Experiment Brief

Monarc Pro

Title

Determining photonic band structure by energy-momentum spectroscopy in an electron microscope

Gatan Instrument Used

The Monarc® Pro system offers the most complete analysis of cathodoluminescence (CL) emissions and empowers all users to capture the highest quality data, whether novice or expert.

Background

Novel optical devices formed from photonic crystals (PhCs) and metamaterials have attracted significant attention due to a plethora of potential applications, including optical computing, telecommunications, and (micro-LED) displays. PhCs and metamaterials take advantage of coherent scattering and near field interactions, which provide opportunities for researchers to control and manipulate light down to the nanoscale. PhCs can be designed with specific photonic band structures that selectively control the transmission or propagation of light at prescribed frequencies and directions defined by the PhC's lattice form and periodicity. However, the optimization of devices requires precise control of the PhC components shape and size, nanoscale arrangement, and experimental techniques that can characterize both physical and optical properties

Materials and Methods

We demonstrate the measurement of the photonic bands of a PhC by energy-momentum (E-k) spectroscopy alongside a detailed analysis of the physical properties using a scanning electron microscope (SEM) and wavelength- and angle-resolved CL (WARCL). [Bertilson, M.; et al., Microscopy and Microanalysis Conference Proceedings (2018)]. The PhC investigated was an array of 6-sided micro-pillars—each pillar was 810 ± 20 nm wide and fabricated from GaN with $In_{13}Ga_{87}N$ quantum wells on the outer surfaces. The pillars were arranged in a 2-dimensional hexagonal lattice at 2.0 ± 0.03 µm pitch. CL emission was excited using a conventional SEM operating at 10 kV while the emission anisotropy and wavelength distribution of the emitted photons were analyzed using the WARCL mode of the Monarc Pro (model 450.P.WAR); the aberration-corrected Monarc Pro system enables capture of WARCL data without loss in spectral or angular resolutions.

Summary

The Monarc was used to capture the photonic band structure of a semiconductor PhC and to directly correlate the optical properties to the PhC's nanoscale-structure. Wavelength-resolved emission patterns from ultraviolet (350 nm) wavelengths through the visible spectrum (750 nm) were collected in just 90 s and converted to the energy-momentum basis to reveal the photonic band structure.

The WARCL mode of the Monarc Pro extends researchers' abilities to characterize light-matter interactions at the nanoscale accelerating the development of novel optical devices.

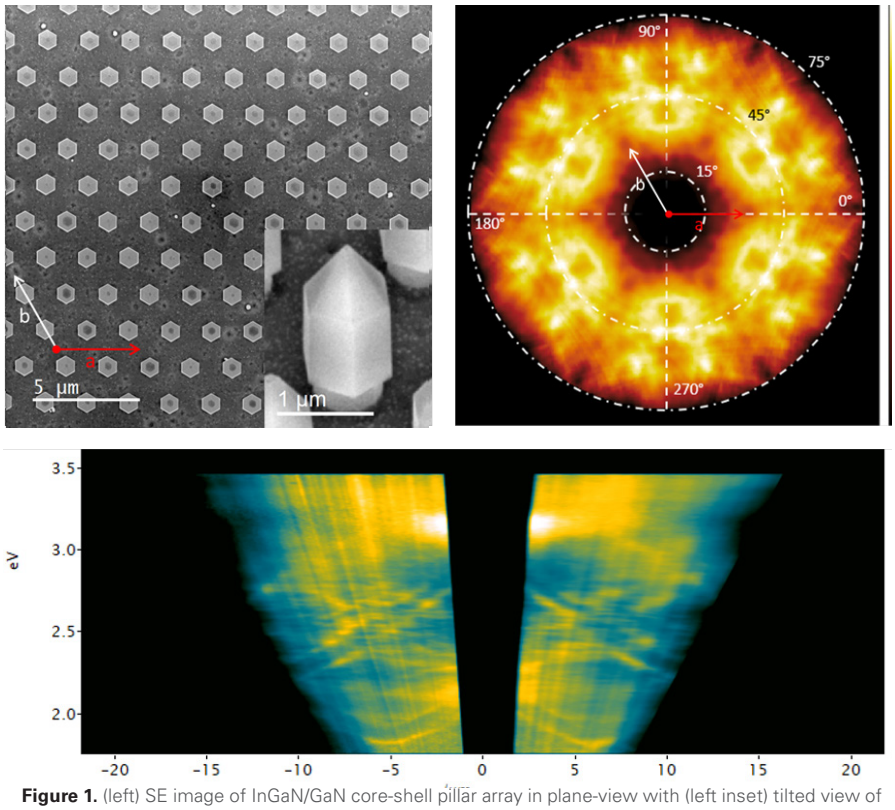

Figure 1. (left) SE image of InGaN/GaN core-shell pillar array in plane-view with (left inset) tilted view of a single pillar, (middle) symmetrically averaged WARCL emission pattern of pillar array extracted from 545 nm, and (right) energy-momentum basis observing k along the a-direction captured with a total acquisition time of 90 s

Credit(s)

Special thanks to Strathclyde and Bath University for providing the sample used in this study.

Gatan, Inc. is the world's leading manufacturer of instrumentation and software used to enhance and extend electron microscopes—from specimen preparation and manipulation to imaging and analysis.

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