Science Bulletin 63 (2018) 527–528

Contents lists available at ScienceDirect

Science Bulletin

journal homepage: www.elsevier.com/locate/scib

Research Highlight

Graphene/ZnO single-mode lasing

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Zinc oxide (ZnO) is a traditional II–VI semiconductor material. Owing to its direct wide band gap and high exciton binding energy, ZnO has been considered as one of the most promising ultraviolet (UV) lasing materials. Its lasing performance has been widely explored for two decades [1–4]. To realize high-quality high-performance lasers, excellent optical cavities are needed. Among various methods to synthesize ZnO microstructure or nanostructure cavities [5,6], hydrothermal method is considered to be an easy and inexpensive way [6]. However, optical properties of hydrothermal ZnO are often poor, which prevents the realization of reliable high-performance ZnO lasers. As reported by Qiu et al. [7], quality (Q) factor of hydrothermal ZnO microcavity with diameters ranging from 150 to 1000 nm is 540 while the Q factor is larger than 600 for chemical vapor deposition (CVD) samples with similar dimensions. It is still challenging to effectively improve structural properties of hydrothermal ZnO for enhanced optical performance.

Graphene, which consists of a monolayer honeycomb lattice of carbon atoms, has attracted a great deal of attention since its discovery in 2004 due to its remarkable properties [8,9]. Recently, many researchers have proved that graphene is an excellent template for epitaxy of semiconductors with high crystal quality. For examples, Chung et al. [10] obtained good-performance light emitting diodes based on epitaxial GaN on graphene using ZnO nanowalls as intermediate layer; Baek et al. [11] achieved epitaxial GaN microdisks using patterned graphene nucleation layers on silicon dioxide and demonstrated whispering gallery mode lasing behaviors of these microdisks. More interestingly, the optical performance of wide bandgap semiconductors such as GaN and ZnO can be significantly enhanced when graphene is attached to these semiconductors because graphene is a material with strong surface plasmon (SP) response in the UV range [12,13]. Some representative research results have been published, for examples, Hwang et al. [14] revealed a SP dispersion relation and demonstrated the resonant excitation of graphene SP and its contribution to ZnO photoluminescence (PL); Liu et al. [15] reported three-time enhanced PL of ZnO microwires coated with gold nanoparticles and a graphene layer. All the reports above show that it is possible to achieve high-performance lasers by forming high-quality ZnO/graphene hybrid cavity through the combination of ZnO and graphene.

Different from previous reports, Qin et al. [16] now proposed a novel way to grow hydrothermal ZnO microrods directly and vertically on graphene. Their results have been published as the story on the front cover of *Journal of Materials Chemistry C*. In this paper, a single-layer graphene was utilized as buffer layer to grow ZnO microrods vertically. Fig. 1a shows the schematic of the ZnO/graphene system, and the inset is a scanning electron microscope (SEM) image of an individual ZnO microrod. Fig. 1b shows PL spectra from an individual ZnO microrod on graphene at difference excitation powers, and Fig. 1c shows energy dispersive X-ray (EDX) mapping results of Zn, O and C elements, which verify the structure. Due to the effect of graphene, ZnO microrod structures are improved, leading to improved optical properties such as increased exciton recombination rates. Single-mode lasing is realized in an individual rod, as shown in Fig. 1b. The lasing performance is better than other hydrothermal samples and the Q factor is above 900. Similar single-mode lasing of graphene-covered ZnO sample was realized by Li et al. [17]. Besides the improvement of the structural properties of hydrothermal ZnO microrods, the lasing improvement is also ascribed to the coupling of graphene SP and ZnO excitonic mode.

To conclude, what Qin et al. [16] have achieved in this effort is the demonstration of a strategy for yielding single-mode lasing in ZnO microrod structures of several micrometers. This work is an important step towards electrically pumped ZnO single-mode UV lasers on various substrates such as Si and plastics.

Conflict of interest

The author declares that he has no conflict of interest.

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https://doi.org/10.1016/j.scib.2018.04.019

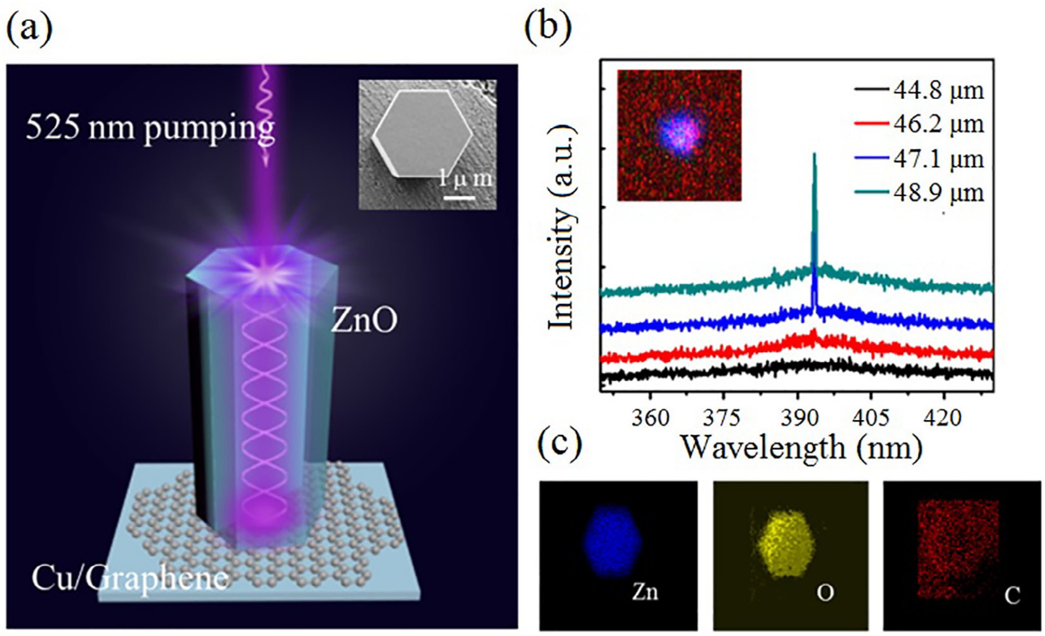

Fig. 1. A ZnO/graphene single-mode laser. (a) Schematic of a vertical ZnO microlaser optically excited with a 325 nm fs laser. The inset shows an SEM image of individual ZnO microrod. (b) Lasing spectra of individual ZnO microrod under different excitation power. (c) EDX mapping of ZnO on graphene.

Acknowledgments

The author acknowledges the support by SHINES, an Energy Frontier Research Center funded by the US Department of Energy, Office of Science, Basic Energy Sciences under Award # SC0012670.

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Jianlin Liu received his Ph.D. degree in Electrical Engineering from UCLA in 2003. Since March 2003, Dr. Liu joined Department of Electrical and Computer Engineering at UC Riverside, where he is currently a Professor. The areas of his research interest include semiconductor thin films, nanowires, quantum dots, and their optoelectronic and nanoelectronic devices.