Patterning of Zinc-Tin-Oxide TFTs Using an Electrohydrodynamic Jet Printer

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An oxide TFT has higher mobility than a-Si and a lower off-current than LTPS, so it is suitable for high-resolution and low-cost display panels. The most studied substance for oxide TFT is InGaZnO (IGZO), which applies to the current industrial manufacturing. However, In and Ga are in limited supply and expensive compared to Zn and Sn. Along with IGZO, zinc-tin oxide (ZTO) is a powerful amorphous oxide semiconductor. Sn increases the electron concentration as In, and it is about 70 times cheaper and less toxic than In.

The traditional vacuum and photolithography process is extremely complex, time-consuming, and costly because the process is repeated at each layer. The time and cost of the process can be reduced by direct patterning, which can circumvent the vacuum and photolithography process. It is also an environmentally friendly technology that can reduce chemical waste. Spin coating is mostly used, and ink-jet techniques are mostly applied for printing.

In the electrohydrodynamic (EHD) jet method, a solution is jetted by a voltage applied between the jetting tip and a substrate. The cone-jet discharge is smaller than the internal diameter of the tip. EHD-jet printing processes have been reported to make oxide TFTs. Oxide TFTs were also prepared by EHD jet spraying with high voltage, but the jetting was random with various drop sizes, resulting in irregular surfaces due to the coffee ring effect. IGZO prepared by cone-jet printing enables a very thin width with an expensive 1.5 μm glass capillary tip. The tip is difficult to fabricate, very brittle under pressure, and requires a gold or palladium coating process to apply a bias voltage between the tip and stage. Our research group studied oxide TFTs using EHD jet printing with a 0.1 mm metal tip instead.

Solution-processed zinc-tin oxide (ZTO) thin-film transistors (TFTs) were prepared using an electrohydrodynamic (EHD) jet printer with different patterning methods, line patterns and direct patterns with mask. The printing parameters were optimized to obtain suitable patterns and mask effects in the printing process with a low viscosity precursor solution. The electrical properties of the EHD jet-printed ZTO show a mobility of 7.0 cm^2/Vs, a threshold voltage of 7 V, and a subthreshold slope of 0.4 V/dec. The gate leakage current can be reduced by minimizing the overlap of active layer with source and drain electrodes without patterning the gate electrode because the patterning of the active layer more effectively controlled the gate leakage current. Blocking oxygen by passivation is the key to protect the threshold voltage shift under positive bias stress.