Supplementary Information (SI) for Journal of Materials Chemistry C.


# **Supporting Information**:

# Stability of Low Voltage Hygroscopic Insulator P3HT Transistors

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## EVOLUTION OF TRANSFER CURVES WITH TIME

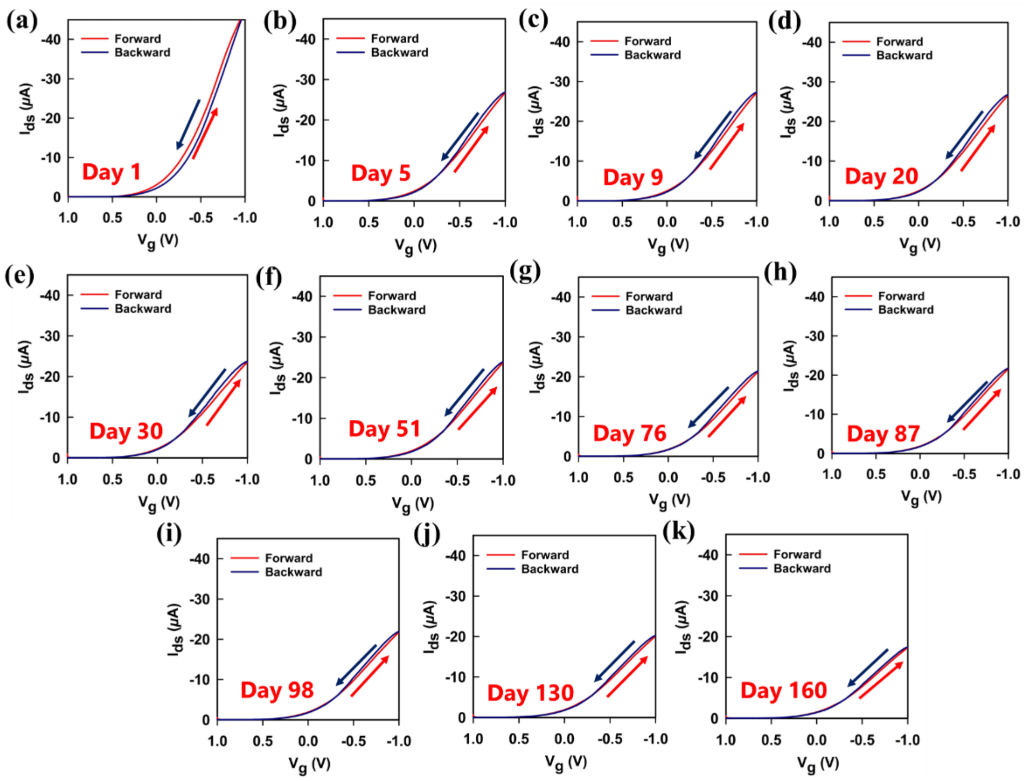


**Figure S1**. Transfer chracteristics of HIFETs stored under ambient condition over time, measured at $V_{ds}$= -1V.

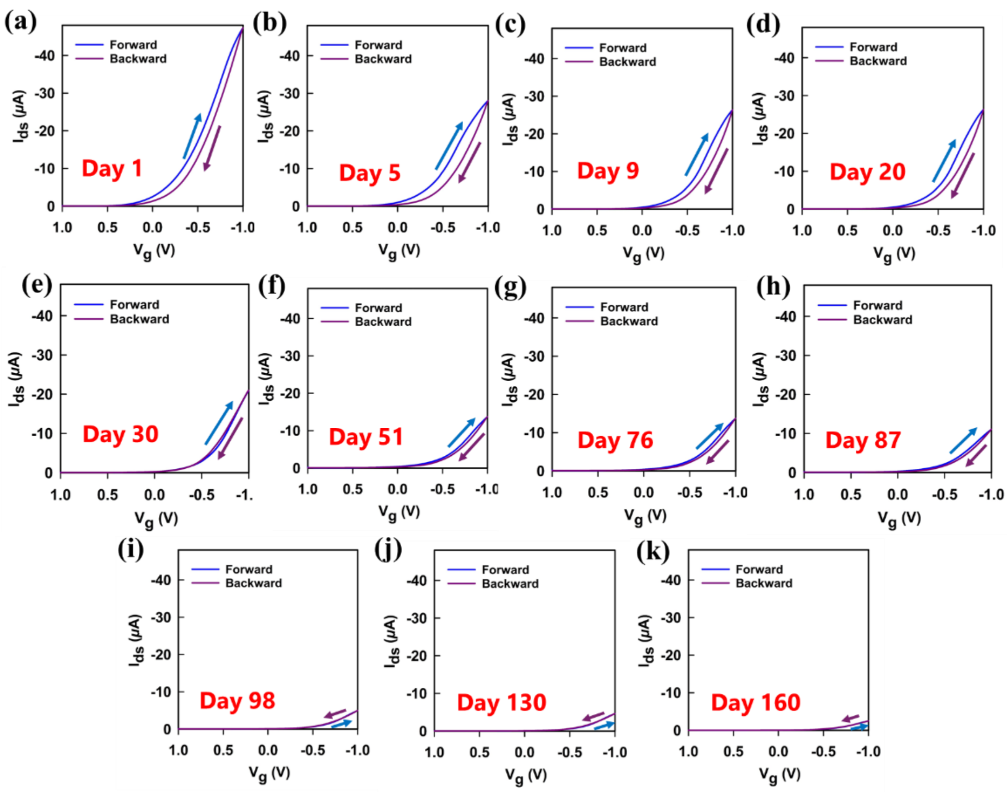


**Figure S2**. Transfer chracteristics of HIFETs stored under high *RH* condition over time, measured at $V_{ds}$= -1V.

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## EVOLUTION OF FIGURES OF MERIT WITH TIME

**Product of Saturation mobility and capacitance ($\mu_{sat} \times C$):** We estimated the field effect saturation mobility using the standard gradual channel approximation equation:

$$\mu_{sat} \times C = \frac{2L}{W}\left(\frac{\partial\sqrt{I_{ds}}}{\partial V_g}\right)^2$$

Here, L and W represent the channel length and width, and $C$ is the dielectric capacitance per unit area. The slope of the linear fit to the $\sqrt{I_{ds}}$ versus $V_g$ curve used in threshold voltage extraction, is used to estimate $\left(\frac{\partial\sqrt{I_{ds}}}{\partial V_g}\right)$.

**Transconductance ($g_m$/W):** It was determined by first fitting a polynomial function to the transfer curve$\left({\partial I_{ds}}/{\partial V_g}\right)$.We then took the derivative of this fitted curve with respect to and the maximum value of this derivative was reported as the peak transconductance. To account for device geometry, the calculated transconductance was divided by the channel width (10 mm), resulting in a normalized value of $g_m$/W.

**Table S1**. Figure of merits  of HIFETs stored under ambient condition.

| | Day1 | Day 5 | Day 9 | Day 20 | Day 30 | Day 51 | Day 76 | Day 87 | Day 98 | Day 130 | Day 160 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***OFF*** (μA) | 0.020 ± 0.006 | 0.030 ± 0.005 | 0.038 ± 0.002 | 0.039 ± 0.002 | 0.039 ± 0.005 | 0.038 ± 0.004 | 0.039 ± 0.002 | 0.041 ± 0.002 | 0.042 ± 0.005 | 0.044 ± 0.003 | 0.046 ± 0.004 |
| ***ON*** (μA) | 42 ± 3 | 34 ± 2 | 30 ± 2 | 26 ± 2 | 25 ± 2 | 24 ± 1 | 21 ± 2 | 20 ± 2 | 20 ± 2 | 20 ± 2 | 19 ± 2 |
| ***ON/OFF*** | 1521 ± 287 | 1418 ± 390 | 922 ± 100 | 644 ± 90 | 629 ± 92 | 618 ± 86 | 600 ± 78 | 598 ± 100 | 580 ± 105 | 576 ± 96 | 545 ± 92 |
| $V_{TH}$ (V) | 0.23 ± 0.05 | 0.29 ± 0.04 | 0.31 ± 0.05 | 0.31 ± 0.07 | 0.32 ± 0.06 | 0.32 ± 0.06 | 0.38 ± 0.04 | 0.38 ± 0.05 | 0.40 ± 0.06 | 0.41 ± 0.09 | 0.43 ± 0.08 |
| $g_m/W$ (μS/mm) | 6.04 ± 0.35 | 4.96 ± 0.28 | 4.56 ± 0.51 | 4.23 ± 0.26 | 4.01 ± 0.37 | 3.20 ± 0.20 | 2.70 ± 0.21 | 2.70 ± 0.27 | 2.60 ± 0.29 | 2.50 ± 0.37 | 2.47 ± 0.44 |
| $\mu_{sat} \times C$ ($cm^2F/Vs$) | 0.33 ± 0.01 | 0.31 ± 0.01 | 0.30 ± 0.03 | 0.28 ± 0.05 | 0.21 ± 0.06 | 0.17 ± 0.07 | 0.14 ± 0.06 | 0.13 ± 0.05 | 0.13 ± 0.06 | 0.12 ± 0.07 | 0.10 ± 0.09 |

**Table S2**. Figure of merits  of HIFETs stored under high *RH* condition.

| | Day1 | Day 5 | Day 9 | Day 20 | Day 30 | Day 51 | Day 76 | Day 87 | Day 98 | Day130 | Day160 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***OFF*** (μA) | 0.020 ± 0.008 | 0.030 ± 0.005 | 0.051 ± 0.002 | 0.057 ± 0.002 | 0.058 ± 0.005 | 0.059 ± 0.003 | 0.060 ± 0.002 | 0.061 ± 0.002 | 0.065 ± 0.002 | 0.068 ± 0.003 | 0.069 ± 0.004 |
| ***ON*** (μA) | 43 ± 3 | 35 ± 2 | 30 ± 2 | 23 ± 2 | 18 ± 2 | 16 ± 1 | 12 ± 2 | 11 ± 2 | 10 ± 2 | 9 ± 2 | 9 ± 2 |
| ***ON/OFF*** | 1489 ± 391 | 1106 ± 241 | 904 ± 97 | 632 ± 89 | 500 ± 90 | 477 ± 82 | 286 ± 74 | 270 ± 94 | 262 ± 89 | 230 ± 79 | 189 ± 96 |
| $V_{TH}$(V) | 0.25 ± 0.06 | 0.28 ± 0.06 | 0.36 ± 0.07 | 0.39 ± 0.06 | 0.42 ± 0.06 | 0.54 ± 0.05 | 0.60 ± 0.04 | 0.62 ± 0.05 | 0.63 ± 0.06 | 0.68 ± 0.09 | 0.72 ± 0.07 |
| $g_m/W$ (μS/mm) | 6.04 ± 0.35 | 5.38 ± 0.28 | 5.32 ± 0.29 | 4.28 ± 0.38 | 3.80 ± 0.36 | 3.12 ± 0.34 | 2.70 ± 0.49 | 2.22 ± 0.42 | 2.10 ± 0.40 | 1.68 ± 0.42 | 1.29 ± 0.46 |
| $\mu_{sat} \times C$ ($cm^2F/Vs$) | 0.30 ± 0.01 | 0.30 ± 0.02 | 0.28 ± 0.03 | 0.26 ± 0.02 | 0.19 ± 0.02 | 0.18 ± 0.03 | 0.10 ± 0.06 | 0.09 ± 0.05 | 0.82 ± 0.07 | 0.06 ± 0.09 | 0.04 ± 0.05 |

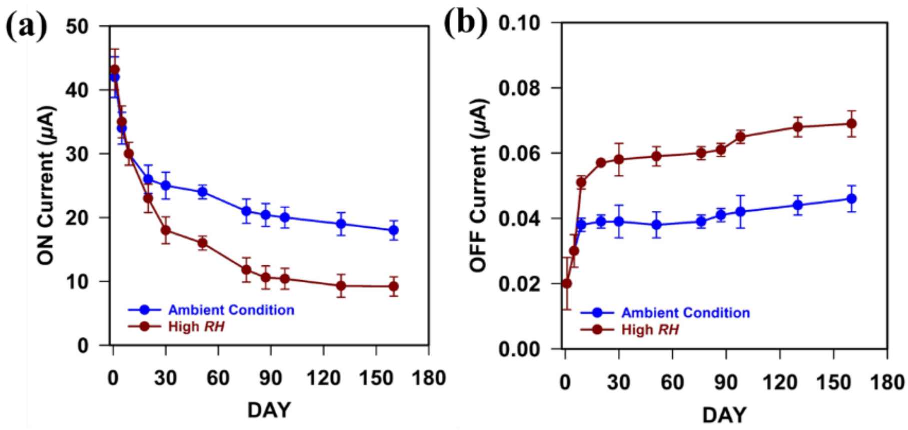


**Figure S3**. Changes in (a) ON and b) OFF currents of HIFETs stored under ambient and high *RH* conditions over time.

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**PERCENTAGE OF WORKING DEVICE WITH TIME**

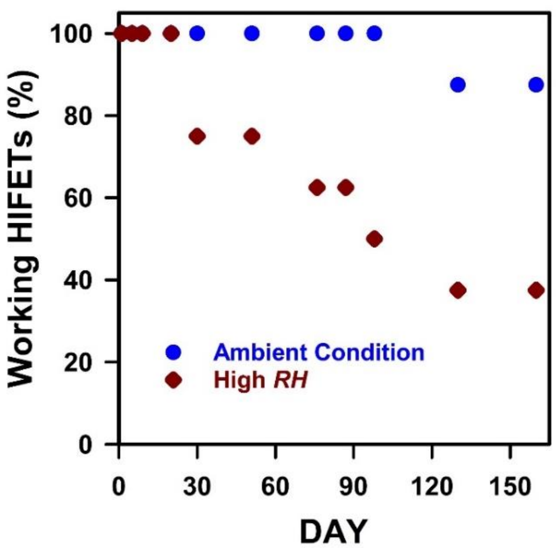


**Figure S4**. Percentage of working HIFETs stored under ambient and high *RH* conditions.

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**EVOLUTION OF SURFACE MORPHOLOGY WITH TIME**

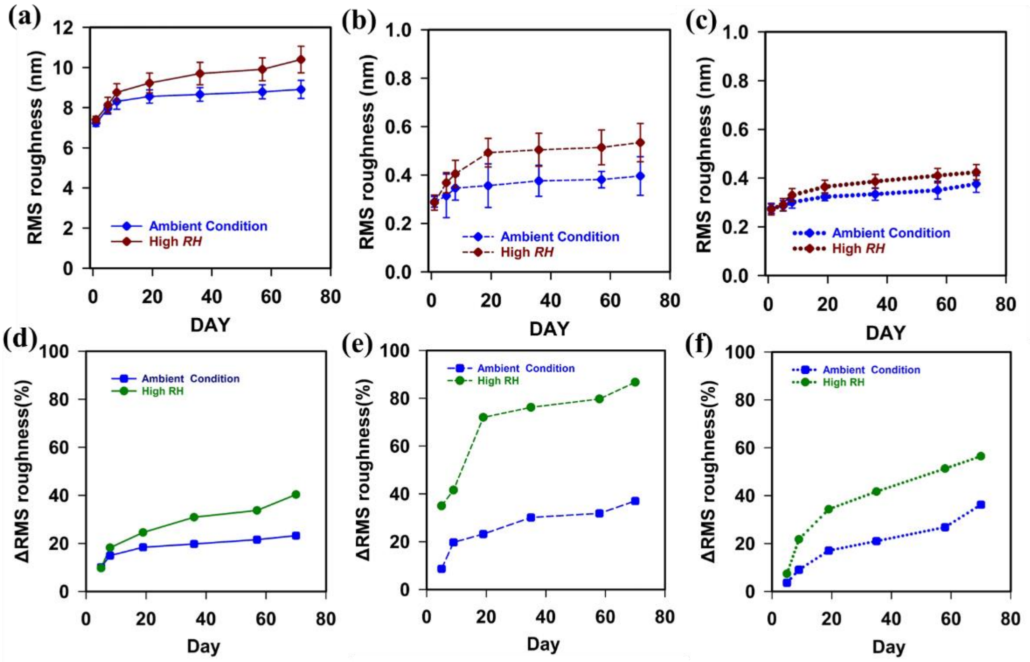


**Figure S5:** Changes in root mean square(RMS) roughness of (a) P3HT, (b) PVP and (c) P3HT/PVP films under ambient and high RH conditions. Percentage change in root mean square roughness for (d) P3HT, (e) PVP and (f) P3HT/PVP films under ambient and high RH conditions with time from day 1.

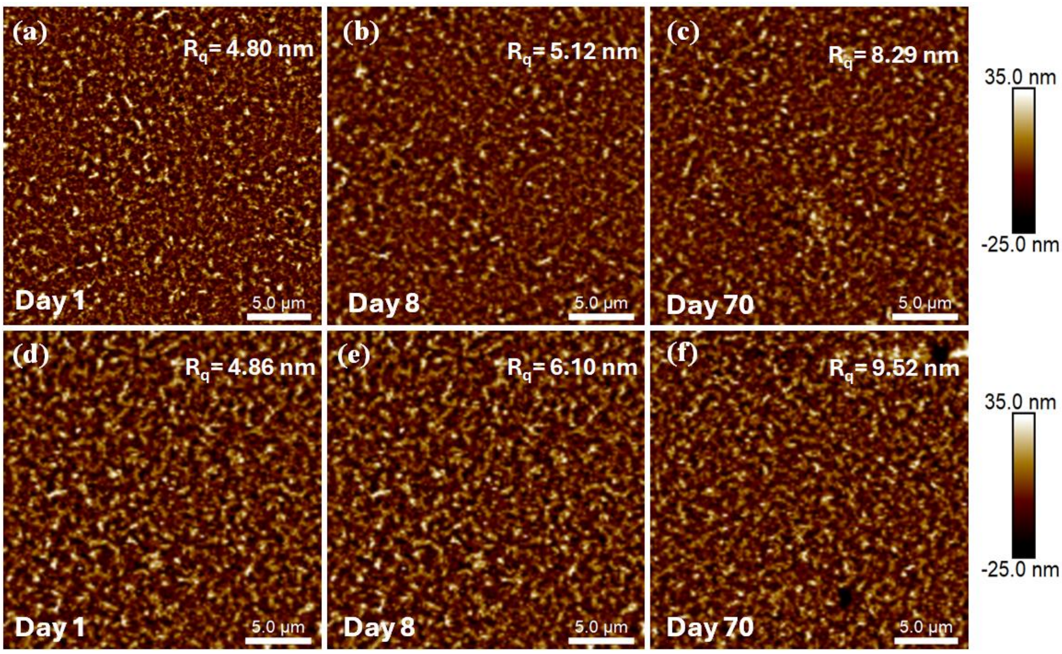


**Figure S6.** AFM images of P3HT films over time, stored in (a-c) ambient and (d-f) high *RH* conditions.

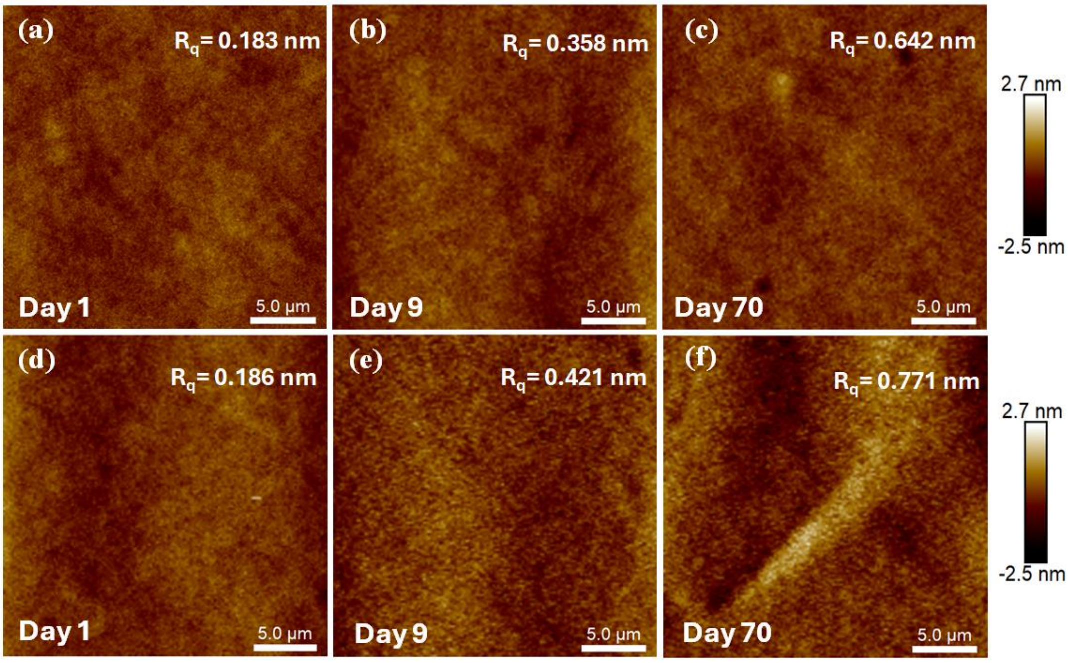


**Figure S7.** AFM images of PVP films over time, stored in (a-c) ambient and (d-f) high *RH* conditions.

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## CONDUCTANCE OF FILMS

We measured the current response of the thin films by applying a voltage sweep ($-1V \leq V \leq 1V$). From the linear fit, the conductance, G, (given by the slope) was extracted.

$$G = \frac{\Delta I}{\Delta V} \tag{1}$$

The change in conductance ($\Delta C$) was calculated using this formula:

$$\Delta\text{Conductance } (\Delta C) = \frac{Day\ x - Day\ 1}{Day\ 1} \times 100\ \% \tag{2}$$

Here, day x represents the conductance measured on a specific day of the experiment, while day 1 refers to the conductance recorded on the first day of measurement.

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## OPTICAL PROPERTIES OF FILMS

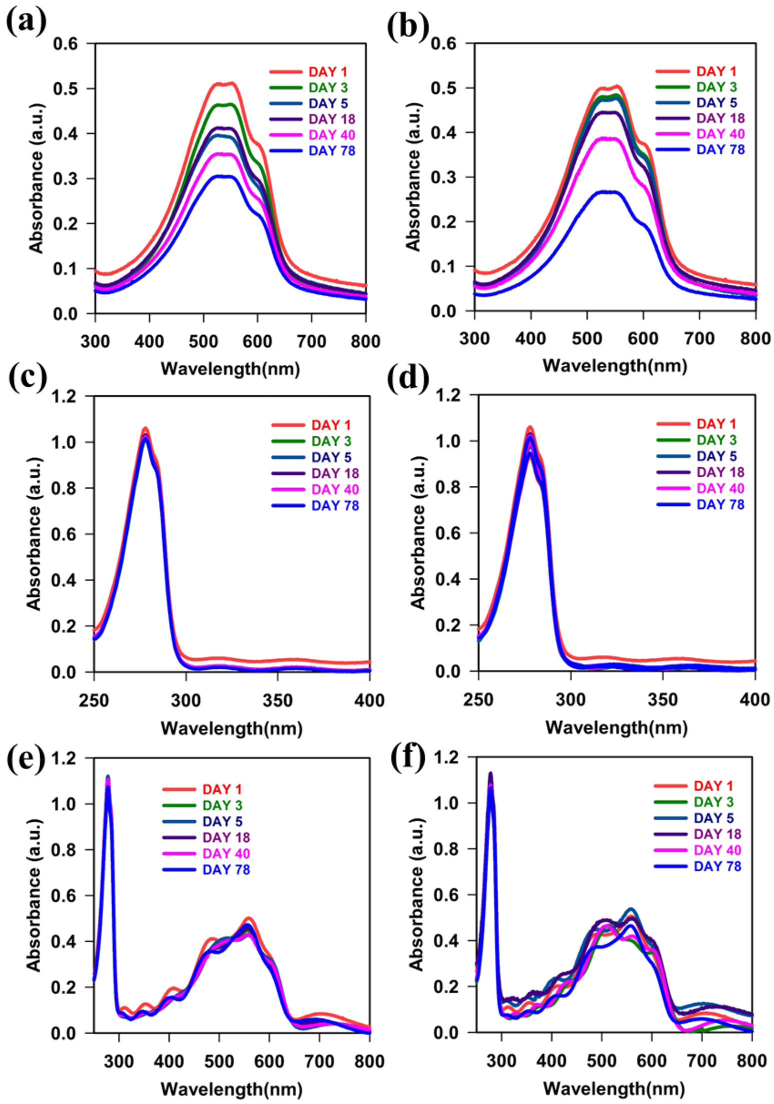


**Figure S8.** Absorption spectra of P3HT(a,b), PVP(c,d) and P3HT/PVP(e,f) thin films under ambient (a,c,e) and high RH (b,d,f) conditions.

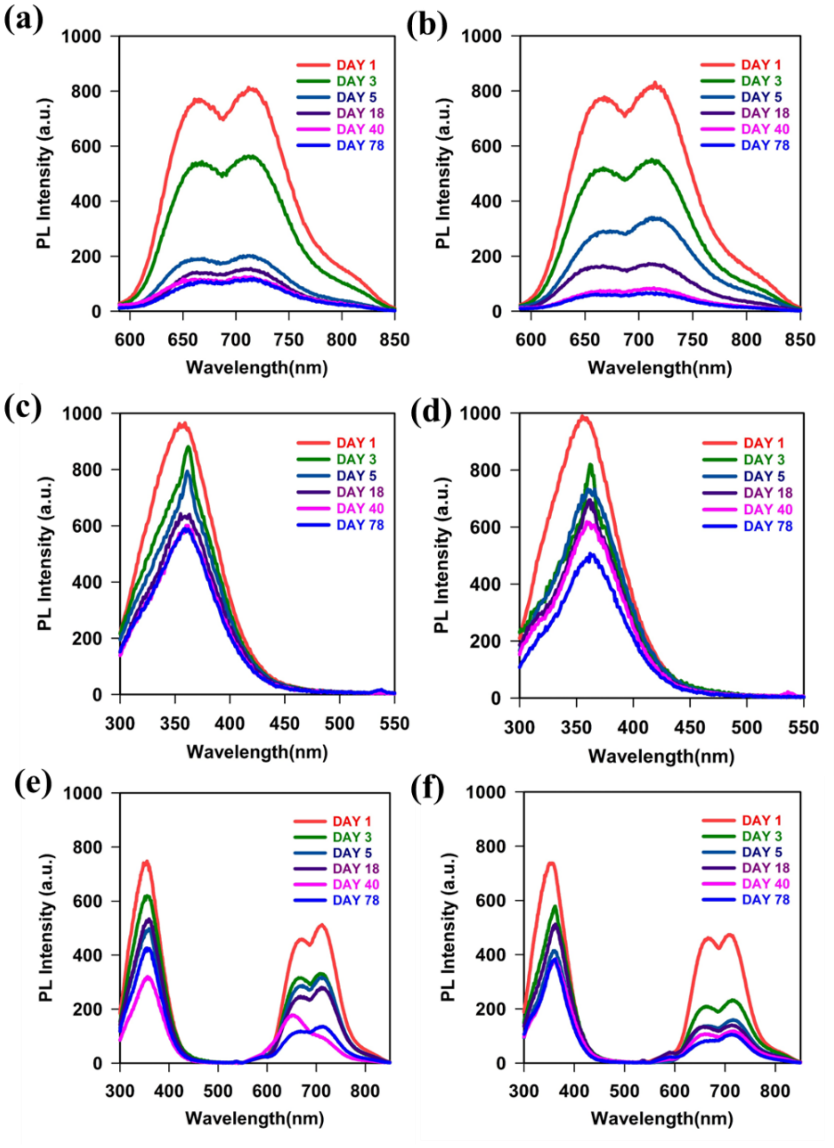


**Figure S9:** Photoluminescence (PL) spectra of P3HT(a,b), PVP(c,d) and P3HT/PVP(e,f) thin films in ambient(a,c,e) and high RH (b,d,f) condition.

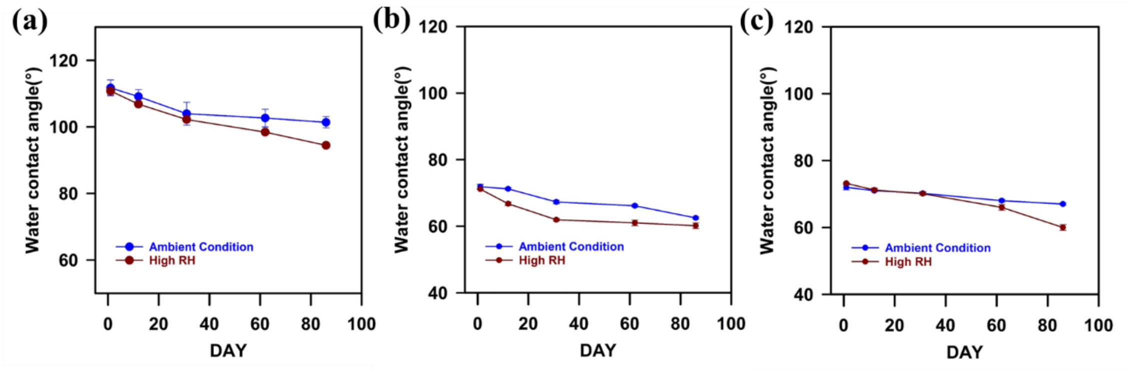


**Figure S10.** Variation in water contact angle of P3HT (a), PVP (b), and P3HT/PVP (c) surfaces over 86 days under ambient and high RH conditions.

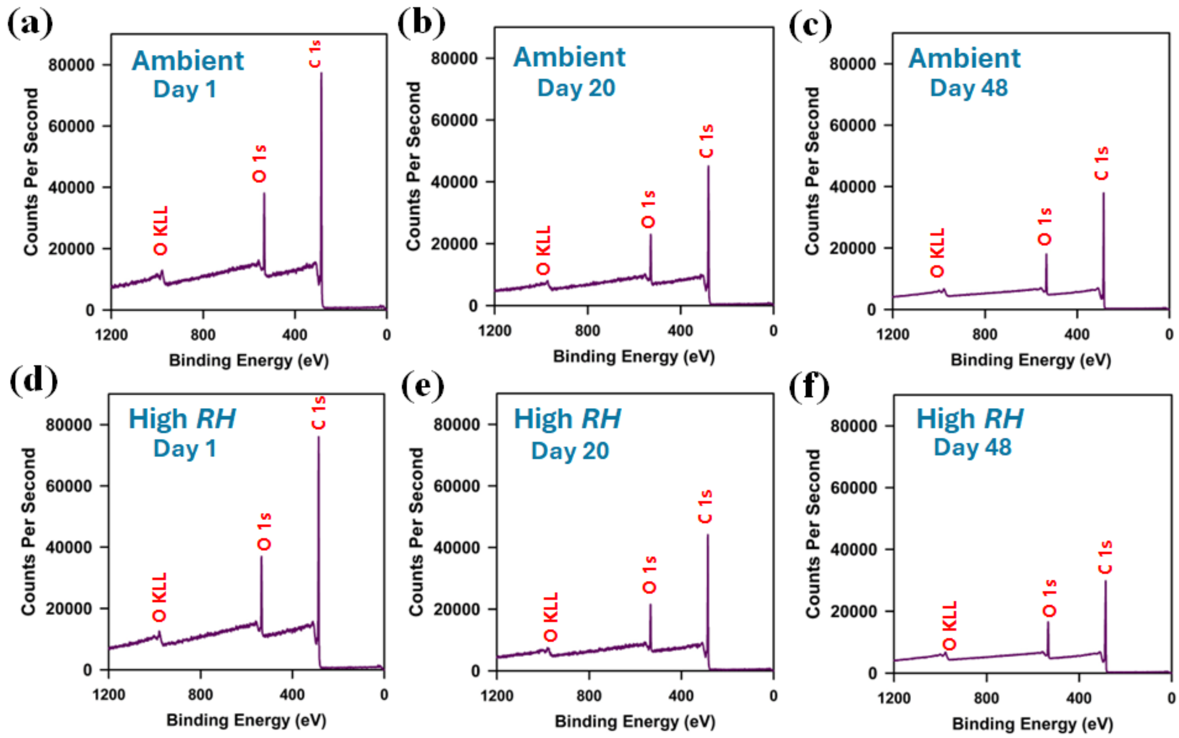


**Figure S11.** X-ray photoelectron spectroscopy (XPS) representation of the deposited P3HT/PVP film under (a, b, c) ambient and (d, e, f) high RH storage conditions.

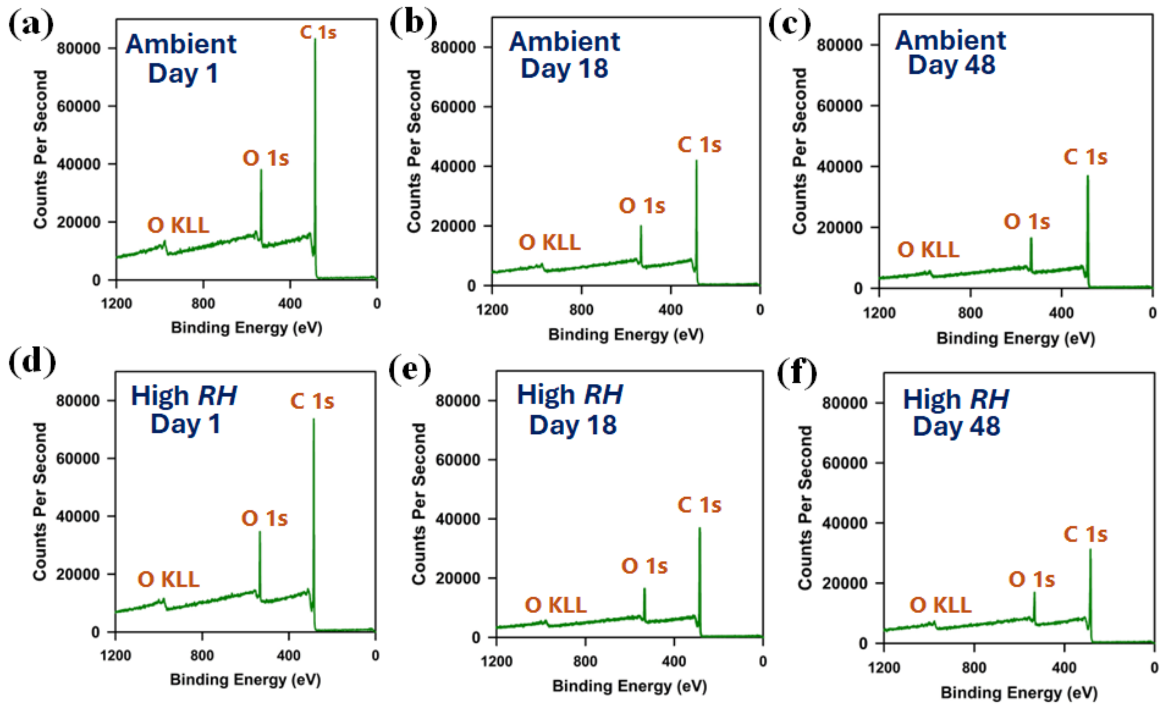


**Figure S12.** X-ray photoelectron spectroscopy (XPS) spectra of the PVP surface under (a, b, c) ambient and (d, e, f) high RH storage conditions.

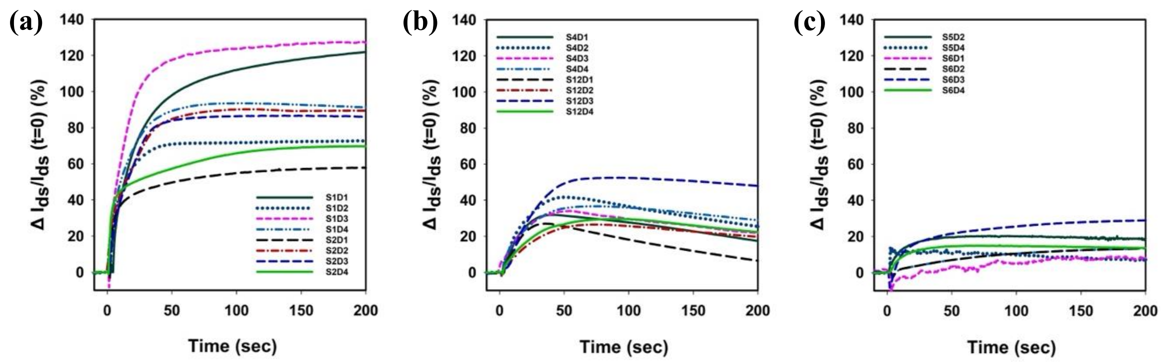


**Figure S13.** $I_{ds}$ modulations for individual HIFETs (designated by slide and device number) exposed to 1 M NaCl solutions, on (a) day 1 following fabrication, and on day 66 following storage under (b) ambient and (c) high RH conditions.