# ZnO nanostructures for e-paper and field emission display applications

X. W. Sun
School of Electrical and Electronic Engineering, Nanyang Technological University, Nanyang Avenue, Singapore 639798
exwsun@ntu.edu.sg

**Abstract**: Applying ZnO for e-paper and field emission display [Nano Lett. **8**, 1884 (2008) and Appl. Phys Lett. **91**, 163502 (2007)] is reviewed.

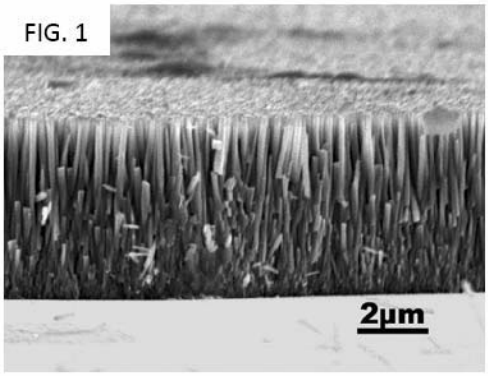
Electrochromic (EC) devices are capable of reversibly changing their optical properties upon charge injection and extraction induced by the external voltage. The characteristics of the EC device, such as low power consumption, high coloration efficiency, and memory effects under open circuit status, make them suitable for use in a variety of applications including smart windows and electronic papers. Coloration due to reduction or oxidation of redox chromophores can be used for EC devices (e-paper), but the switching time is slow (second level). Recently, with increasing demand for the low cost, lightweight flat panel display with paper-like readability (electronic paper), an EC display technology based on dye-modified $TiO_2$ nanoparticle electrode was developed. A well known organic dye molecule, viologen, was adsorbed on the surface of a mesoporous $TiO_2$ nanoparticle film to form the EC electrode. On the other hand, ZnO is a wide bandgap II-VI semiconductor which has been applied in many fields such as UV lasers, field effect transistors and transparent conductors. The bandgap of the bulk ZnO is about 3.37 eV, which is close to that of the $TiO_2$ (3.4 eV). As a traditional transparent conductor, ZnO has excellent electron transport properties, even in ZnO nanoparticle films. In the past few years, one-dimension (1D) nanostructures of ZnO have attracted extensive research interest. In particular, 1D ZnO nanowires renders much better electron transportation capability by providing a direct conduction path for electron transport and greatly reducing the number of grain boundaries. These unique advantages make ZnO nanowires a promising matrix electrode for EC dye molecule loading. ZnO nanowires grow vertically from the substrate and form a dense array (Fig. 1). The ZnO nanowires show regular hexagonal cross section and the average diameter of the ZnO nanowires is about 100 nm. The cross-section image of the ZnO nanowires array (Fig. 1) indicates that the length of the ZnO nanowires is about 6 μm. From one on/off cycle of the ZnO EC cell (Fig. 2). We can see that, the switching time of a ZnO nanowire electrode EC cell with an active area of 1 x 1 $cm^2$ is 170 ms and 142 ms for coloration and bleaching, respectively. The coloration and bleaching time is faster compared to the $TiO_2$ mesoporous EC devices with both coloration and bleaching time of about 250 ms for a device with an active area of 2.5 $cm^2$. With further optimization, it is possible that the response time can reach ten(s) of millisecond, i.e. capable of displaying video. Fig. 3 shows a prototype with two different transmittance states. It can be seen that good contrast was obtained. The retention was at least a few hours for these prototypes.

Being an oxide, ZnO is oxidation resistant, i.e. it is more durable for field emission cathode. ZnO nanotetropods were also applied to realize the first prototype triode field emission device, making use of scattered surface-conduction electrons for field emission (Fig. 4). The device has a high efficiency (field emitted electron to total electron ratio) of about 60%. With this high efficiency, we were able to fabricate some prototype displays (Fig. 5 showing some alphanumerical symbols). ZnO tetrapods have four legs, which guarantees that there is one leg always pointing upward, even using screen printing method to fabricate the cathode.

References

1. X. W. Sun and J. X. Wang, "A fast switching electrochromic display using a viologen-modified ZnO nanowire array electrode", Nano Lett. **8**, 1884 (2008), and references there in.
2. C. Li, Kai Hou, Wei Lei, Xiaobing Zhang and Baoping Wang, and X. W. Sun, "Efficient surface-conducted field emission from ZnO nanotetrapods", Appl. Phys. Lett. **91**, 163502 (2007), and references there in.

FIG. 1



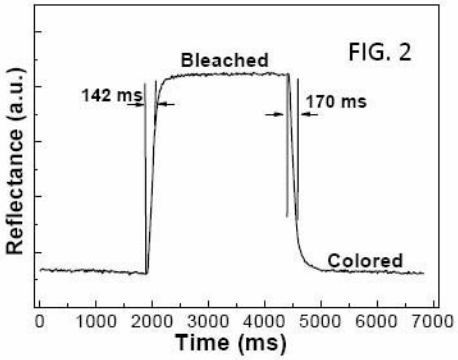




FIG. 2

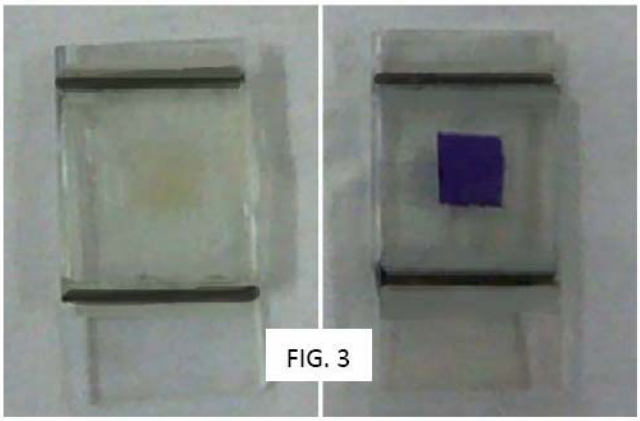


FIG. 3

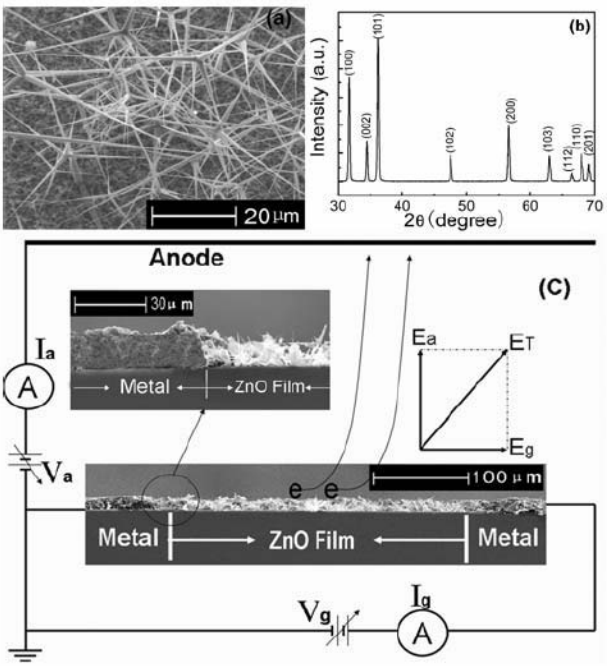



FIG. 4

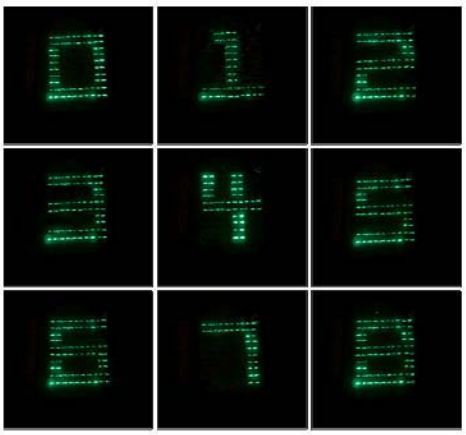


FIG. 5