High Resolution X-ray Diffraction for In-line Monitoring of Ge MOSFET Devices

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Introduction

- The semiconductor industry is moving from 2D planar devices to 3D fin-shaped field transistors (FinFETs).
- Keep Moore’s law alive for logic at 22 nm and below.
- Increase performance and reduce power consumption.
- Many challenges in the fabrication of FinFETs:
  - Multiple patterning lithography, new and complex materials, processes and integration schemes.
  - Serious challenges for established characterization and metrology techniques / tools used for R&D and process control.
- We discuss the analysis of Ge MOSFET structures using high-resolution X-ray diffraction (HRXRD).

HRXRD: Fundamentals

- X-rays have similar wavelengths to the distances between atoms in solids.
- Parameters X-rays are characterized, which are properties of materials and structures at atomic length scales.
- X-ray diffraction arises from constructive scattering from periodic arrangement of atoms in a single-crystal material.
- Measurement and simulation of HRXRD spectra are straightforward and well established.
- HRXRD does not depend on variable material properties (such as N & k optical constants) but on first principle theory.

Equipment: JVX7300LSI

- JVX7300LSI Small & Large-Spot X-Ray Metrology tool for:
  - In-situ wafer production process monitoring of semiconductor substrates.
  - X-ray reflectometry:
    - SAXS: 1060 & High-density lamellas.
    - 324 (1D detector) & 1576 (2D detector) & 3240 (2D detector)
  - Film thickness, film composition & relaxed parameters of thin films.
  - In-situ 3D inspection:
  - Advanced X-ray topography scanning from HRXRD, 3D, 4D, 5D, in-focus 2D.
  - In-situ configuration, alignment and measurement - Multiple LSS source.

Results: Relaxed Ge

- SiGe peak is shifted in Qx in both cases indicating relaxation.
- Ge peak is shifted from SiGe peak when measuring across fins but not shifted when measuring along fins.
- Uniaxial relaxation of Ge layer across fins.
- Relaxation across the fins depends on fin width.

Results: Strained Ge on SiGe

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Results: Ge on SRB Layers

- Ge peak position shows no Qx shift from 1st substrate.
- X-ray diffraction is taken on Ge peaks from SiGe buffer layer.
- SiGe SRB peak positions indicate:
  - Composition of buffer layers.
  - All layers relaxed.

HRXRD for FinFET processes

- HRXRD fitting can be automated.
- Create a model with peak broadening in reciprocal space.
- Select strain type.
- Uniaxial or biaxial / tilt supported.
- Peak locations and heights are fit in 3D to determine position within RSM.
- Fit positions are used to determine composition and relaxation of each peak.
- Fit widths give information on defect density.

Conclusions

- High-resolution XRD delivers valuable information on nanostructures relevant to FinFET devices.
- Composition and relaxation of complex structures can be obtained from single reciprocal space maps collected on asymmetric reflections.
- The latest generation of lab / fab tools can yield good quality data on minutes, not several hours.
- Including symmetric / asymmetric RSM using 1D detectors.
- In-situ X-ray metrology tools, like the JVX3000 series, enable advanced materials and process development and provide novel solutions for production monitoring.

References


www.jvsemi.com