# Investigation of acid deprotonation in electrolyte thin film through protonic field-effect transistor

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The protonic field-effect transistor ($H^+$-FET) with electrochemical impedance spectroscopy (EIS) measurement was established to investigate the proton ($H^+$) transport properties of electrolyte thin film containing a carboxylic acid group. The external gate voltage ($V_g$) applied to the $H^+$-FET device can modulate the flow of the $H^+$ charge carrier in electrolyte thin film, and then the $H^+$ transport properties can be extracted.[1-3] However, the palladium (Pd) electrode reaction under an $H_2$ atmosphere with a DC system, which can provide the excess $H^+$ carrier, was used in the reported $H^+$-FETs.[1,2] Pd electrode reaction and strong contact resistance of a DC system were expected to interrupt the investigation of the thin film properties. In this work, a gold (Au) electrode combined with EIS measurement under air atmosphere was performed. This established method can provide intrinsic information on the $H^+$ transport properties of electrolyte thin film, including the amount of $H^+$ charge carrier or carboxylic acid deprotonation behavior without the electrode reaction and contact resistance effects.

Polyacrylic acid (PAA) thin film (45 nm) was studied using our $H^+$-FET, which consists of comb-shaped Au electrodes deposited on a $Si/SiO_2$ substrate. $V_g$ from −5 V to +5 V was applied, and the $V_g$ dependence of in-plane $H^+$ conductivity ($\sigma$) was observed (Fig. 1a). The $H^+$ transport mobility ($\mu_{H+}$) of $8\times10^{-4}$ $cm^2$ $V^{-1}$ $s^{-1}$ was successfully estimated. The mobile $H^+$ concentration ($n'_{H+}$) was calculated from $\mu_{H+}$, showing the dependence on $V_g$. The change of $H^+$ carrier concentration depending on $V_g$ might refer to the difference in carboxylic acid deprotonation behavior. Therefore, the effective p$K_a$ (p$K_a$') was then estimated and displayed in Fig. 1b. Furthermore, the influence of $V_g$ on the electrolyte thin film Debye length ($\kappa^{-1}$) would be discussed.

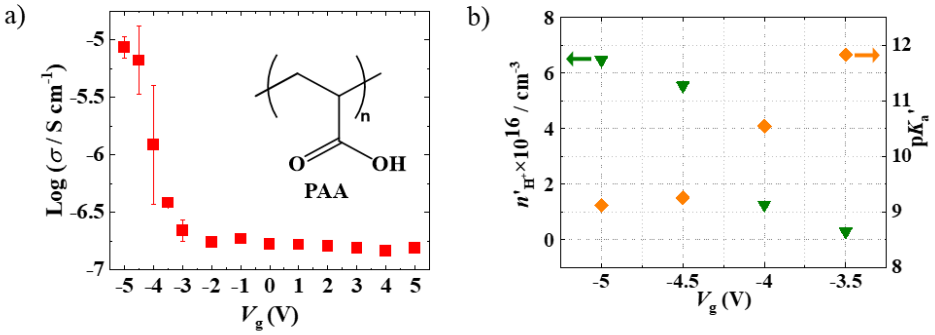


Figure 1 The $V_g$ dependence of PAA thin film's a) $\sigma$, and b) $n'_{H+}$ and p$K_a$'.

References; 1) C. Zhong *et al.*, *Nat. Commun.* **2011**, *2*, 476. 2) H. Zhong *et al.*, *Adv. Mater.* **2020**, *32*, 2000730.
3) S. Mondal *et al.*, *Small* **2020**, *16*, 2005526.