Solid-state heteroepitaxy of Si(111) by Aluminum-induced Crystallization

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Silicon heteroepitaxy on substrates such as sapphire typically requires high temperature (≥900°C) chemical vapor deposition[1]. Here, we demonstrate solid-state heteroepitaxy using aluminum-induced crystallization (AIC) at 450°C. AIC has been previously used to fabricate thin (t < 50nm) Si and Ge (111) films with > 95% surface orientations on amorphous substrates. In this regime, Si nucleation has been hypothesized to initiate at the substrate/Al interface[2]. Therefore, using a monocrystalline substrate should allow its crystal lattice to influence nucleation and growth of the silicon film.

AIC-Si films were fabricated by depositing ~30nm of Al onto single crystalline (0001) sapphire, and (0001) GaN substrates. Following a brief air exposure, ~30nm of amorphous silicon was deposited. Subsequent annealing in N_2 at 450°C led to silicon thin film nucleation and growth.

Highly oriented Si (111) films form preferentially on both substrates, even with large lattice mismatches (17% for GaN (0001) vs Si (111), 28% for (0001) sapphire[2]). X-ray rocking curve full-width half-maximua of 0.26° and 0.12° on GaN (0001) and sapphire (0001) respectively are comparable to conventional, high-temperature epitaxial Si films[1]. Cross-section transmission electron microscopy confirms epitaxial relationships between the Si and underlying substrates. Finally, we demonstrate solid-state heteroepitaxy of thicker 90snm Si(111) films on sapphire (0001) with no loss in film quality, well above previously reported[2] thickness limits for preferential <111> orientation on amorphous substrates.

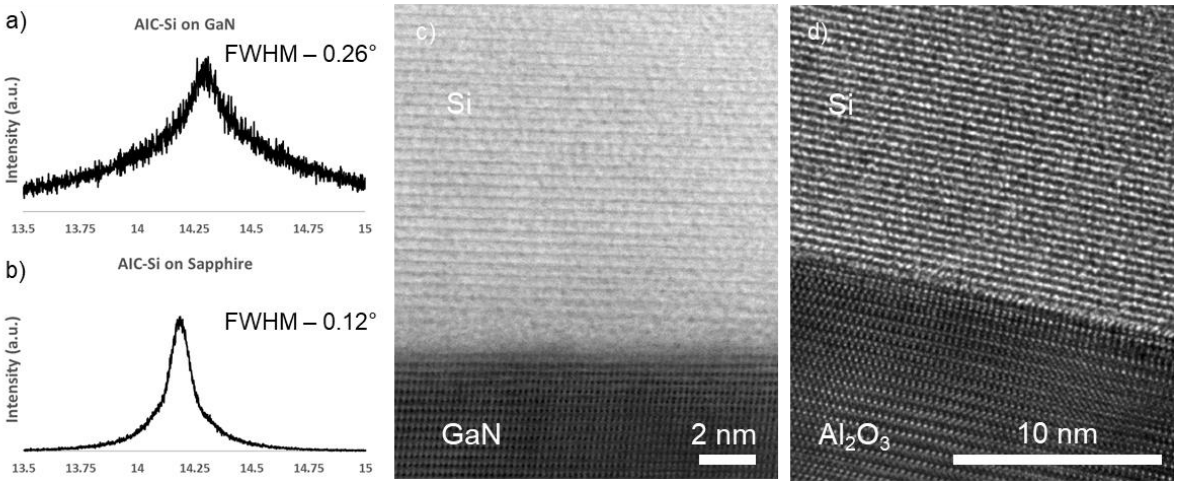

Figure 1 – XRD of AIC-Si films on a) GaN (0001), b) Sapphire (0001). Cross-section TEM of AIC-Si on c) GaN and d) sapphire showing epitaxial relationships between Si and substrate.

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