

## Single-grain Si TFTs fabricated by liquid-Si and long-pulse excimer-laser

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Printed flexible electronics will open novel applications with a lower cost compared with those based on the vacuum- and photolithography-process. While printed organic TFTs have been improving their performance in the last decade [1,2], the carrier mobility and reliability are much inferior in comparison with silicon devices. In 2006, Shimoda, et al., have reported that using liquid silicon, which is a hydrogenated polysilane in an organic solvent, amorphous Si can be printed and poly-Si TFTs have been fabricated with laser crystallization of the layer [3]. However the performance is limited by the grain boundaries in the channel because of the randomly positioned poly-Si grains. We have fabricated single-grain (SG) Si TFTs in location-controlled Si grains, which are formed with laser crystallization of a-Si using spin-coated liquid-Si [4]. Si grains with a diameter of 1.6  $\mu\text{m}$  at predetermined positions, and TFTs with the mobilities of 391  $\text{cm}^2/\text{Vs}$  and 111  $\text{cm}^2/\text{Vs}$  for the electrons and holes, respectively, have been achieved.

In this study, we have used a long-pulse excimer-laser for crystallization of the a-Si printed using the liquid-Si for further improvements in the grain size and field-effect mobilities.

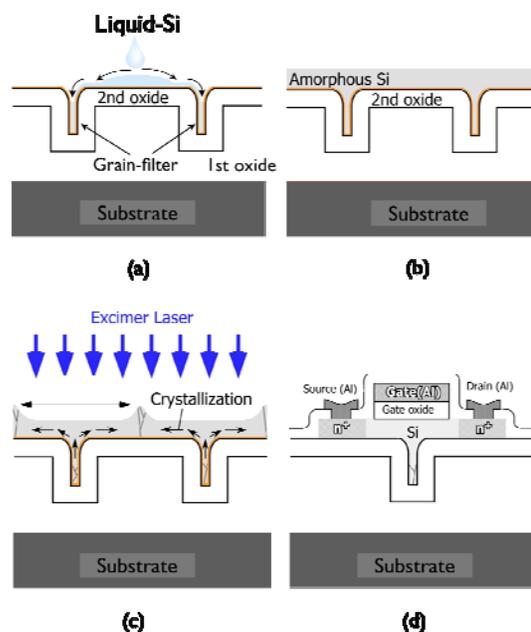
As shown in Fig. 1, liquid-Si was first spin-coated on the grain filters formed on oxidized silicon wafers [4] in a glove-box. After removal of the organic solvent, annealing at 450°C on a hotplate formed a-Si film. Raman spectroscopy showing a peak at 480  $\text{cm}^{-1}$  proves that it is an a-Si film. Then the film was dehydrogenated at 650°C for 1 hour and crystallized by XeCl excimer with a pulse-duration of 250ns at a substrate temperature of 450°C. As shown in Fig. 2, Si grains were obtained with the maximum grain size of 3.5  $\mu\text{m}$ . Compared with the short-pulse (25ns) excimer-laser case, the grain-size was increased because of the elongated pulse duration.

Then TFTs were fabricated inside the single-grain with the same process described in [4]. 41 nm thick gate  $\text{SiO}_2$  is formed by ICP oxidation at 250°C and successive PECVD TEOS deposition at 350°C. Source and drain region were ion implanted with phosphorous or boron and were activated by XeCl excimer laser. Aluminum pads formation completed the process. The width and the length of the TFTs are both 1  $\mu\text{m}$ .

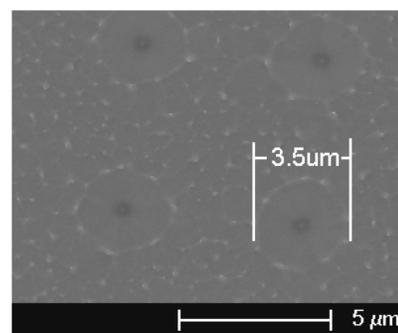
Figure 3 shows field-effect mobilities of the electron and holes as a function of the laser energy density. Carrier mobilities were estimated in the linear region at a low drain voltage in transfer characteristics of NMOS and PMOS SG-TFTs. Maximum mobilities for electrons and holes are 423  $\text{cm}^2/\text{Vs}$  and 118  $\text{cm}^2/\text{Vs}$ , which were obtained at 1000  $\text{mJ}/\text{cm}^2$  and 1050  $\text{mJ}/\text{cm}^2$ , respectively. The carrier mobilities were increased from our previous

results as a result of the longer solidification duration hence better crystalline quality.

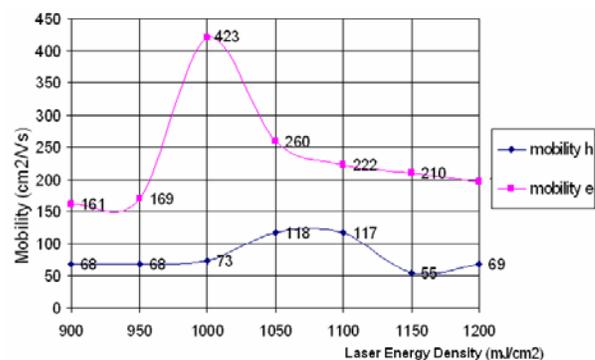
In summary, we have fabricated single-grain Si TFTs on location-controlled Si grains with long-pulse excimer laser crystallization of spin-coated liquid Si film. The maximum grain diameter is 3.5  $\mu\text{m}$ , and the mobilities for electrons and holes are 423  $\text{cm}^2/\text{Vs}$  and 118  $\text{cm}^2/\text{Vs}$  respectively.



**Figure 1:** Schematic view of the fabrication process of the single-grain Si TFT using the liquid-Si



**Figure 2:** SEM image of Si film after crystallization with the long pulse



**Figure 3:** Electron and hole mobilities vs. laser energy density

### Reference

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