A 100X100 active-matrix microfluidic system based on high-voltage thin-film transistors

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Droplet-based digital microfluidics are useful alternative to channel-based continuous flow microfluidics. Particularly, droplets actuated by EWOD or DEP forces allow facile manipulation of droplets in large scale using microfabricated electrode arrays. In recent years, electrode arrays driven by active-matrix thin-film transistors (TFTs) are gaining increasing attention due to its automatic operation and potential in scalability. However, current TFTs from flat panel display industry operates at a voltage of 40-60 volts, and this voltage level is often insufficient in driving droplets with less polarity, which sometimes requires a driving voltage of more than 100 volts. Additionally, droplet heating required in applications such as on-chip PCR often expedite the threshold voltage shift in TFTs and render the TFTs unusable after prolonged period of heating and electrical biasing.

To address the limitations of current TFTs in actuating digital microfluidic platform, we design, fabricate and tested a new architecture of TFTs. The cross-sectional view of the new design and a fabricated device based on a-Si is shown in Fig. 1. By splitting channel into two sections and employing internal floating back gates, the new device can withstand high source-drain voltage while approximately maintains the same source-drain current level. Electrical characterizations of the device are shown in Fig. 2. The transfer curve (top left) and the output curve (top right) show a well-behaved a-Si TFT. The high-voltage biasing in Fig. 2 (bottom left) shows the new device can withstand up to ~ 390 volts before breakdown, which has much better high-voltage performance compared to conventional device structure. The device after breakdown is shown in Fig. 2 (bottom right).

A 100x100 AM array of electrodes driven by our high-voltage TFTs is fabricated through a multi-project on glass (MPG) program from Tianma (Fig. 3). With custom-built peripheral electronics and user-interface software, we build a droplet microfluidic platform, which is capable of fully automatic actuation of hundreds of droplets. By utilizing AI imaging sensing, we achieve droplet splitting with high accuracy (~2% CV). We also demonstrate that biologically meaningful applications such as sample preparations for genomics and proteomics analysis can be completed reliably on our platform.

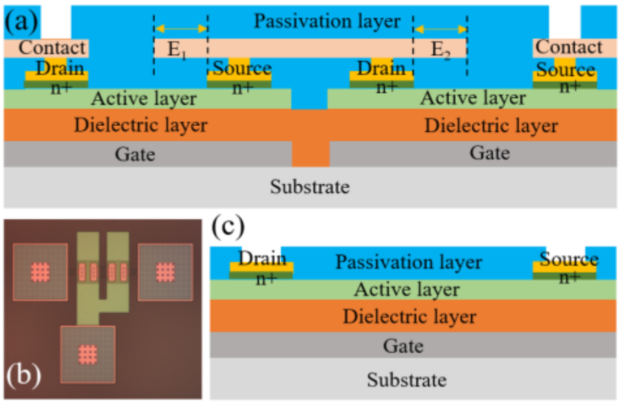

Fig. 1. (a) Device structure schematic for high-voltage TFT. (b) Optical image of high-voltage a-Si TFTs. (c) Device structure schematic of conventional a-Si TFTs for comparison.

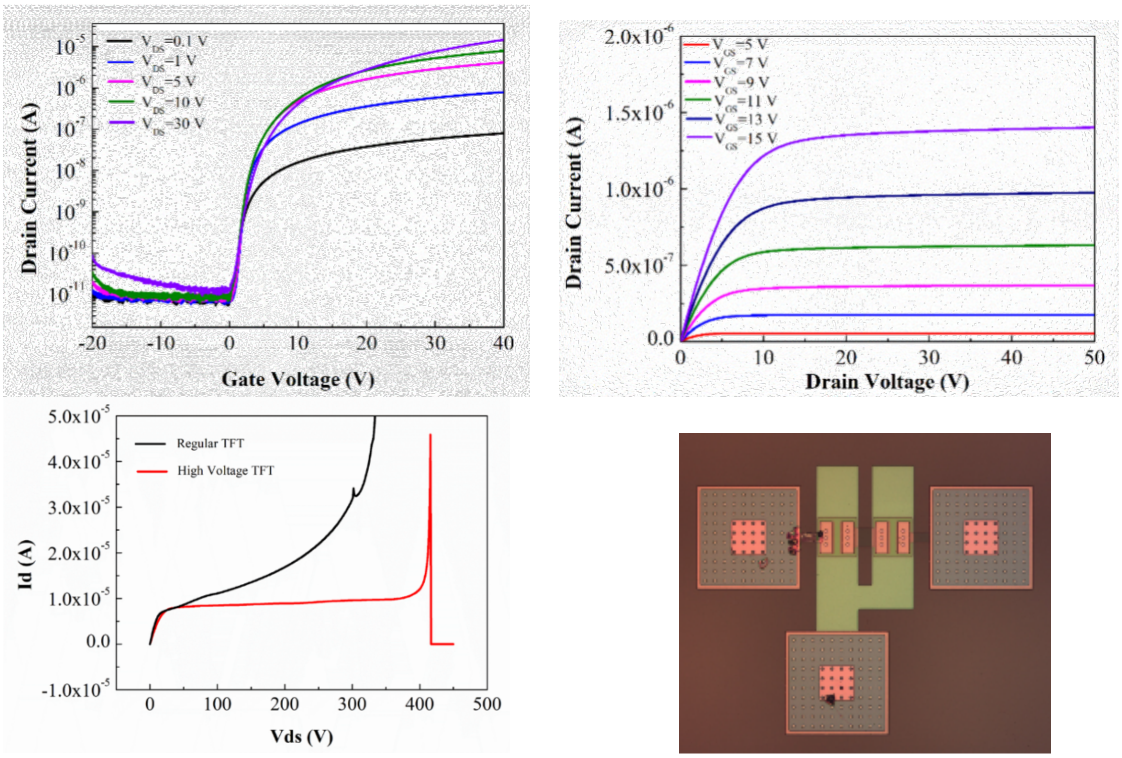

Fig. 2. Electrical performance of high-voltage a-Si TFTs. Top left: transfer curve; Top right: output curve; Bottom left: high-voltage performance; Bottom right: optical image after electrical breakdown.

Fig. 3. Left: Optical image of a 100x100 AM electrode array with high-voltage a-Si TFTs; Right: Parallel droplet actuation on digital microfluidic platform.