Stress mapping and dislocation density distribution on micro-pillar patterned GaN templates

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Introduction

In the present work we have studied a GaN layer grown on a micro-pillar patterned GaN template in order to understand the stress variation, the tilt and twist mosaic on the micro-pillars, and also to detect and quantify the threading dislocations (TDs). The stress distribution and TD density of GaN layer grown on micro-pillar patterned GaN templates have been investigated by high resolution-electron backscatter diffraction (HR-EBSD), Raman spectroscopy, and electron channeling contrast imaging (ECCI).

HR-EBSD

Methodology

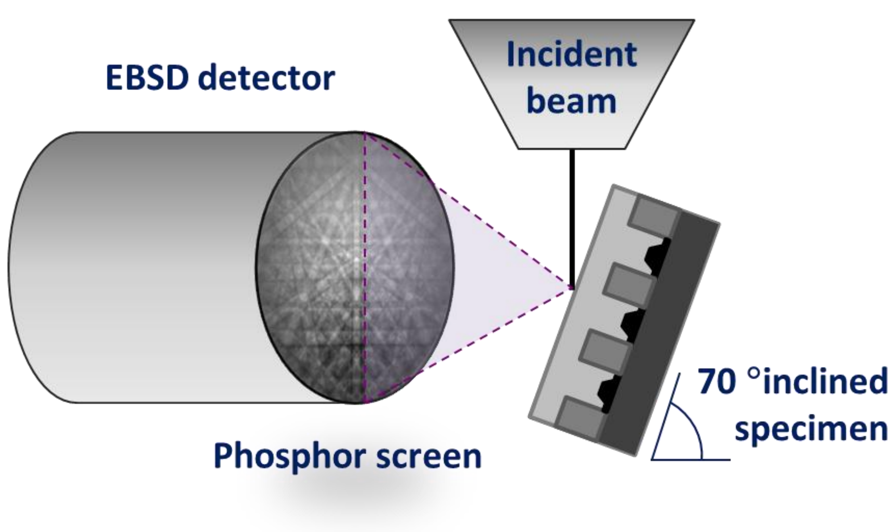

Figure 2: Schematic diagram to show the experimental set up of an EBSD system. An EBSD pattern (EBSP) image will be formed on the CCD comprising a large number of nearly straight bands termed Kikuchi bands.

Cross-correlation analysis can be used to determine the shift of features (eg zone axes) in the test pattern from their positions in a reference (known strain) pattern. This can be done at a sensitivity of ±0.05 pixels. The shifts at many (>4) regions of interest can be used determine a best fit strain and rotation tensor. A sensitivity of $\pm 10^{-4}$ averaged over all components of strain and rotation tensors can be achieved [2,3].

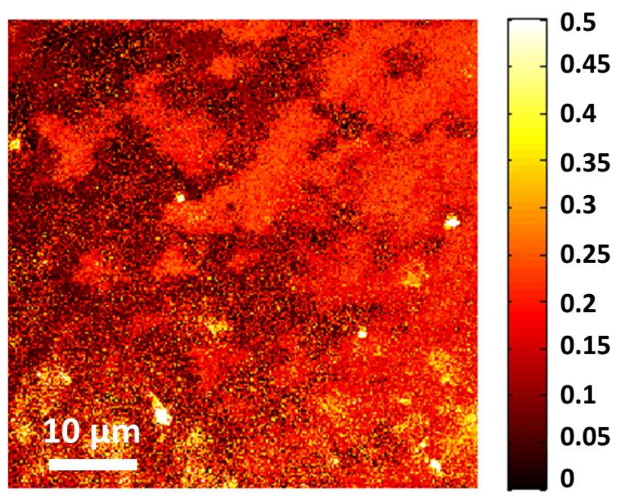

Figure 3: Misorientation map for GaN sample. The misorientation scale is shown, with a variation of up to 0.5°.

Raman

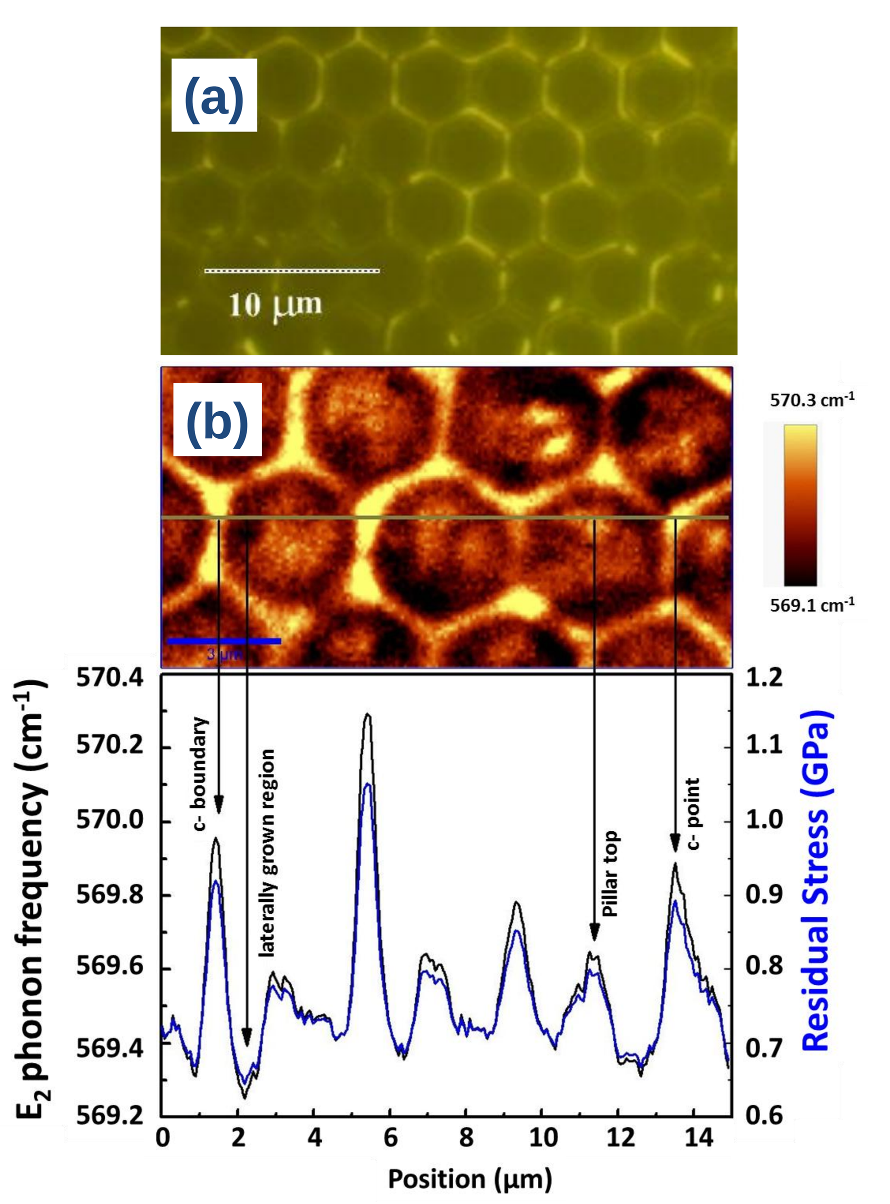

Figure 6: (a) Optical microscopy image of completely coalesced smooth 5 µm thick GaN layer grown on micro-pillar GaN template and (b) Raman mapping of E_2 phonon measured in the region of 560 cm^{-1}-580 cm^{-1}. The scale bar shows the frequency position. The calculated residual stress value of the top surface of the GaN layer is shown in blue color [4].

ECCI

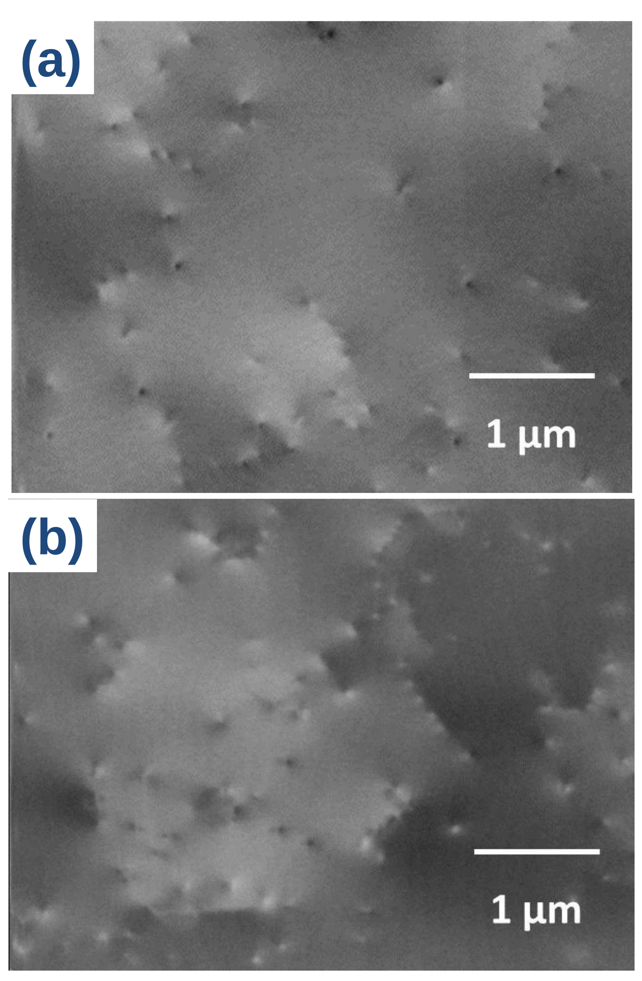

Figure 7: ECC image of (a) GaN layer grown on GaN micro-pillar template and (b) 5-µm-thick GaN layer grown directly on sapphire substrate [4]. The total TD density (edge, screw, and mixed) was estimated to be 1.5 x 10^8 cm^{-2}. This is lower than the TDs for the GaN layer grown directly on sapphire (3.3 x 10^8 cm^{-2}).

Sample

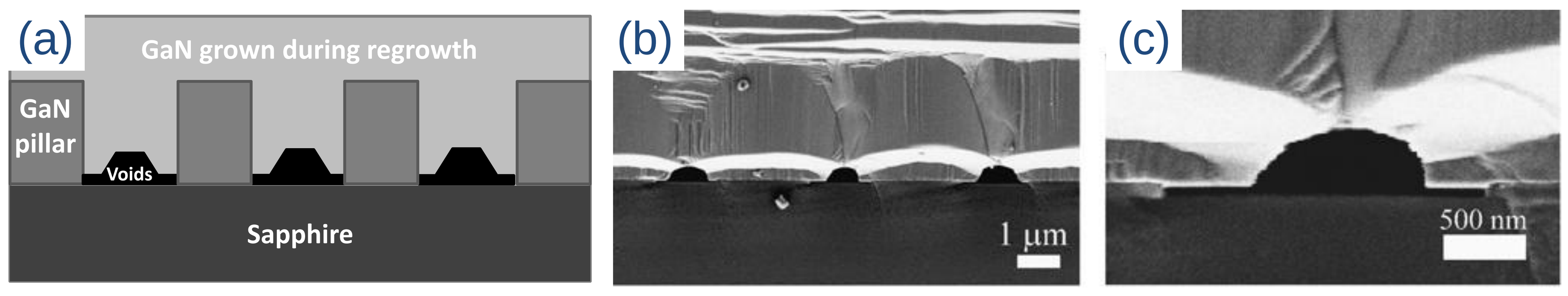

Figure 1: (a) Schematic image of the GaN cross-section with air voids between the pillars, (b) cross-sectional SEM image of the cleavage plane regrowth GaN layer with voids, and (c) a close up SEM image from a void cross-section [1].

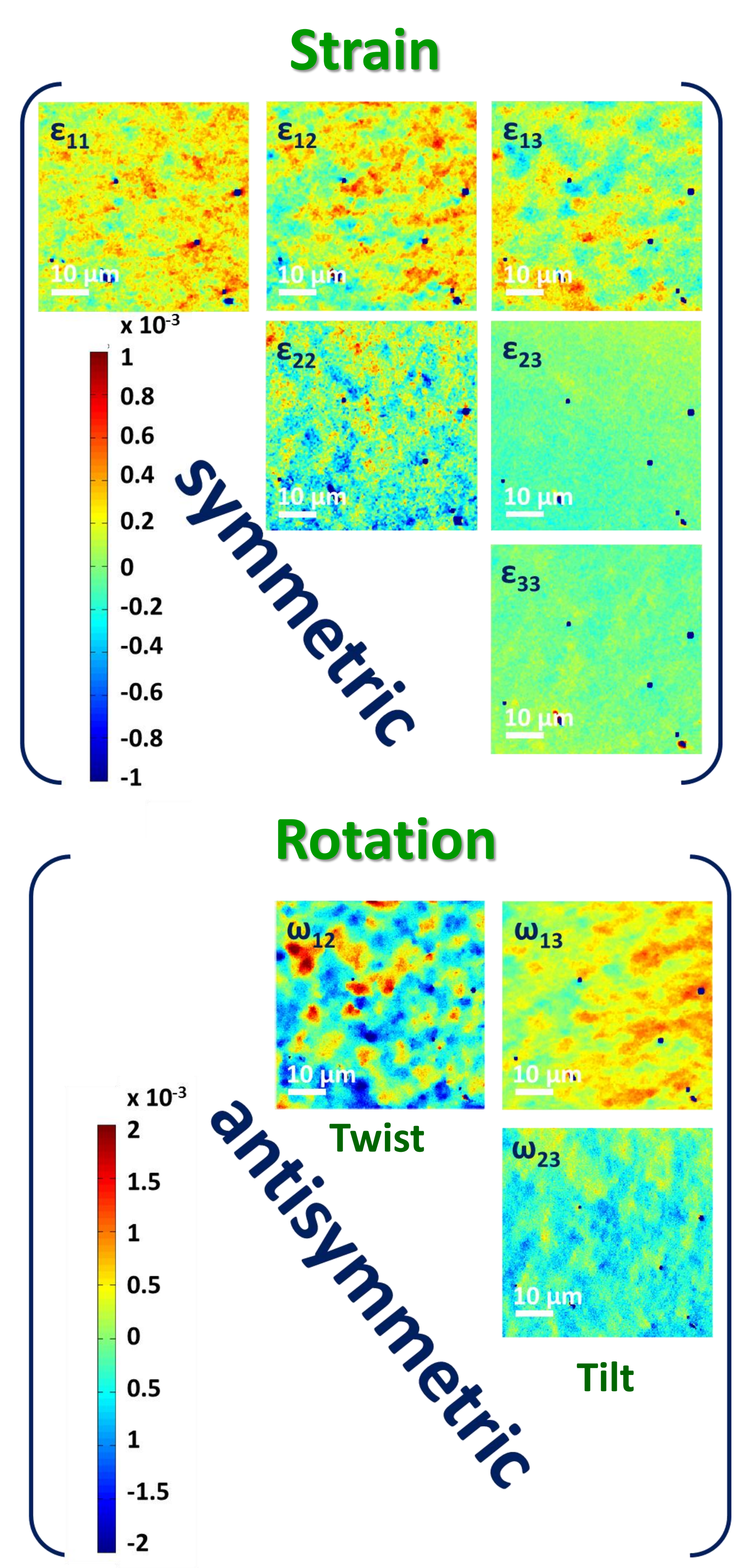

Figure 4: Variation in elastic strains and lattice rotation for the scanned region on top of the coalescent GaN film. The step size was 0.2 µm.

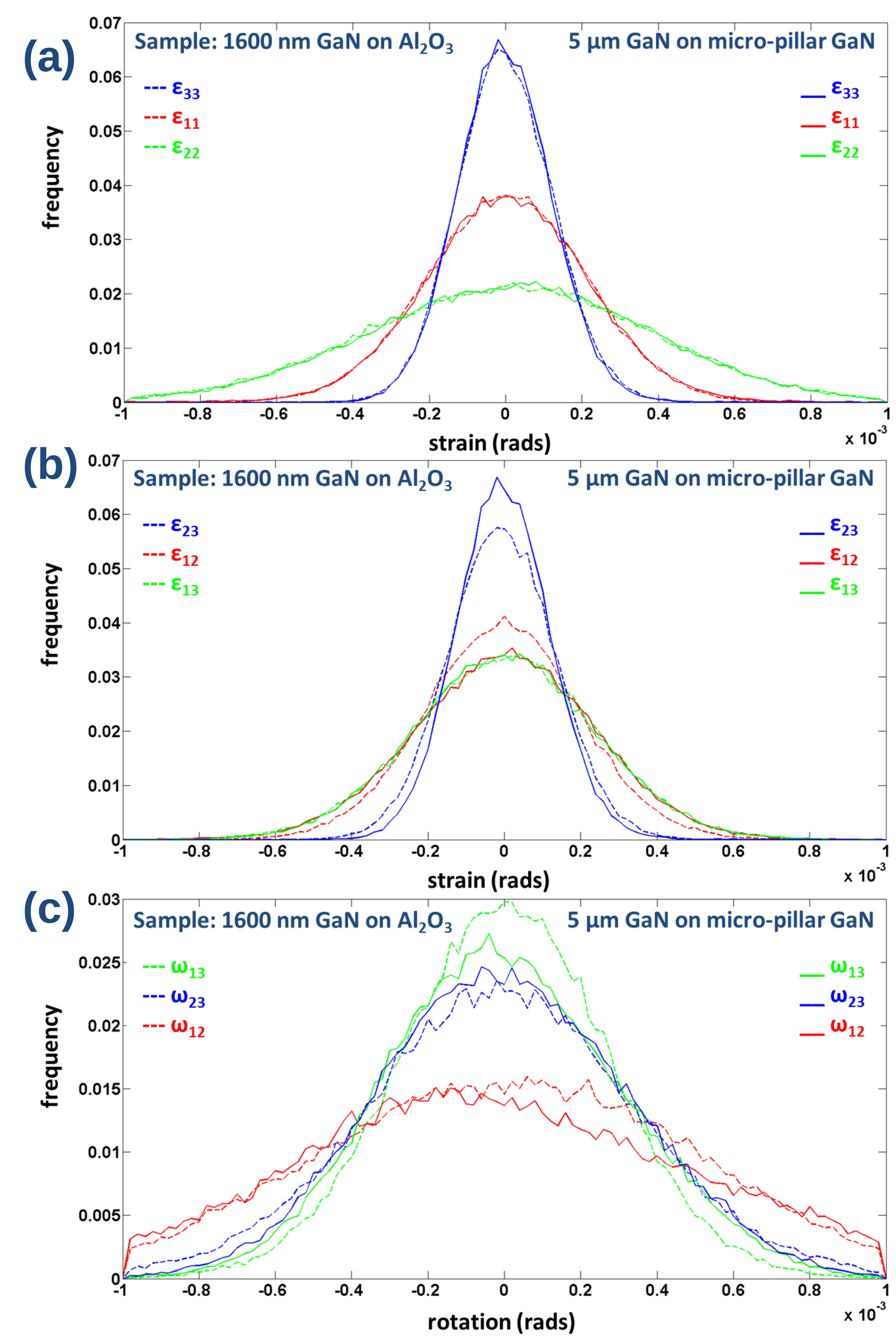

Figure 5: Distribution of (a) normal strain, (b) shear strain, and (c) tilt (ω_{12} and ω_{13}) and twist (ω_{23}) in 1600nm thick GaN layer on sapphire (dashed plots) and GaN grown on micro-pillar patterned GaN template (line plots).

Results

- Maps histograms were constructed of the rotations about the surface normal (twist mosaic) and two orthogonal axes in the surface plane (tilt mosaics).
- The width of the twist mosaic was larger than the tilt mosaic and the strain variations were somewhat smaller than those for the rotations.
- Raman mapping of E_2 (high) phonon shows differences in stress between the coalescing boundary, the top surface of the pillar region and around the GaN micro-pillar. This strain distribution was not observed by EBSD probably related to the coalescent GaN thick film.
- The ECC imaging reveals the reduction of threading dislocation density in the GaN layer grown on the micro-pillar patterned GaN template.

Reference

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Acknowledgments

We gratefully acknowledge funding from the EPSRC (EP/J015792/1 & EP/J016098/1) and the Academy of Finland through Project No. 13256332.