Mobility of proton conduction in thin films using the electric field effect

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The proton (H^+) transport properties of weak-acid polymer thin film, such as H^+ transport mobility (μ_{H+}) and mobile H^+ concentration (n'_{H+}), were revealed through a protonic field-effect transistor (H^+-FET) with electrochemical impedance spectroscopy (EIS) measurement for the first time. H^+-FET is a promising device for H^+ conductive materials investigation since it can control H^+ charge carrier flow by applying external gate voltage (V_g). [1-3] The H^+ charge carrier provided by the Pd electrode reaction with a DC measurement system is essential in the reported H^+-FETs.[1,2] However, we suspect that the excess H^+ carrier Pd electrode reaction and strong contact resistance effect might interfere with the material's properties investigation. Therefore, the H^+-FET with the gold (Au) electrode coupling with EIS measurement under an air atmosphere was established to overcome the electrode reaction and contact resistance effects.

Our H^+-FET device, named Au-CFET, consists of comb-shaped Au electrodes deposited on Si/SiO_2 substrate. Polyacrylic acid (PAA) thin film (45 nm) was spin-coated on Au-CFET and was investigated as H^+ conductive material. The measurement was performed by individually applying V_g from −5 V to +5 V. We observed the V_g dependence of in-plane H^+ conductivity (σ), which increased when stronger negative V_g was applied (Fig. 1 (a)). The μ_{H+} of 8×10^{-4} cm^2 V^{-1} s^{-1} was successfully estimated from the slope of the σ-V_g curve (−5 V to −3.5 V). As shown in Fig. 1 (b), we also discovered the influence of V_g on n'_{H+} and the effective pK_a (pK_a') of PAA thin film. Moreover, the V_g dependent of the film Debye length (κ^{-1}) would be further investigated.

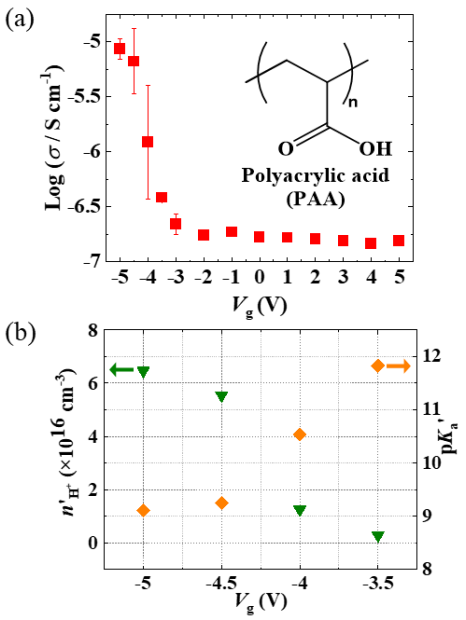

Figure 1 The applied V_g dependence of PAA thin film's (a) σ, and (b) n'_{H+} and pK_a'.

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