All-Solution Approach to Oxide Thin-Film Transistor Fabrication using Photo-assisted Methods

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Amorphous oxide semiconductors, such as amorphous InZnO (IZO), have been established to result in high-performance thin-film transistors (TFTs) when fabricated using vacuum processes. However, research interests have recently shifted into solution approaches mainly to exploit its merits of high raw material utilization, low production energy requirement, and large-area scalability.[1] Although there have been few reports on all-solution-based oxide TFT fabrication, the devices either displayed poor mobility (μ) of <1 cm^2 V^{-1} s^{-1} [2] or employed complicated fabrication methods with various patterning steps and high temperature (>400˚C).[3] In this study, low-temperature ($T_{\max}$ = 300˚C) all-solution approach for oxide TFT fabrication is demonstrated using photo-assisted methods, namely UV and excimer laser irradiation.

Top gate oxide TFTs were fabricated by spin-coating IZO for channel and electrode materials, and fluorinated-polysiloxane (F-PSQ) for gate insulator as shown in the inset of Fig 1a. The self-aligned TFT structure enabled the semiconductor-to-conductor conversion of IZO electrode areas using photo-assisted methods as illustrated in the inset of Fig. 1c. Fig. 1a shows that switching cannot be achieved without any treatment. On the other hand, after subjecting the devices to UV treatment (λ=254 nm) (Fig. 1b) and a combination of UV and excimer laser (λ=248 nm) irradiation (Fig. 1c), the IZO were functionalized as electrodes which results in the TFT exhibiting proper switching characteristics. In addition, a combination of UV and excimer laser yields more stable transfer characteristics. Table 1 summarizes the electrical characteristics for UV and excimer laser irradiated samples where a laser fluence of 120 mJ cm^{-2} gives a high μ of 38.0 cm^2 V^{-1} s^{-1}. Our secondary ion mass spectrometry analysis shows incorporation of fluorine from the gate insulator into the channel which possibly contributed to the high μ by occupying oxygen vacancies (V_o) and donating free electrons due to electronegativity difference. Moreover, XPS, XRD, and STEM measurements suggest V_o generation and IZO crystallization after UV and excimer laser irradiation.

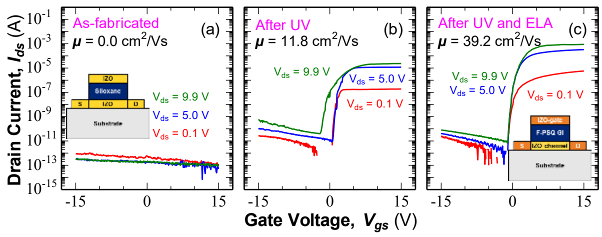

Fig. 1. Transfer characteristics of all-solution processed IZO TFT (a) without treatment and after (b) 60 mins UV and (c) additional excimer laser irradiation in vacuum at 120 mJ cm^{-2}.

Table 1. Summary of electrical characteristics of all-solution processed IZO TFTs irradiated with UV for 60 mins and excimer laser in vacuum

Fluence (mJ/cm^2)	μ (cm^2/Vs)	V_{on} (V)	SS (mV/dec)
100	23.9 ± 8.3	-0.2 ± 0.7	338 ± 155
120	38.0 ± 14.3	-0.4 ± 0.2	225 ± 49
140	26.7 ± 12.0	-0.3 ± 0.2	233 ± 52

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