Supporting Information

Polarity Control in Growing Highly Ga-doped ZnO Nanowires with Vapor-liquid-solid Process

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Figure S1(a1) shows an a-plane ABF image of Ga-face GaN, in which the blue spots and greenish tails correspond to the positions of the heavier and lighter atoms, i.e., Ga and N atoms, respectively. In the lower two rows of atom, we use black and white circular dots to represent Ga and N atoms, respectively, and to indicate the positions of those atoms. It is noted that the relative sizes of the circular dots represent the atomic weights, instead of ionic sizes. N^{3-} ion is actually larger than Ga^{3+} ion in size. We also line-scan the ABF signal intensity along the dashed arrow shown in Fig. S1(a1) to give the intensity profile in Fig. S1(a2). Here, we can evaluate the distance between the Ga and N atoms (the local minima) to give 0.103 nm. This distance is close to the theoretical Ga-N bond length of 0.109 nm, confirming the GaN structure. This Ga-N bond corresponds to that labeled by the red arrow in the atomic structure of Ga-face GaN shown in Fig. S1(a3). By comparing the ABF image in Fig. S1(a1) and the a-plane atomic structure in Fig. S1(a3), we can assure that this GaN template is Ga-face. Figures S1(b1)-S1(b3) show the results similar to Figs. S1(a1)-S1(a3), respectively, for N-face GaN. Here, a different structure of the opposite polarity can be clearly seen. Figures S1(a1)-S1(a3) and S1(b1)-S1(b3) demonstrate the standard procedures for determining the polarity of a compound structure, including GaZnO NW or thin film.

Figure S2(a1) shows the TEM image of the GaZnO NW sample grown on Ga-face GaN

under the O-rich condition. Here, a thin-film portion grown through the VS process is circled for ABF analysis, as shown in Fig. S2(a2), which indicates Zn polar. Figures S2(b1) and S2(b2) show the results similar to Figs. S2(a1) and S2(a2), respectively, for the GaZnO NW sample grown on N-face GaN under the O-rich condition. Here, one can see that on N-face GaN, the GaZnO thin film is O-polar. Therefore, the polarity of GaZnO thin films grown through the VS process always follows that of the used GaN template. The result is independent of the growth condition (Zn-rich or O-rich).

Figure S3(a) shows a TEM image of the NWs grown on Ga-face GaN under the O-rich condition. The magnified TEM image of the circled portion shown in Fig. S3(a) is shown in Fig. S3(b). The Bragg image along the c-axis corresponding to the TEM image in Fig. S3(b) is demonstrated in Fig. S3(c). Here, one can see quite many planar defects in this area, as exemplified by those within the dashed squares. Figure S3(d) shows the derivative GPA image corresponding to the image in Fig. S3(c). Those high color contrast features correspond to planar defects with five of them circled. Figures S4(a)-S4(d) show the results similar to Figs. S3(a)-S3(d), respectively, for the NWs grown on N-face GaN under the O-rich condition to again show that plenty planar defects exist at the early stage of growing a GaZnO NW.

Figure captions:

Fig. S1 (a1): An ABF image of Ga-face GaN. The Ga and N atoms are marked by black and white dots, respectively, in the lower two rows of atom. (a2): Line-scan ABF signal intensity profile along the dashed arrow shown in part (a1). (a3): Atomic structure of Ga-face GaN with the red arrow indicating the Ga-N bond along the dashed arrow in part (a1). (b1)-(b3): Results similar to parts (a1)-(a3), respectively, for N-face GaN.

Fig. S2 (a1): TEM image of the GaZnO NW sample grown on Ga-face GaN under the O-rich condition. (a2): An ABF image of GaZnO in a circled thin-film portion grown through the VS process. (b1) and (b2): Results similar to parts (a1) and (a2), respectively, for the GaZnO NW sample grown on N-face GaN under the O-rich condition.

Fig. S3 (a): TEM image of the NWs grown on Ga-face GaN under the O-rich condition. (b): Magnified TEM image of the circled portion shown in part (a). (c): Bragg image along the c-axis corresponding to the TEM image in part (b). (d): Derivative GPA image corresponding to the image in part (c). planar defects exist in the circled regions.

Fig. S4 (a)-(d): Results similar to Figs. S3(a)-S3(d), respectively, for the NWs grown on N-face GaN under the O-rich condition.

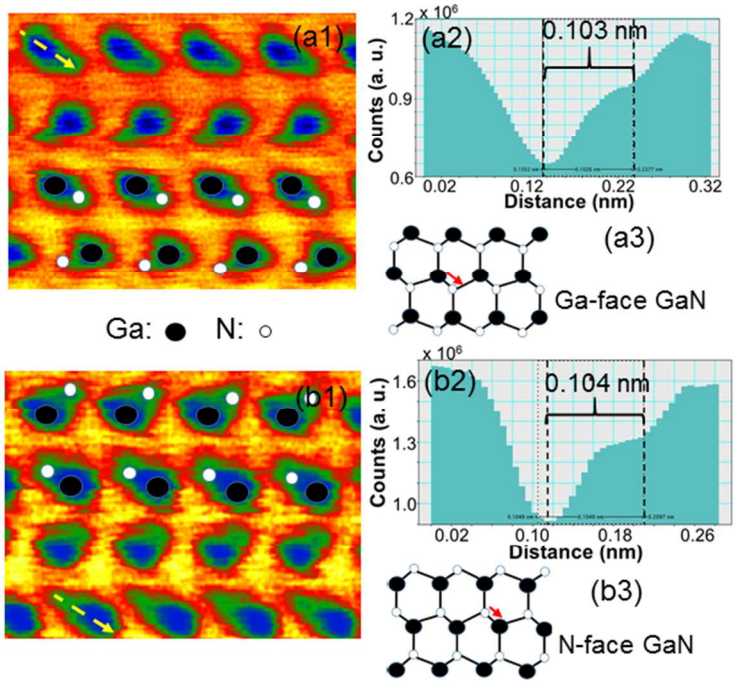

Fig. S1 (a1): An ABF image of Ga-face GaN. The Ga and N atoms are marked by black and white dots, respectively, in the lower two rows of atom. (a2): Line-scan ABF signal intensity profile along the dashed arrow shown in part (a1). (a3): Atomic structure of Ga-face GaN with the red arrow indicating the Ga-N bond along the dashed arrow in part (a1). (b1)-(b3): Results similar to parts (a1)-(a3), respectively, for N-face GaN.

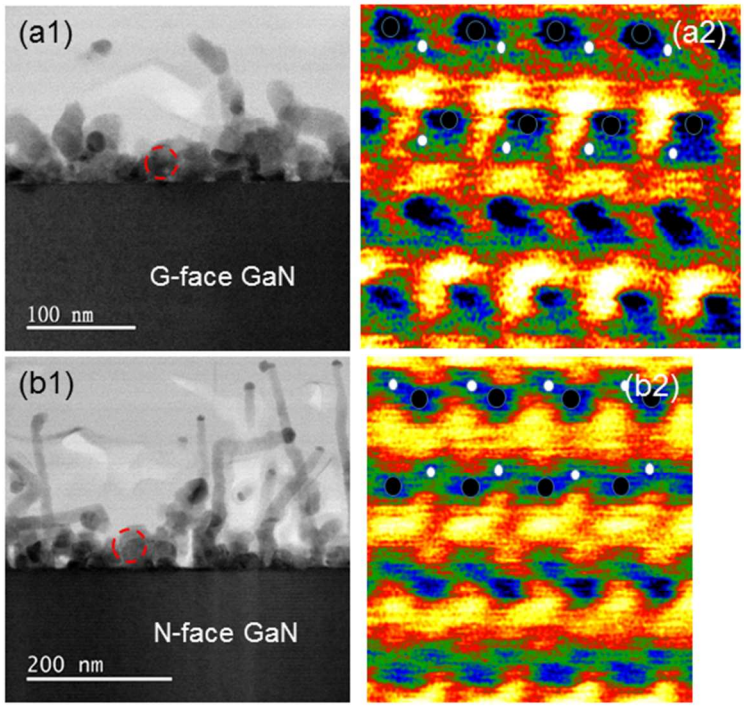

Fig. S2 (a1): TEM image of the GaZnO NW sample grown on Ga-face GaN under the O-rich condition. (a2): An ABF image of GaZnO in a circled thin-film portion grown through the VS process. (b1) and (b2): Results similar to parts (a1) and (a2), respectively, for the GaZnO NW sample grown on N-face GaN under the O-rich condition.

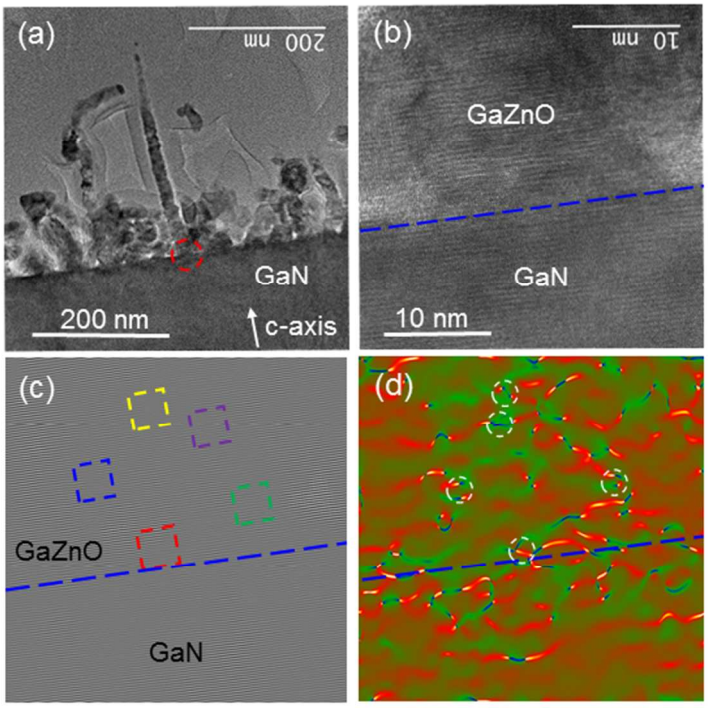

Fig. S3 (a): TEM image of the NWs grown on Ga-face GaN under the O-rich condition. (b): Magnified TEM image of the circled portion shown in part (a). (c): Bragg image along the c-axis corresponding to the TEM image in part (b). (d): Derivative GPA image corresponding to the image in part (c). Planar defects exist in the circled regions.

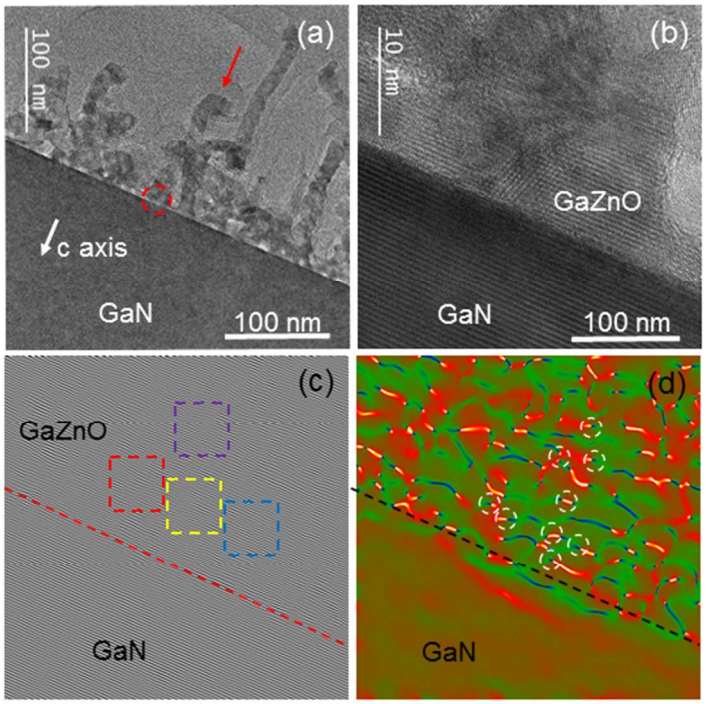

Fig. S4 (a)-(d): Results similar to Figs. S3(a)-S3(d), respectively, for the NWs grown on N-face GaN under the O-rich condition.