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Investigation of N-Polar AlGaN/GaN and InAlN/GaN Thin Films Grown by MBE

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Due to the steadily increasing demands of wireless communication, more robust and reliable materials are needed. High-electron-mobility transistors (HEMTs), which are a special type of heterostructure field-effect transistor (HFET), are being targeted to address this need for improved high power and high frequency devices [1]. In particular GaN/AlGaN HEMTs are outpacing the GaAs/AlGaAs HEMT competition due to the capacity of these devices to operate at higher temperature with much higher power densities [2]. An additional improvement of these devices comes from the replacement of AlGaN layers with InAlN, since InAlN can potentially increase the sheet charge density by more than a factor of two. Although InAlN offers the possibility of lattice-matching with GaN substrates, growth conditions require careful optimization because of the likelihood of lateral compositional inhomogeneity [3]. Thus, structural changes due to variations of plasma assisted molecular beam epitaxy (PAMBE) growth parameters of GaN/AlGaN and InAlN/GaN layers on N-Polar GaN were investigated. An FEI Nova 200 dual-beam FIB was used to prepare *in situ* <11$\underline{2}$0> and <1$\underline{1}$00> XTEM samples which were studied with a Phillips-FEI CM 200-FEG and a JEM-4000EX.

Figure 1 shows two PAMBE-grown GaN layers on an N-polar HVPE GaN substrate each with a 15-Å-thick AlN nucleation layer, one that was not heat-treated (a), and one that was heat-treated (b). A high density of threading dislocations initiated at the interface and extending to the surface is apparent in the field of view in Fig. 1(a), compared to the accompanying micrograph in Fig. 1 (b), which shows no visible defects. Further experiments revealed that 3 or more heat cycles of Ga deposition at ~730 ^{o}C and Ga desorption at ~815 ^{o}C provided the best quality material with minimal defects. The effect of temperature on InAlN growth by PAMBE is demonstrated in Figure 2. Contrast striations consistent with the development of lateral In inhomogeneity during growth are clearly visible in Fig. 2 (a), corresponding to the InAlN layer grown at low temperature (500 ^{o}C), while much improved materials quality is apparent in Fig. 2 (b), which corresponds to the layer grown at high temperature.

References:

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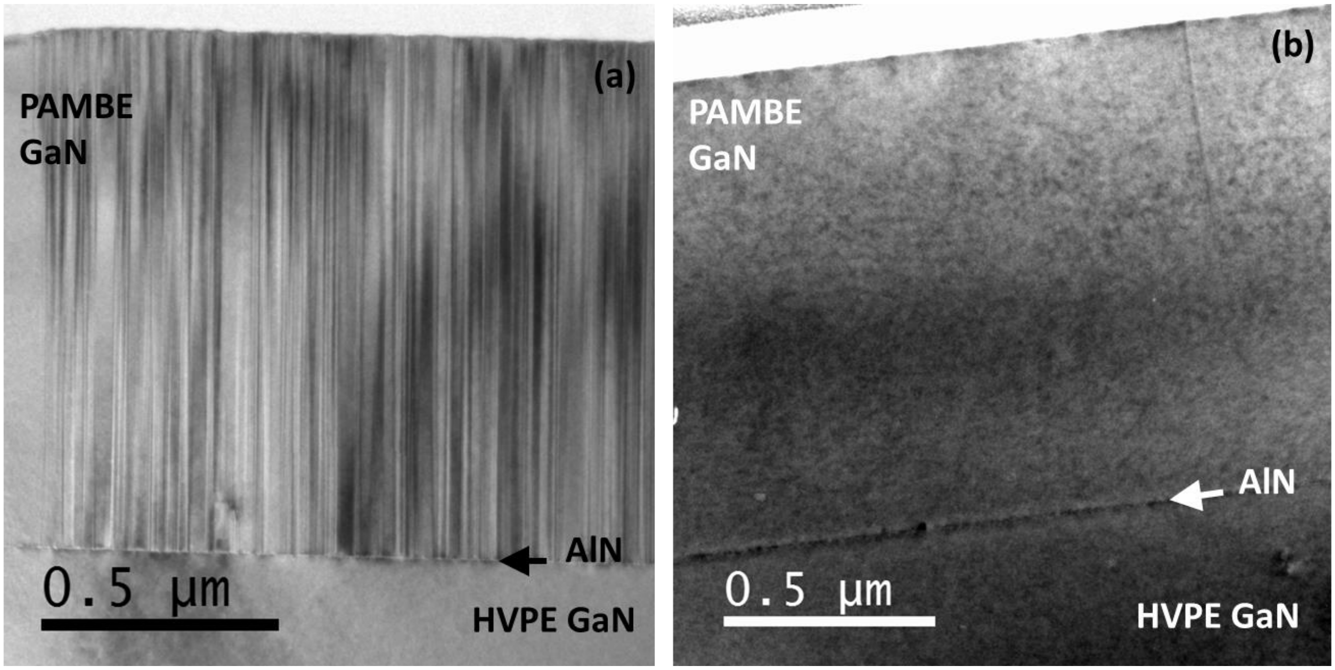

Figure 1. PAMBE-prepared samples of N-polar GaN with 15-Å-thick AlN nucleation layer and no heat treatment (a), and with 3 cycles of Ga deposition and desorption (b). Note the high density of threading defects in the PAMBE GaN layer in the left image.

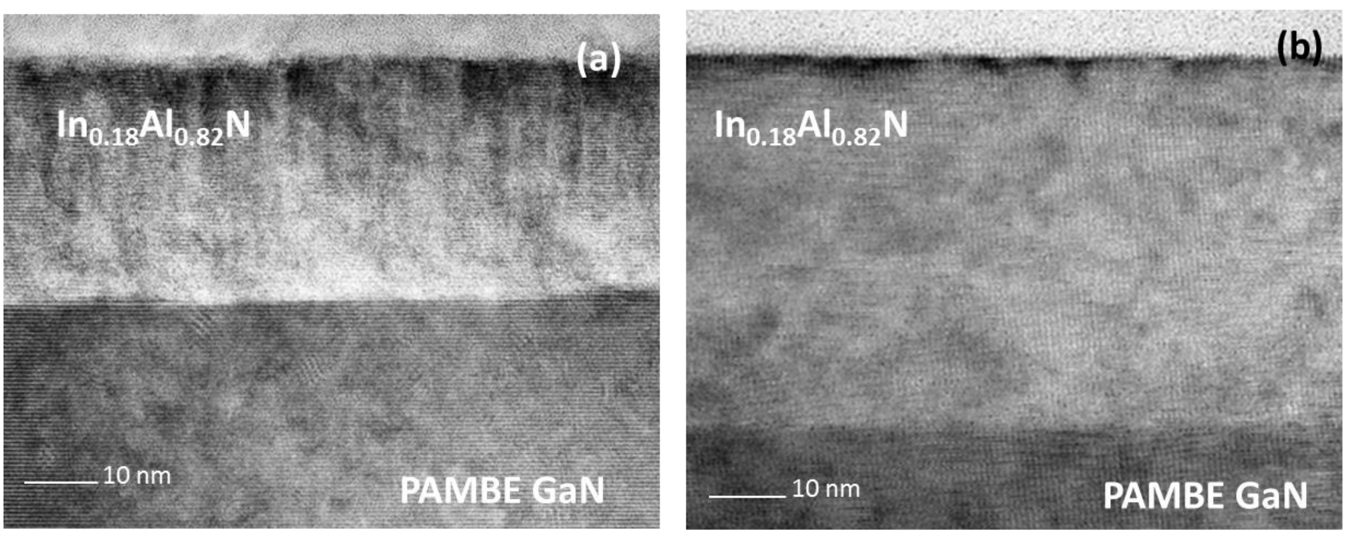

Figure 2. Cross-sectional TEM micrographs of N-polar InAlN thin films grown at (a) low temperature (500 °C), and (b) high temperature (650 °C). The sample grown at low temperature shows vertical stripes of dark-light contrast consistent with lateral inhomogeneity, whereas the other sample (b) has much better contrast uniformity and no visible threading defects in the field of view.