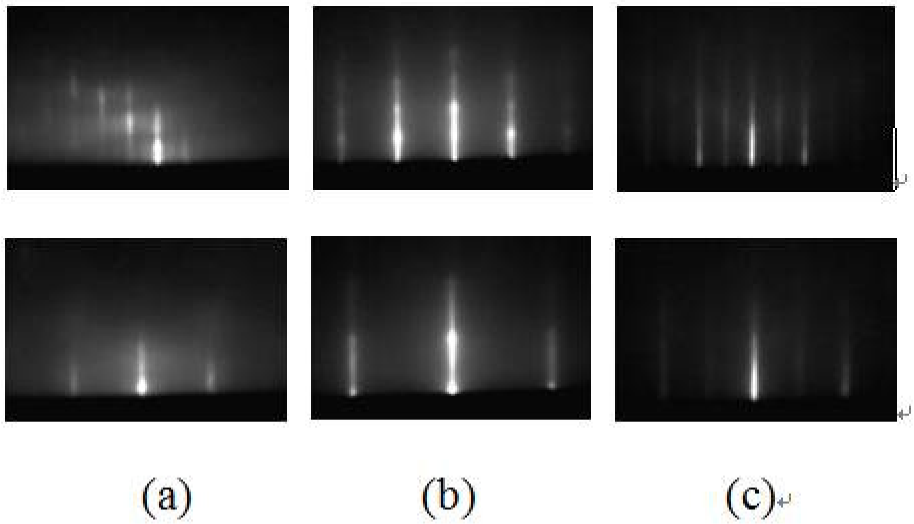

Fig. 1.