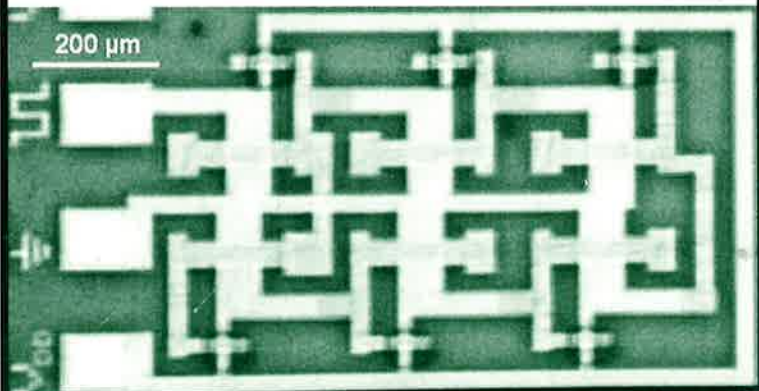
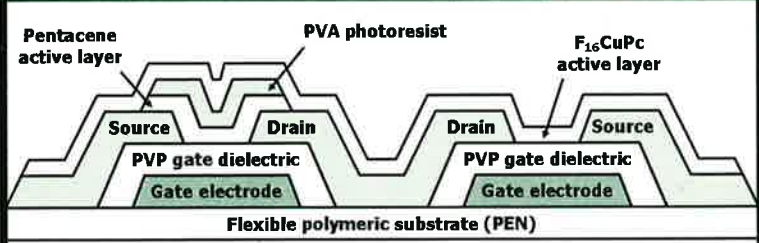
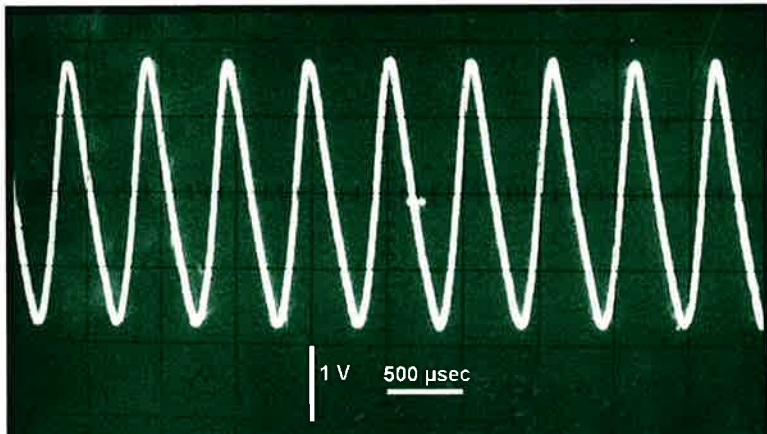


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Short Channel Amorphous-Silicon TFT's on High-Temperature Clear Plastic Substrates

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To achieve light-weight flexible AMOLED displays on plastic substrates, the substrates must be optically clear for the light emitted by a bottom-emitting OLED to pass through the transparent anode ITO and the substrate. Standard amorphous Si TFT's on glass (as for AMLCD's) are processed at ~250-350°C, which is too high for plastic. High-temperature plastics such as polyimide (e.g. Kapton® E) have a glass transition temperature(T_g) of ~350°C, and allow for TFT's with excellent performance at process temperatures of 150-180°C [1]. However, these substrates are not transparent (orange-brown). In this talk we present TFT's with excellent short-channel performance fabricated at temperature of 180 °C on clear plastic substrates.

The first OLED's on flexible clear plastic substrates were made on poly(ethylene terephthalate) (PET) [2], which has a T_g of ~ 70-100°C – too low for high quality a-Si:H TFT's. Clear poly(ethylene naphthalate) (PEN) has a T_g of ~ 120°C. Using the structure of Fig. 1, we have developed TFT's on PEN at a maximum temperature of 130°C. The electron mobility is 0.3 cm²/Vs vs. ~ 0.8 cm²/Vs for the TFT's fabricated at 150°C on Kapton E. In addition, the TFT's on PEN have high source-gate leakage current (up to 1 nA), that is a common problem for TFT's deposited at temperatures below 150°C. The low electron mobility would limit the brightness of the OLED's, and the high leakage current would hinder the data storage on a pixel capacitor (~ 2 pF) over a display frame time.

Higher deposition temperature and thus a higher T_g is required to decrease the leakage and increase the mobility of the TFT's. Making high-temperature substrates transparent is fundamentally related to a high coefficient of thermal expansion (CTE), leading to cracking of the TFT films with our standard process. Thus the TFT process temperature is not limited by the T_g of the substrate, but by the CTE mismatch between the substrate and the device layers. We then modified the TFT device structure and PECVD process to enhance the adhesion between the SiN_x buffer and the substrate. This yielded TFT's with no cracking and excellent performance (Fig. 3 and Fig. 4). For an 80μm/5μm TFT, the threshold voltage is 3.4 V, the ON/OFF ratio is ~10⁷, the linear mobility is 0.73cm²/Vs and the saturation mobility is 0.67 cm²/Vs. The source-gate leakage current is smaller than 0.01 nA, and it is limited by the measurement apparatus. The performance of the TFT's on this clear plastic substrate is as good as that of TFT's made on glass substrates at the same temperature (Fig. 5). In contrast to previous work on high temperature plastic substrates[3], the substrates were freestanding and not mounted to rigid substrates for fabrication, which is critical for maintaining a clean and clear back surface for the optical devices(e.g. OLEDs). These results will enable AMOLED displays on clear plastic substrates.

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[1] H. Gleskova, S. Wagner, and Z. Suo, *Mat. Res. Soc. Symp. Proc.* 508 (1998), p. 73.

[2] G. Gustafsson, Y. Cao, G. M. Treacy, F. Klavetter, N. Colaneri, and A.J. Heeger, *Nature* 357 (1992), p. 477.

[3] D.B. Thomasson, M. Bonse, R.J. Koval, J.R. Huang, C.R. Wronski, and T.N. Jackson, *Dev. Res. Con. Digest* (1998), p. 126.

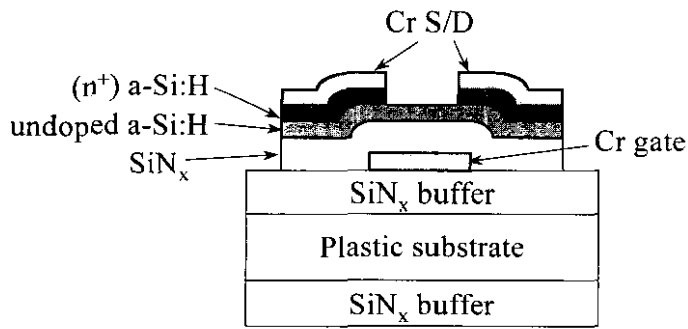


Figure 1. Schematic cross-section of a low-T a-Si TFT on plastic substrate [1].

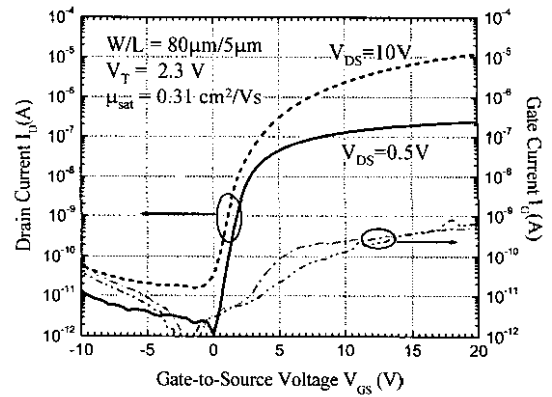


Figure 2. Transfer characteristics of a TFT on clear PEN substrate deposited at 130°C.

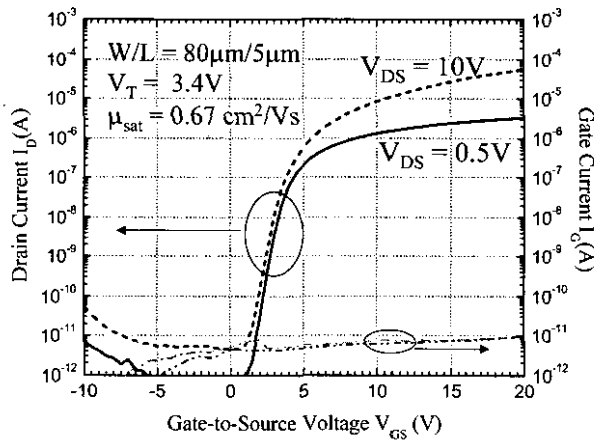


Figure 3. Transfer characteristics of a TFT on a new clear plastic substrate deposited at 180°C. Note the low leakage current and the improvement vs. Fig. 2.

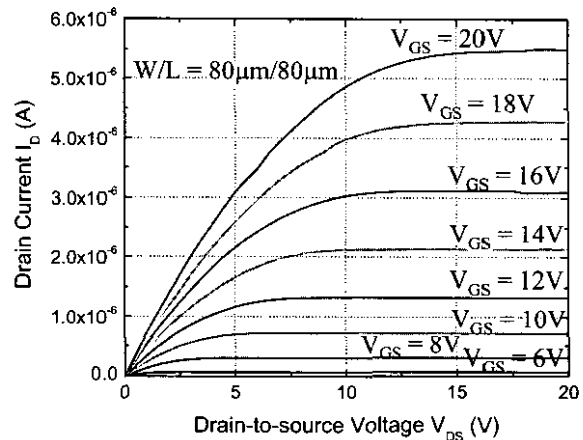


Figure 4. Output characteristics of a TFT on a new clear plastic substrate deposited at 180°C.

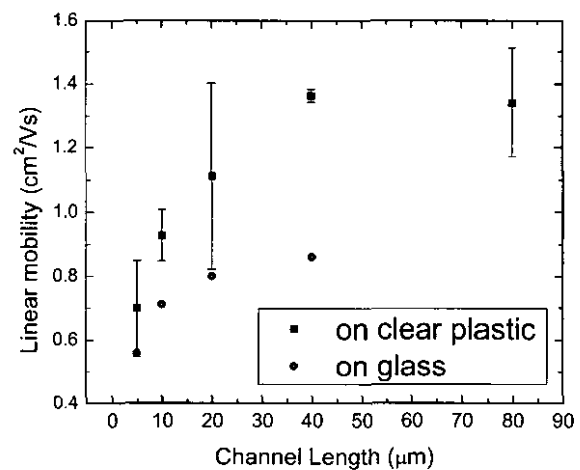
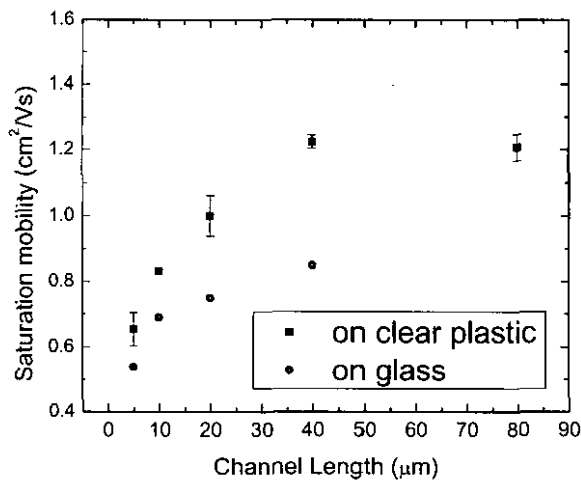


Figure 5. Mobility vs. channel length for a-Si:H TFTs on clear plastic and glass substrates. $W=80\mu\text{m}$. Left: Saturation region; Right: Linear region.