Electronic Supplementary Material (ESI) for RSC Advances.

Supporting Information

InGaN/GaN Nanowires Epitaxy on Large-Area MoS_2 for High-Performance Light-Emitters

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1. Sulfurization of Mo substrates at different temperatures

We have studied the effect of sulfurization temperature on the Mo substrates. Fig. S1 shows the optical microscope images of Mo substrates after sulfurization from 800 °C to 1050 °C. The other conditions are the same. Although strong MoS_2 Raman peak could be obtained for all samples, the surface became rough after sulfurization at 800 °C, as shown in Fig. S1(a). The surface of the substrate sulfurized at 900 °C was relatively smoother (see Fig. S1(b)). When sulfurized at 1050 °C, the sample had large-area smooth surface separated by grain boundaries (see Fig. S1(c)), which is necessary for subsequent nanowires growth.

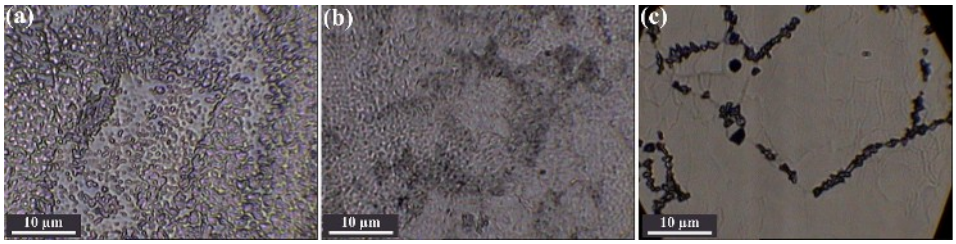

Fig. S1 OM images of the Mo substrate surface after sulfurization at (a) 800 °C; (b) 900 °C; (c) 1050 °C.

2. Growth of GaN on Mo and MoS_2/Mo

We have studied the effect of the MoS_2 buffer layer on the growth of nanowires. The substrate temperature was fixed at 700 °C, the beam equivalent pressure of Ga was 2.5×10^{-8} Torr, the growth lasted 2 hours. Fig. S2(a) and (b) show the plan-view and elevation-view SEM images of the GaN grown on Mo substrates. Without MoS_2 buffer layer, only formation of GaN islands with facets was observed on the surface of Mo substrates. On the contrary, vertical nanowires with a hexagonal shape formed at the same growth conditions when the MoS_2 buffer layer was present as shown in Fig. S2(c) and (d), although the coalescence happened at the grain boundaries (see Fig. S2(c)).

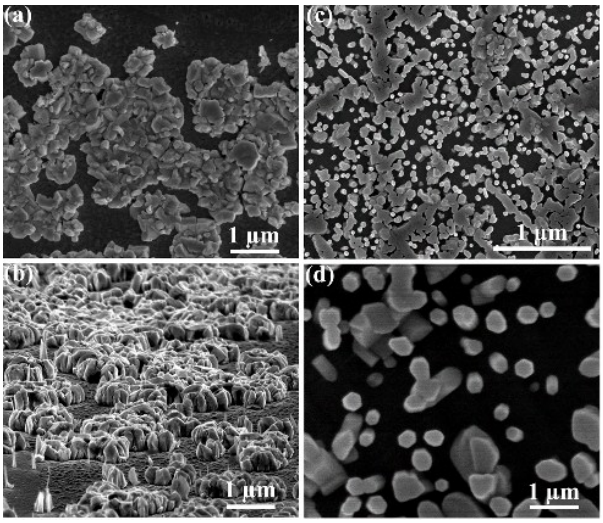

Fig. S2 (a) (b) Plan-view and elevation-view SEM of GaN grown on Mo; (c) plan-view SEM of GaN grown on MoS_2/Mo; (d) high magnification SEM of GaN grown on MoS_2/Mo, which shows the hexagonal shape.

3. Photoluminescence (PL) of the whole p-GaN/MQW/n-GaN/MoS2/Mo structure

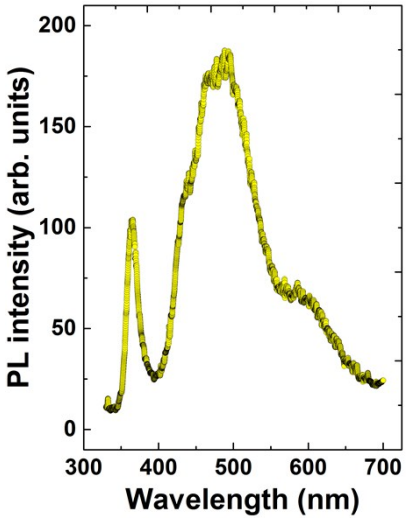

Fig. S3 PL of p-GaN/MQW/n-GaN/MoS2/Mo structure.

4. FIB-TEM of GaN on MoS_2/Mo

We have characterized the interface between nanowires and MoS_2/Mo substrate using FIB-TEM to study the role of the MoS_2 layer in the growth of GaN nanowires. To make the interface clear, we avoided the grain boundary area when preparing the FIB sample, as shown in Fig. S4(a). Fig. S4(b) shows the FIB sample after lift-out and being fixed to the TEM grid. The Mo

grains of Mo substrates, the buffer layer, and vertical nanowires can be clearly seen. Although the sample surface was rough, the single-crystalline nanowires could grow vertically on the buffer layer, as shown in Fig. S4(c). The HR-STEM image of nanowires/substrate interface in Fig. S4(d) shows the nanowires are nearly defect-free; the measured lattice spacing of ~4.2 Å for the buffer layer is in good agreement with the known value of Mo_2N crystal along [100], and the measured lattice spacing of ~5.2 Å parallel to the growth direction of the nanowire is in good agreement with the reported value for wurtzite GaN crystal (c axis).

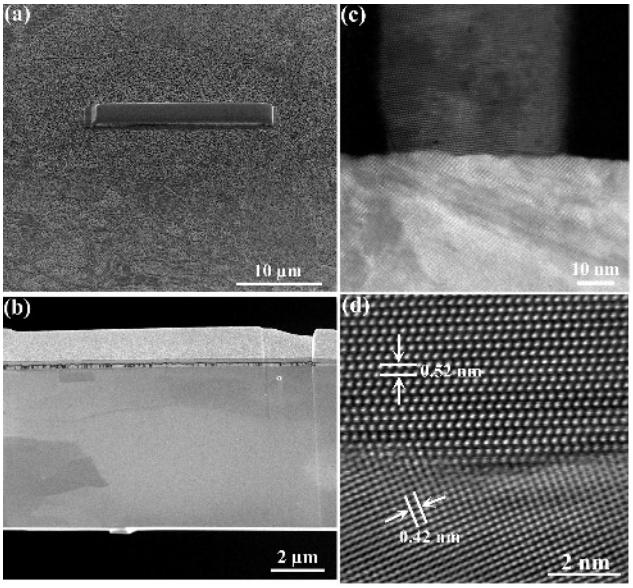

Fig. S4 (a) 52° tilted view SEM images after carbon and Pt deposition; (b) after lift-out and being fixed to the TEM grid; (c) GaN NWs cross-sectional STEM; (d) HR-STEM of nanowires/substrate interface.

5. GaN nanowires epitaxy after etching

We have explored different scenarios of transferring GaN nanowires epitaxy after etching MoS_2. By controlling the etching process, the resulting nanowire membranes can be transferred to arbitrary substrates such as plastic, as shown in Fig. S5(a). The etching can also result in nanowire rolled-up membranes as shown in Fig. S5(b). From SEM images of the gap on nanowire membranes shown in Fig. S5(c) and (d), we can clearly see the bottom of vertical nanowires with a hexagonal shape, indicating the quality of the nanowire epitaxy was maintained during the etching. Thus, it is a useful large-scale exfoliation process for epitaxy layers.

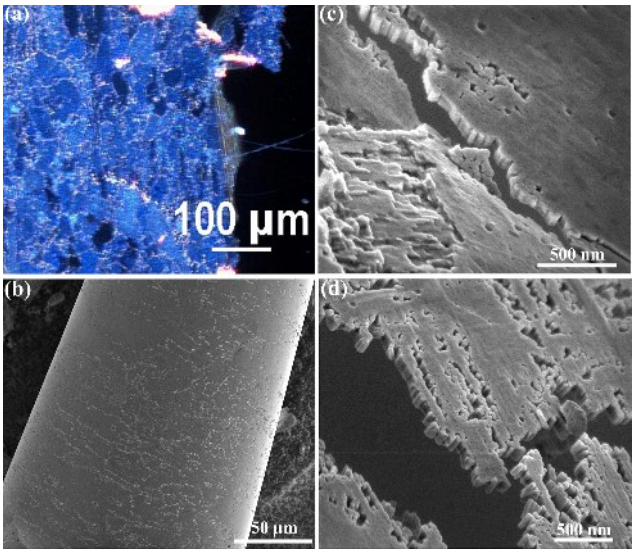

Fig. S5 (a) OM image of nanowire membranes on plastic; SEM images of (b) GaN nanowire rolled-up membranes; (c) GaN nanowires membranes; (d) bottom of the nanowires.