GaN Nanorod-Based Subwavelength Optical Media

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Abstract
Vertically self-aligned gallium nitride nanorod arrays grown by plasma-assisted molecular-beam epitaxy are shown to behave as subwavelength optical media in both their discrete and integrated forms, which have important implications for optoelectronic applications.

Introduction

Gallium nitride (GaN)-based light-emitting diodes (LEDs) and laser diodes have become the devices of choice for optoelectronic applications operating in the short-wavelength range. One of the remaining challenges for improving GaN-based LEDs is to reduce their optical losses, originating from the high refractive index of GaN (~2.5) [1]. The low optical reflection from low effective refractive index (low-*n*) nanorod arrays could be exploited to overcome this difficulty. Indeed, there are a few reports of light extraction enhancement by employing transparent, conductive indium-tin oxide [2] and zinc oxide [3] nanorod arrays deposited on top of GaN LEDs. In this talk, we will present our recent results on GaN nanorod arrays.

Results and Discussion

In comparison with other nanorod materials, GaN nanorod arrays [4] have the same physical and thermal properties as the bulk GaN crystal, making them more suitable and durable for high-power GaN-based optoelectronic applications. In spite of these prospects, there are very few reports of their fundamental optical properties. Recently, by analyzing the reflectivity interference fringes (Fig. 1), we have quantitatively determined that GaN nanorod arrays behave as low-*n* transparent media in the entire visible spectra region [5]. Moreover, the polarized properties of single GaN nanorods have been demonstrated and studied in detail [6]. By measuring linearly polarized photoluminescence from individual, isolated GaN nanorods (Fig. 2) with the rod diameters in the subwavelength regime (30−90 nm), we present clear experimental evidence for the size dependence of polarization anisotropy, which can resolve the long-standing issue related to the giant luminescence polarization anisotropy observed from various semiconductor nanorods and nanowires.

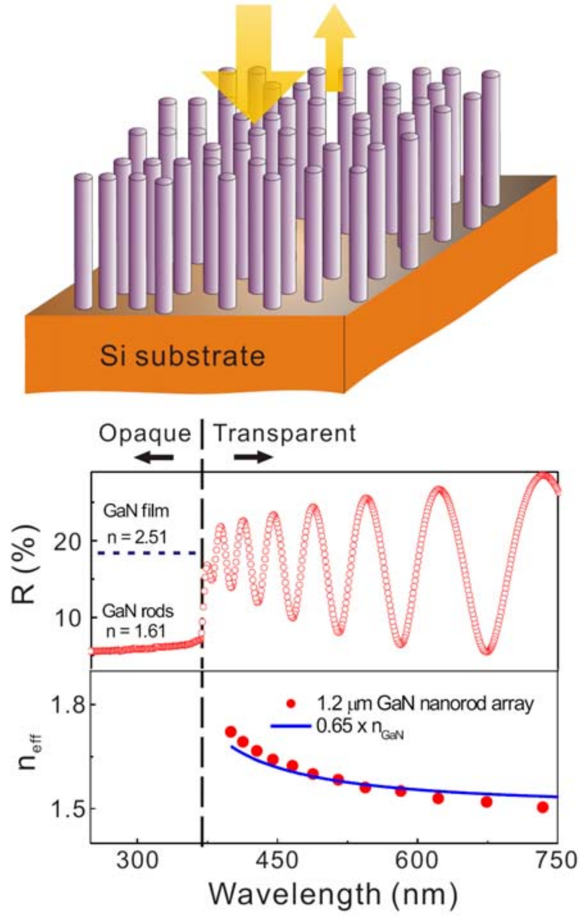

Figure 1. A vertically aligned GaN nanorod array behaves as a low-refractive-index optical medium in both transparent and opaque spectral regions.

Conclusions

Based on our optical measurements results, vertically aligned GaN nanorod arrays grown by PA-MBE can act as subwavelength low-refractive-index optical media in both transparent and opaque regions. We have also found that the optical confinement effects dominate the linearly polarized properties of GaN nanorods with diameters in the subwavelength regime of 30−90 nm. Because of the superior material properties of GaN nanorods in terms of optical transparency, availability of *n*- and *p*-type conductivity, and excellent thermal and chemical stabilities, these results could have important implications for nanophotonics and optoelectronics applications.

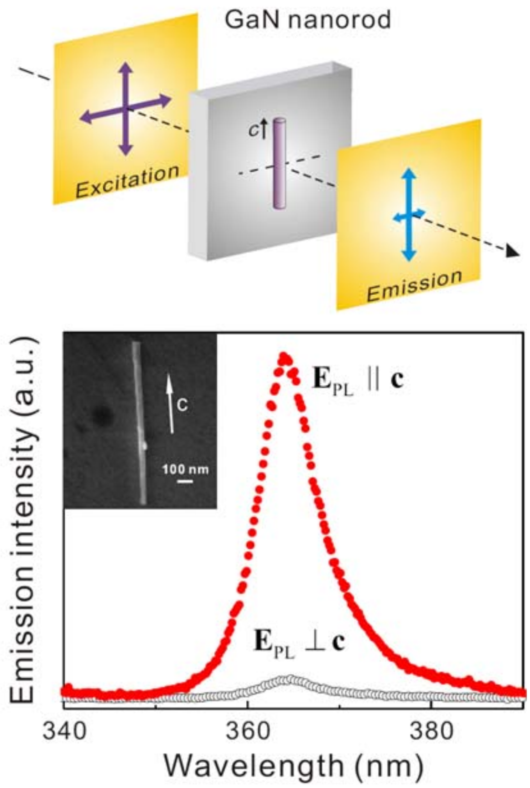

Figure 2. Linearly polarized photoluminescence (PL) from an isolated GaN nanorod (length: 1.2 μm, diameter: 40 nm). By measuring linearly polarized PL from individual, isolated GaN nanorods with the rod diameters in the subwavelength regime (30−90 nm), clear experimental evidence for the size dependence of polarization anisotropy is found, consistent with the theoretical model based on subwavelength optical confinement in GaN nanorods [6,7].

References

[1] E. F. Schubert, J. K. Kim, H. Luo, and J.-Q. Xi, *Rep. Prog. Phys.* **69**, 3069 (2006).

[2] J. Y. Kim, T. Gessmann, E. F. Schubert, J.-Q. Xi, H. Luo, J. Cho, C. Sone, and Y. Park, *Appl. Phys. Lett.* **88**, 013501 (2006).

[3] J. Zhong, H. Chen, G. Saraf, Y. Lu, C. K. Choi, J. J. Song, D. M. Mackie, and H. Shen, *Appl. Phys. Lett.* **90**, 203515 (2007).

[4] H.-Y. Chen, H.-W. Lin, C-H. Shen, and S. Gwo, *Appl. Phys. Lett.* **89**, 243105 (2006).

[5] H.-Y. Chen, H.-W. Lin, C.-Y. Wu, W.-C. Chen, J.-S. Chen, and S. Gwo, *Opt. Express* **16**, pp. 8106 (2008).

[6] H.-Y. Chen, Y.-C. Yang, H.-W. Lin, S.-C. Chang, and S. Gwo, *Opt. Express* **16**, 13465 (2008).

[7] H. E. Ruda and A. Shik, *J. Appl. Phys.* **100**, 024314 (2006).