Core-shell nanowires (NWs) are an ingenious discovery of interfacial nanoengineering that comprises structural characteristics, which cannot be reproduced by any kind of epitaxial growth. This stems from the fact that core-shell NWs tolerate a larger lattice mismatch without interfacial defects than other heterostructures, thus offering a wider area of band-gaps with several potential optoelectronic applications. It is established that wurtzite NWs grown along the polar direction are bounded by the \{10\-10\} m-planes. As a result, core-shell NWs comprise non-polar \{10\-10\} interfaces between the core and the shell.

The structural properties of core-double shell (GaN/AlN/GaN) NWs, grown by plasma-assisted molecular beam epitaxy (PAMBE) on Si(111), were explored by transmission electron microscopy (TEM) methods. GaN NWs were grown on a thin AlN nucleation layer (3 nm) for 3h, with intermediate AlN spacers (10-15 nm thick) deposited at 1h and 2h growth time [Fig. 1(a)]. High-resolution TEM (HRTEM) imaging revealed the core-double shell morphology with an AlN shell of 0.7-1 nm thick, and a GaN shell varying from 1.6 to 2.7 nm [Fig. 1(b)]. Line profiles of HRTEM images along the growth axis showed that this particular configuration imposes the c-lattice constant of the AlN shell to be adapted to the c-lattice constant of the GaN core. Therefore, a full elastic accommodation of the AlN on GaN is established, considering the absence of misfit dislocations (MDs) from the interface.

The strain state of NWs was evaluated by geometrical phase analysis (GPA). A gradual relaxation of the AlN spacers was observed from the GaN/AlN interfaces towards the center of the spacer for the a-lattice parameter as illustrated in Fig. 1(c), without the presence of MDs. The corresponding FFT is shown in Fig. 1(e). The GPA strain map of the AlN spacer/GaN along the growth direction and the corresponding line profile are shown in Figs. 1(d&f). Regarding the AlN shell, the GPA lattice strain along the growth direction was estimated near zero, verifying the HRTEM observations on the full lattice registration. Considering the very small thickness of the shell, the average in-plane lattice constant approximates pseudomorphic growth. This implies that the AlN shell deviates from the biaxial strain state. Moreover, the GaN shell exhibits the relaxed lattice constant values in both in-plane and out-of-plane directions. It seems that the core-shell configuration of the NWs induces strain fields, which may be exploited in band-gap engineering.

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Fig. 1: (a) TEM image illustrating the NWs morphology along with their schematic model. Black arrows denote the AlN spacers (b) HRTEM image depicting the double shell-core configuration (c) In-plane GPA phase image of the AlN/GaN and (e) the corresponding FFT (d)&(f) GPA strain map of the AlN/GaN along the growth direction and the corresponding line profile