

Novel Physical Properties of Nanomaterials

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Nanostructures with large surface areas and possible quantum-confinement effects exhibit distinct electronic, optical, mechanical and thermal properties and are believed to be essential to much of modern science and technology. Some of the most important and widely studied candidates in the family of nanomaterials are metal oxides nanostructures. In our lab, many nanostructures have been fabricated and the physical properties are investigated. Our results give a proof-of-principle demonstration of applications based on semiconductor nanomaterials.

Recently, we developed a new method with more practical attributes such as mass production, rapid growth, catalyst-free, materials-diversified, low-formation temperature, reasonably low costs and ease of nanomaterials assembly onto various substrates for further characterizations and applications (Figure 1).

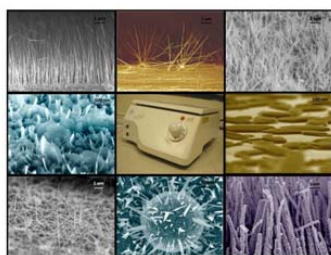


Figure 1: Electron micrographs of our nanostructures

For example, field induced electron emission of individual nanowires and nanowire array are investigated (Figure 2), which shows that they can become the potential candidates for use in future field emission electron sources and displays (FEDs).

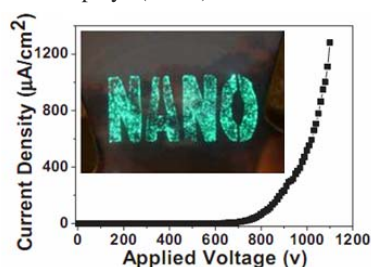


Figure 2: Field emission properties of nanowire arrays

Field effect transistors (FETs) form the basis of most of our present small-signal electronics industry, in particular logic circuits used in computers. Conventional FETs are fabricated by using a highly complicated top-down approach, which, in spite of the long lifetime of Moore's law, is expected to reach its limit in the near future. This, together with the rapidly increasing costs of continuing miniaturization, has driven the search for completely different methods of electronic-circuit fabrication. A bottom-up approach is an obvious choice. The leading contenders for such bottom-up FETs are 1D nanotubes and nanowires. Recently, we reported the fabrication and characterization of ZnO nanowire memory devices using a ferroelectric $\text{Pb}(\text{Zr}_{0.3}\text{Ti}_{0.7})\text{O}_3$ (PZT) film as the gate dielectric and the charge storage medium (Figure 3). Our results demonstrate the memory application based on a combination of nanowires (as channels) and ferroelectric films (as gate oxide).

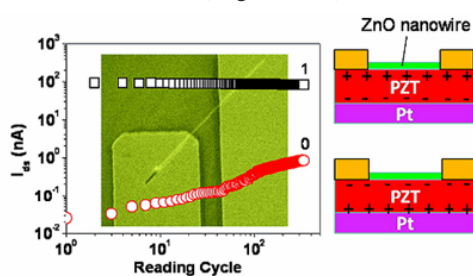


Figure 3: SEM image and field effect model of a nanowire FET.

The fabrication of one-dimensional single-crystal nanomaterials is of great scientific interest and technological significance, which will bring about the impetus of photonic integration and promote the development of optical information technology. Considering the smooth surface and high refractive index which give rise to the tight optical confinement, efficient light propagation in V_2O_5 nanoribbons was demonstrated (Figure 4). The results provide useful information for the construction of future nanoscaled waveguide structures. Moreover, regular V_2O_5 waveguides were found to exhibit Raman signals with near-resonance excitation and guide these modes through the nanoribbon cavity. The results provide experimental support for the development of novel nanophotonic elements.

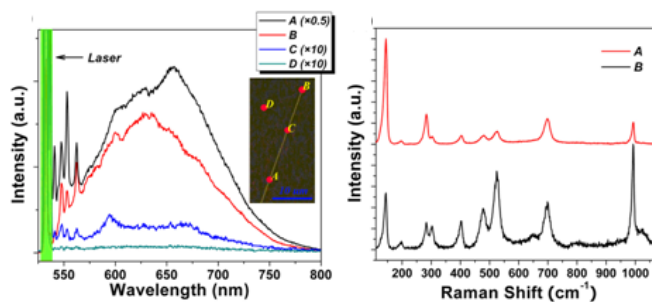


Figure 4: Spatially resolved waveguiding emission spectra and the corresponding Raman signals

In addition, with the rise of graphene, engineering band structures of graphene and developing graphene-based materials for new energy, will be a promising direction for our further research on nanomaterials (Figure 5).

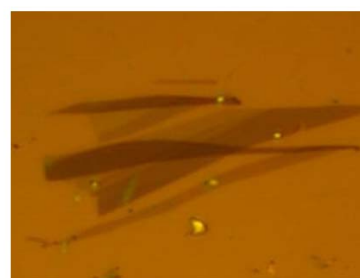


Figure 5: Optical microscope image of graphene.

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Selected Publications:

1. T Yu, YW Zhu, XJ Xu, ZX Shen, P Chen, CT Lim, JTL Thong and CH Sow, *Advanced Materials*, 17, 1595, (2005).
2. T Yu, YW Zhu, XJ Xu, KS Yeong, ZX Shen, P Chen, CT Lim, JTL Thong and CH Sow, *Small*, 2, 80, (2006).
3. Z. Ni, H. M. Wang, J. Kasim, H. M. Fan, T. Yu, Y. H. Wu, Y. P. Feng, Z. X. Shen, *Nano Lett.* 7, 2758, (2007).
4. Z. Zheng, B. Yan, Y.M. You, JX. Zhang, Z.X. Shen, C-T. Lim, T. Yu, *Adv. Mater.* 20, 352, (2008).
5. B. Yan, L Liao, Y.M. You, XJ Xiu, Z Zheng, ZX Shen, J Ma, LM Tong, T Yu, *Adv Mater* (accepted).
6. L. Liao, HJ Fan, B. Yan, Z. Zhang, L. L. Chen, B. S. Li, G. Z. Xing, Z. X. Shen, T. Wu, X. W. Sun, J. Wang, and T. Yu, *ACS Nano* (accepted)