Orientation control of non- and semi-polar GaN using directional AlN sputtering on (10-10) Sapphire

Nan Hu[1], Duc V. Dinh[1], Markus Pristovsek[1], [1]IMaSS, Nagoya University

E-mail: pristovsek@imass.nagoya-u.ac.jp

Directional sputtering has been developed at Nagoya University to realize (10-13) GaN and (10-15) GaN oriented layers on (001) Si substrates, although FWHM in X-ray diffraction (XRD) were rather broad and thickness on Si is quite limited. The proposed mechanism was shadowing during the directional sputtering. The (10-13) GaN orientation has the lowest lattice mismatch to the sapphire surface unit cell for $[0001]_{Al2O3}$ || $[11\text{-}20]_{GaN}$. Hence, we used (10-10) sapphire as a substrate. The sputtering sequence was taken from the Si process: It consists of a short period of Al sputtering with Argon, followed by sputtering of Al with N_2, which results in AlN layers on sapphire. The sputter target was fixed at an angle of about (35±8)°. Just by shadowing, both (10-13) and (10-14) grains will form because of this large angle range. The AlN/sapphire wafers were annealed in metal-organic vapour phase epitaxy under NH_3 at ~1200°C and then overgrown with 10 nm of AlN, followed by 5-50 µm of GaN at 1080°C with a V/III ratio of 12.5.

Without initial Al sputtering, we obtained (10-10) orientation (symmetric GaN XRD FWHM <2000”), for optimized Al times we obtained (10-13) orientation (FWHM <700”), and for longer Al sputter times we obtained (10-14) orientation (FWHM <1500”). Therefore, shadowing is not the only contribution for orientation control with directional sputtering. Instead, the orientation is given by the interface to sapphire. Without initial Al sputtering the AlN just continues the lattice order of the (10-10) substrate, because lateral diffusion is very short on sapphire at ~600°C. However, diffusion is enhanced on an initial Al layer, which results in the (10-13) orientation because it has the lowest lattice mismatch. For much longer Al sputter times (or if the [11-20] of sapphire is not pointing towards the target), the AlN layer will lose its connections to the substrate, and the final orientation is given by the shadowing. Since the growth is fastest along [0001], the less inclined (10-14) orientation will be preferred over (10-13).