Technical University of Denmark

Sidewall roughness measurement of photonic wires and photonic crystals

Svalgaard, Mikael; Frandsen, Lars Hagedorn; Garnæs, Jørgen; Kühle, A.

Published in:
European Conference on Lasers and Electro-Optics, 2007 and the International Quantum Electronics Conference. CLEOE-IQEC 2007.

Link to article, DOI:
10.1109/CLEOE-IQEC.2007.4386571

Publication date:
2007

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Svalgaard, M., Frandsen, L. H., Garnæs, J., & Kühle, A. (2007). Sidewall roughness measurement of photonic wires and photonic crystals. In European Conference on Lasers and Electro-Optics, 2007 and the International Quantum Electronics Conference. CLEOE-IQEC 2007. (pp. 1-1). IEEE. DOI: 10.1109/CLEOE-IQEC.2007.4386571

Sidewall Roughness Measurement of Photonic Wires and Photonic Crystals

M. Svalgaard, L.H. Frandsen
Department of Communications, Optics & Materials,
Technical University of Denmark, DK-2800 Lyngby, Denmark.

J. Garnæs, A. Kühle
Danish Fundamental Metrology Ltd.,
Technical University of Denmark, DK-2800 Lyngby, Denmark.

The performance of nanophotonic building blocks such as photonic wires and photonic crystals are rapidly improving, with very low propagation loss and very high cavity Q-factors being reported [1]. In order to facilitate further improvements in performance the ability to quantitatively measure topological imperfections such as sidewall roughness on a sub-nm scale becomes essential [2]. In this paper we use atomic force microscopy (AFM) on tilted samples to obtain the most detailed sidewall roughness measurements yet on nanophotonic structures.

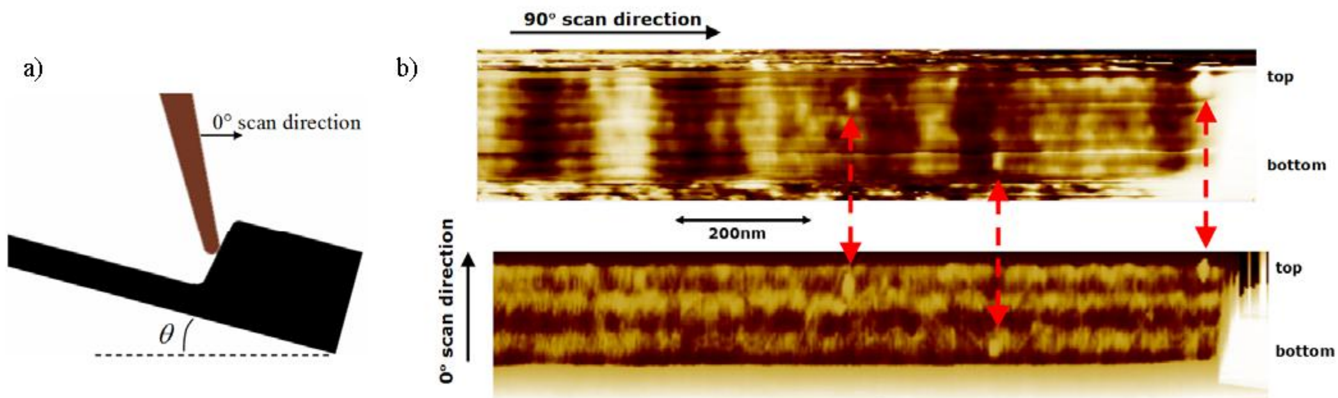

Fig. 1: (a) AFM measurement geometry with 0° scan direction indicated; (b) Roughness features along two directions of a 1.2μm long, linear sidewall section in GaAs. Point-like defects common to both measurements are indicated by arrows.

The measurements were performed using a tapping mode AFM on samples that could be tilted up to 20° to better sample near-vertical sidewalls (fig. 1a). The AFM tip used here had a 1.5μm long extension with a 5° half-cone angle and a tip radius <15nm (Nanosensors Inc.). An example of a measurement on a 150nm deep, linear sidewall in GaAs is shown in fig. 1b. Due to slow drift and line-wise distortions, roughness is best revealed along the fast-scan direction: in our case either perpendicular (0°) or parallel (90°) to a sidewall, as seen from above. Along the 0° scan direction a number of nearly equidistant bands are revealed which match the cyclic GaAs etching used during fabrication. The 90° scan direction reveals a less uniform, curtain-like pattern which is likely associated with roughness of the etch mask. Point-like defects are common to both measurement directions, examples are indicated by red arrows. The roughness features shown here extend roughly ±1.5 nm normal to the slope surface. For 160nm diameter holes in a photonic crystal similar results were obtained, however the small hole size lead to scanning artifacts from probe - meniscus layer interactions so that measurements could only be done near the hole center-line.

The measurements presented here represent, to the best of our knowledge, the highest resolution and most quantitative assessment yet of sidewall roughness in photonic wires and photonic crystals. The technique of tilted AFM is non-destructive in nature and can reveal both point-like defects, vertical curtains and horizontal bands which can be related to various fabrication steps which is essential for further optimization of device performance.

References

1. B.-S. Song et al., Nature Materials, **4**, 207-210 (2005)
2. E. Kuramochi et al., Phys. Rev. B **72**, 161318(R) (2005)