Analyzing nanopillars on gallium arsenide wafers using electron backscatter diffraction

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INTRODUCTION

Gallium arsenide (GaAs) semiconducting nanopillars are showing much promise in the fields of solar cells, microelectronics and energy storage. For example, a surface solar-cell composed of a carpet of nanopillars provides a large surface area for light absorption, opening possibilities for significantly improved light conversion efficiency compared to current silicon photovoltaic technology.

GaAs nanopillars have the added advantage that they potentially can be used to produce flexible solar cells. Large-scale assembly of such devices requires precise control over the wire chemical composition, morphology, crystal structure, and growth direction with respect to the substrate.

Preliminary work concentrated on electron backscatter diffraction (EBSD) analyses of the apex of individual pillars. For complete pillar characterization, investigation along the growth axes of individual GaAs nanopillars is required. This task requires fully understanding and optimize the beam-to-sample-to-detector geometry of the experiments.

EXPERIMENTAL

GaAs nanopillars grown by selective area epitaxy on GaAs (111) B (zinc blende) substrate were analyzed in a JEOL 7001 field-emission electron microscope (FESEM) using a Thermo Scientific NORDAN System 7 microanalysis system and a Thermo Scientific QuasOr electron backscatter diffraction (EBSD) detector.

The nanopillars were only grown in a few test regions on a 1 cm$^2$ wafer. Each test region was less than ~1 mm$^2$. The nanopillars are hexagonal cross-section columns that are designed to be 700 nm in height and 50 nm in diameter.

RESULTS

EBSD of the pillars on the wafer in the as-grown geometry will only permit analysis of the axis orientation of the pillars at the apex. Since the orientation along the pillars is needed, the pillars need to be oriented with their growth axes orthogonal to the EBSD detector axis, preferably horizontally.

The initial experiments confirmed the problem that the large wafer shadows at least half of the diffraction pattern from pillars in the central regions of the wafer. This means that the pillars need to be mounted with no exposed wafer closer to the EBSD detector than the pillar under investigation to cause shading. That is why the wafer needed to be cleaved near or through the test region of pillars.

Once this was accomplished (Figure 2), the sample was mounted in the needed geometry for EBSD acquisition (Figure 3). Using this mounting, there were many pillars that were in suitable geometries to produce EBSD patterns with no shadowing from the wafer or neighboring pillars.

The EBSD diffraction pattern from a traditional sample has a small diffraction signal on a high background intensity. For optimum diffraction pattern analysis, a background pattern was collected and removed from each acquired pattern.

For these pillar samples, an adequate background image could not be collected, so only a software flat-fielding operation was performed on the acquired diffraction patterns. Due to the thin nature of the pillars and stress-free surface, very good diffraction patterns were collected and analyzed in this manner.

The EBSD patterns collected from the pillars,
Figure 4 patterns were of sufficient quality to perform orientation analysis along their entire length [1, 2].

CONCLUSIONS
EBSD is a potential tool for analyzing the orientation along the growth direction of nanopillars when they are still attached to their wafer substrates. The wafers must be cleaved to place the pillars in the optimum EBSD geometry. EBSD analyses can proceed with a few limitations on the nanopillars compared to bulk samples. Using EBSD to analyze the crystal structure of nanowire ensembles can speed the analysis and feedback of critical nanowire properties compared to conventional techniques. EBSD analyses play an important role in the development of new energy technologies.

REFERENCES

BIOGRAPHIES
Patrick Camus received a PhD in materials science and engineering from the University of Pittsburgh, PA, USA, working on materials characterization using microanalysis techniques. Patrick is now a Senior Product Scientist with Thermo Fisher Scientific, having joined the company in 1998 when it was known as NORAN Instruments. In the X-ray Microanalysis group he is responsible for EDS, WDS and EBSD techniques.

Joshua Shapiro is a Ph.D. candidate at the Integrated Nanomaterials Laboratory at UCLA. His research interests include growth and controlled heterostructure formation in III-V nanopillars and computational modeling of epitaxial growth. He has a M.S. in Electrical Engineering from New Mexico Institute of Mining and Technology and a B.A. in Astrophysics from UC Berkeley.

Sergey V. Prikhodko received a PhD in materials science from the Institute of Metal Physics National Academy of Science of Ukraine, Kiev, working on materials characterization using electron microscopy and spectroscopy related techniques. Sergey is currently a Staff Scientist with the Department of Materials Science at University of California, Los Angeles. In 2010 he received the PTSA Award from the Microscopy Society of America.

ABSTRACT
We briefly describe the difficulties that arise and a solution that was employed when performing EBSD investigations of creative sample geometries in their native state. Some geometries require non-traditional sample preparation techniques to obtain a complete and accurate understanding of the sample and its relation to its environment.

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