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Soldering of solution-processed organic vertical transistor and light-emitting diode on separate glass substrates by tin micro-balls ☆

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ABSTRACT

The vertical organic space-charge-limited transistor made of P3HT and small-molecule phosphorescent organic light-emitting diode (OLED) are made on two separate glass substrate by blade coating, then soldered vertically together by tin balls with 40 μm diameter. The soldering is done by hot wind of 150 °C for 5 min Contact resistance is only 10 Ω. The vertical transistor is annealed at 150 °C for 5 min before soldering to enhance the output current up to 25 mA/cm^2 and give high thermal stability. Both OLED and the annealed vertical transistor are not affected by the soldering process. The vertical transistor has 1/4 of the OLED area and turns on the bottom-emission white OLED up to 300 cd/m^2 and orange OLED up to 600 cd/m^2. The entire operation is within 8 V. OLED and transistor array can therefore be made on separate glass substrates then soldered together to form the display.

1. Introduction

Active-matrix organic light-emitting diode (AMOLED) is an emerging technology for display. It has the advantages of good color quality, high response speed, and low thickness compared with the conventional liquid crystal display. A variety of vacuum-processed transistor backplanes are used for the pixel driving circuit of AMOLED including amorphous silicon, poly-crystalline silicon, oxide semiconductor like IGZO [1–3], and organic field-effect transistors [4,5]. The OLED and the transistor are usually fabricated on the same glass substrates [1–5]. The aperture ratio is limited by the pixel area occupied by the transistors, therefore the OLED can only have top emission [3]. In top-emission OLED the device structure is usually more complicated and the view angle is narrow because of the optical cavity effect. Furthermore, the efficiency of white OLED is greatly reduced in the top-emission structure relative to the conventional bottom emission structure. This is because only part of the broad white emission spectrum matches the cavity resonance wavelength. For large area AMOLED white OLED in combination with color filter has the great advantage that no patterning is necessary for all the organic semiconductor layers. Indeed the difficulty related to the shadow mask patterning for individual red, green, and blue OLED increases dramatically with display size. If the OLED and the transistor can be fabricated on separate substrates and connected together afterwards, OLED with convenient bottom emission structure and white OLED without any patterning can be used in AMOLED. In addition, such

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afterward connection avoids the potential conflict in OLED and transistor process temperature and the devices can be individually optimized. Connection of OLED and amorphous-silicon on separate substrates are reported by direct hard metal contact [6]. Without any soldering such contact gives high contact resistance [6], and poor uniformity is expected due to the inevitable random air gap up to 10 μm between the glass substrates resulting from the glass unevenness. Large-area AMOLED will become practical only if both OLED and the transistor can be solution-processed without patterning, and they can be reliably soldered together after separated optimized fabrication.

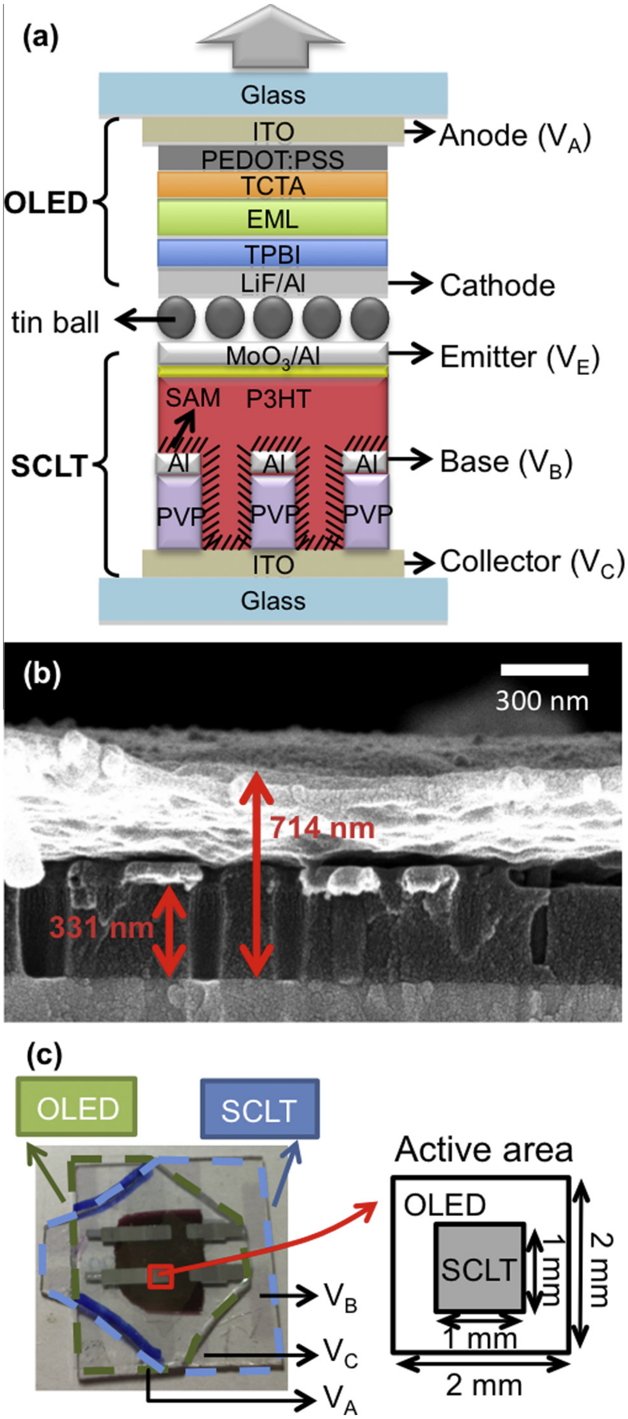

Fig. 1. (a) Schematic diagram of OLED and SCLT after soldering by tin balls. The device structure consists of two separate glass substrate, i.e., the bottom substrate involving SCLT with SAM treatment and the top substrate involving bottom-emission white OLED. (b) The SEM cross-section image of SCLT structure. (c) The active areas and relative position of the two devices.

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