Making a display just like printing a newspaper? The use of liquid metal EGaIn electrode has made that dream possible

Quantum dot light-emitting diode (QLED) is a promising candidate for the next generation display due to its advantages of high color saturation, tunable emission color and inherent high stability. Compared with organic light-emitting diode (OLED), QLED can be fabricated through solution-processed which makes the fabrication both low cost and compatible with printing technology. However, the back electrode, usually based on Al, Ag or Cu metal thin films, still need to be deposited by costly vacuum evaporation. To lower the fabrication cost and achieve full printing procession, the back electrode should also be deposited by solution/printing methods. The traditional solution-processable conductive materials such as Ag paste, metal nanowires, graphene and/or carbon nanotubes are usually dissolved in organic solvents, and during the coating processes, the underneath functional layers could be dissolved and damaged by these solvents, further leading to the instability even failure of the devices.

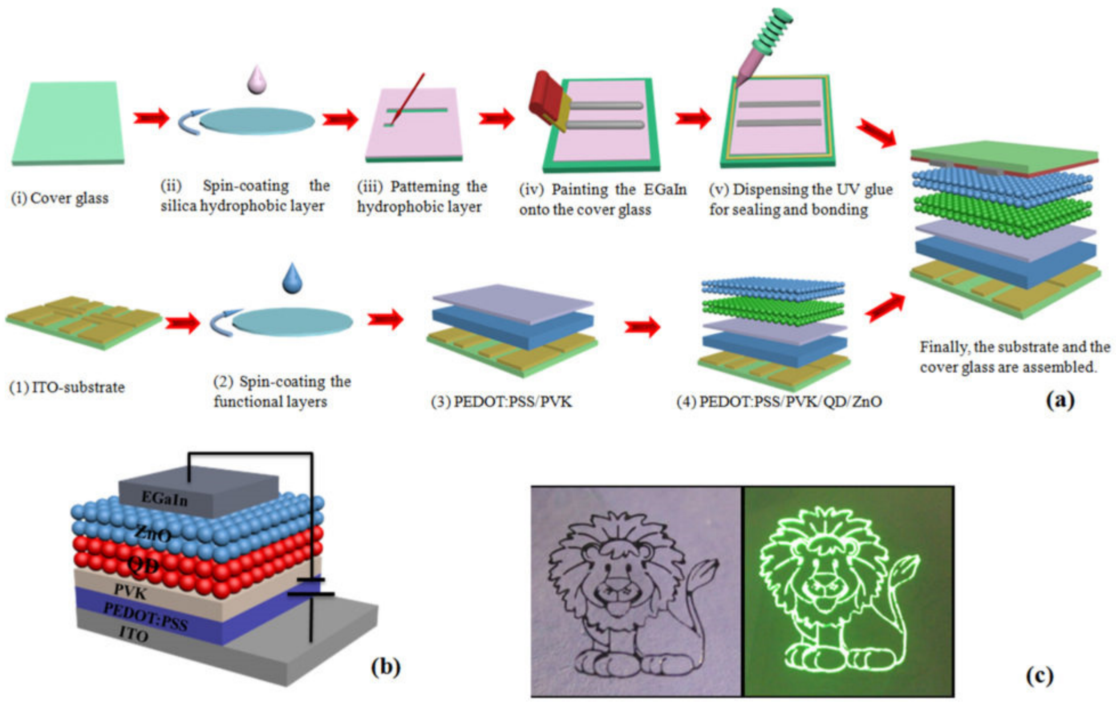

Fig. 1. (a) The fabrication processes of the QLED, (b) The structure of the QLED, (c) Photos of the fully printed QLED display.

Therefore, to avoid the damage and improve the stability, it is necessary to develop a solvent-free printable electrode material. Researchers in Southern University of Science and Technology have recently proposed a method to apply liquid gallium alloys as a printable electrode for QLED. The study had been published on the *Nanoscale*. Eutectic gallium indium (EGaIn, 75 wt% Ga, 25 wt% In) have a low melting point <15.7 °C, and thus it is in liquid state at room temperature. It can be easily deposited and patterned by printing methods. In addition, the liquid metal alloy does not contain organic solvents and thus does not need high-temperature thermal-annealing treatment. Plus the high electrical conductivity and appropriate work function, it is a promising printable electrode material for QLED.

During the fabrication process, the functional layers are spin-coated on the pre-patterned ITO substrate, while the EGaIn cathode is printed onto the cover glass (Fig. 1). Finally, the functional layer-coated-substrate and the EGaIn-coated-cover glass are assembled together and sealed by UV epoxy. Because EGaIn is in liquid state and is soft in nature, a good electrical contact between the functional layers and the EGaIn can be obtained. With printed EGaIn cathodes, vacuum-free-processed QLEDs exhibit high external quantum efficiency (EQE) of 11.51%, 12.85% and 5.03% for R-, G- and B-devices, respectively, which are about 2-, 1.5- and 1.1-fold higher than those of the devices with thermally evaporated Al cathodes. The improved performance is attributable to the reduction of electron injection by the native oxide of EGaIn, which serves as an electron-blocking layer for the devices and improves the balance of carrier injection.

The results demonstrate EGaIn-based solvent-free liquid metals are promising printable electrodes for realizing efficient, low-cost and vacuum-free-processed QLEDs. The elimination of vacuum and high-temperature processes significantly reduces the production cost and paves the way for industrial roll-to-roll manufacturing of large area displays.

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