Supplementary material

Threshold voltage mapping at the nanoscale of GaN-based high electron mobility transistor structures using hyperspectral scanning capacitance microscopy

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I.

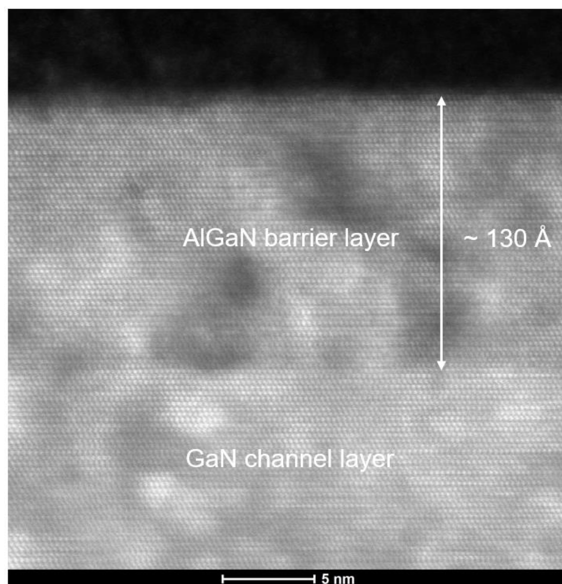

Fig. S1. High-angle annular dark-field scanning transmission electron microscopy (HAADF-STEM) image of the HEMT structure. The GaN lattice is used as reference for thickness calculation. The AlGaN barrier layer thickness is determined as about 13 nm and includes the nominally 1nm-thick AlN exclusion layer with which the barrier growth was started. Also note the absence of a GaN capping layer.

II.

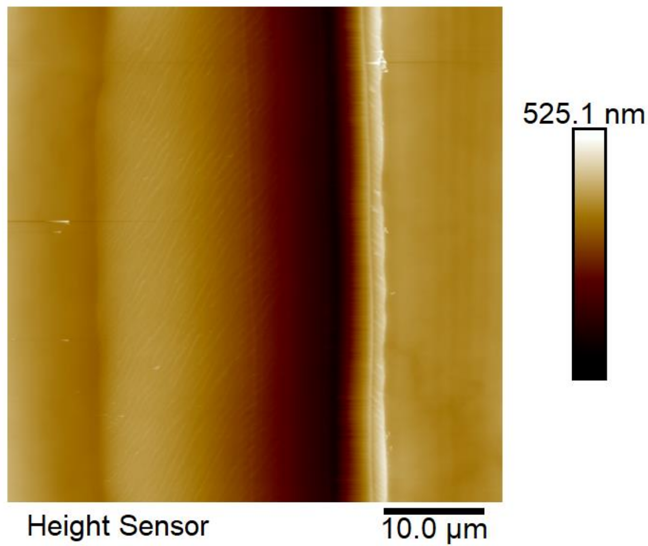

Fig. S2. Topographical image of a mechanically-prepared scratch on the HEMT structure sample surface to which an indium contact was later soldered. The scratch was prepared using a weighted cantilever equipped with a diamond scribe mounted on an X/Y translation table, allowing for consistent depth control. The AFM-measured depth of the scratch shown in the image is about 525 nm which is substantially smaller than the total thickness of the nitride layer (of about 3 µm). Hence, the subsequently added indium metal will not reach the Si substrate below the nitride layer.

III. Method of identifying the same area in each AFM-based technique for multi-microscopy

First, we scanned a 1 µm × 1 µm area of the sample surface in PF-AFM mode. This specific area becomes our target area. Then, we zoomed out to scan a 5 µm × 5 µm area, and recorded the relative position of the initial 1 µm × 1 µm area within this 5 µm × 5 µm region. Next, we zoomed out further to scan a 20 µm × 20 µm area, recording the relative position of the 5 µm × 5 µm area within this 20 µm × 20 µm region. Finally, we withdrew the tip from the sample surface. Using the integrated optical microscope, we recorded the tip's position relative to the corner of the sample. In order to locate the target 1 µm × 1 µm area using another AFM-based technique (e.g., conventional or hyperspectral SCM mode), we simply repeated the above process in reverse.

IV.

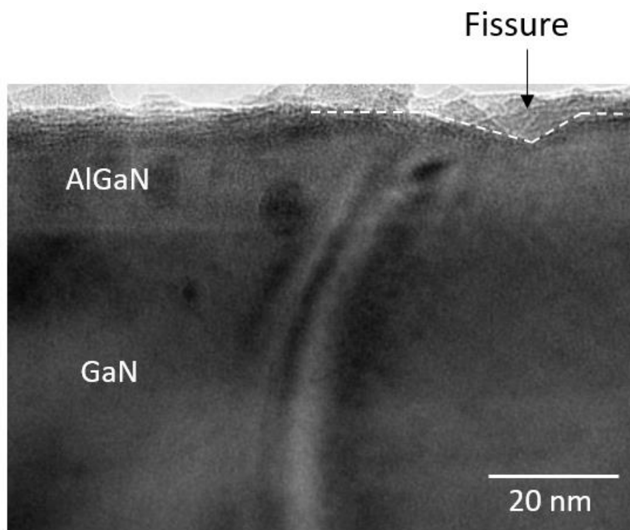

Fig. S3. Bright-field TEM image of a fissure in the HEMT structure sample. The fissure does not penetrate through the AlGaN barrier layer.