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Perspective

Aligned ZnO nanorod arrays growth on GaN QDs for excellent optoelectronic applications

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Abstract

Uniformly aligned ZnO nanorod (NR) arrays grown on GaN quantum dots (QDs) as preferred nucleation sites are imperative for designing field emission emitters, ultraviolet photodetectors and light-emitting diodes for a wide range of new optoelectronic applications. In a recent study (2015 *Nanotechnology* **26** 415601), Qi *et al* reported a novel method of fabricating ZnO NRs arrays with uniform shape, the density of which is easily tunable by adjusting the density of GaN QDs. This approach opens a door to obtaining a combination of 0D and 1D structures for optoelectronic applications.

Keywords: ZnO nanorods, GaN QDs, optoelectronic applications

(Some figures may appear in colour only in the online journal)

Zinc oxide (ZnO) is a promising candidate for optoelectronic applications such as ultraviolet (UV) photodetectors [1, 2], photovoltaic devices [3], and light-emitting diodes [4] owing to its direct wide band gap (3.37 eV) and high exciton binding energy (60 meV). As one-dimensional (1D) nanostructures, ZnO nanorods (NRs) have attracted considerable attention owing to their large surface area, good crystal quality, increased quantum confinement effect and unique photonic properties [5]. Various methods have been used to grow aligned ZnO NRs, including metal-organic chemical vapor deposition [6], vapor liquid-solid epitaxy [7], pulsed laser deposition [8], as well as hydrothermal methods [9]. Among them, the hydrothermal method by Qi *et al* [10] is an excellent technique as it leads to well-ordered arrays of ZnO NRs that are low cost, low temperature, have a non-toxic operation and are environmentally friendly [9]. Over the past decade, well-aligned ZnO NRs have been obtained by the precursor ZnO seed-layer assisted method, which usually results in a large turn-on voltage and poor stability in ZnO-based LEDs [11]. The study by Qi *et al* [10] provides an effective approach for growing large-scale, uniformly aligned ZnO NR arrays utilizing GaN QDs as preferred nucleation sites, which provides a possibility of combining 1D structures with 0D nanoscale structures for optoelectronic applications.

In Qi *et al's* work [10], GaN QDs were first grown on a *c*-plane sapphire substrate by metal organic chemical vapor deposition (MOCVD) in Stranski–Krastanov mode. Their density can be tuned by simply adjusting the period of growth interruption. Then, ZnO NRs were epitaxially grown on GaN/$Al_{0.5}$GaN QDs with the hydrothermal method. The density of ZnO NR arrays on low density GaN QDs is obviously lower than that on high density QDs. A sharp peak at 377 nm and a weak broad green luminescence band in the photoluminescence (PL)

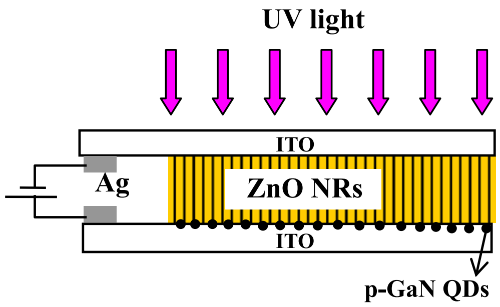

Figure 1. Schematic diagram of the *n*-ZnO NRs/*p*-GaN QDs heterojunction.

spectra demonstrated extremely high-quality ZnO NR arrays. The optical performance of ZnO NRs on low-density QDs is better than that of NRs on high-density QDs. Therefore, this will be an effective approach to improve the optical properties of ZnO NR arrays by controlling their density.

Meanwhile, the ZnO NRs and GaN QDs achieved better NR/QD nanoscale heterojunctions. This composite structure can effectively improve carrier injection efficiency by reducing the contact area at the interface, which decreases the interfacial strain and defects. Moreover, these NR/QD heterojunctions could have a wide range of applications on field emission devices. For example, the seed layers of ZnO NRs can affect the field emission properties; Liu *et al* [12] recently investigated the effect of ZnO seed layers on the growth of ZnO NRs, and proposed that ZnO NR arrays growth assisted by a few seed layer can be a promising candidate as a field emission emitter. The GaN QDs show promising field emission performance with a low turn-on field and a high current density. Tuning the density of GaN QDs and ZnO NRs may influence the field emission feature.

Of the various p-type materials that can be used for ZnO based heterojunctions photodetector, GaN is one of the most promising candidates in terms of the same lattice structure (wurtzite) and the relatively small in-plane lattice mismatch (1.8%) with ZnO [13–15]. Yet, n-ZnO NR/p-GaN heterojunctions have been systhesized to fabricate UV photodetectors [16] and LEDs [4, 17]. The study by Qi *et al* [10] reported that GaN QDs can decrease the interfacial strain and defects of the composite structure. Therefore, n-ZnO NR/p-GaN QDs nanoscale heterojunctions would improve the properties of UV photodetector and LEDs. The as-grown ZnO is intrinsically an n-type semiconductor due to its self-compensation process [18]. The p-GaN QDs can be obtained by doping Mg [4, 19]. Since the study of n-ZnO NR/p-diamond heterojunctions as UV photodetectors has been reported [18, 20, 21], the n-ZnO NR/p-GaN QD nanoscale heterojunction device reported by Qi *et al* [10] can be designed similarly as follows (figure 1): p-GaN QDs can be deposited on transparent conductive indium-tin-oxide (ITO) glass, ZnO NRs are then fabricated on the p-GaN QDs, another conductive indium-tin-oxide (ITO) glass layer is pressed on the top of ZnO NRs as an electrode. This n-ZnO NR/p-GaN QD nanoscale heterojunction will shed light on designing NR/QD nanoscale heterojunctions for wide optoelectronic applications.

In summary, the study of Qi *et al* [10] is particularly meaningful because they provide a new approach of growing ZnO NR arrays using GaN QDs as nucleation sites which could pave the way for the development of ZnO vertical 1D devices. In the future, a combination of 1D ZnO NRs and 0D GaN QDs structures may open a new door for the applications of sensor arrays, field emission devices, optoelectronic devices and LEDs.

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