

Supporting Information

Interface engineering for stable chemical structure of oxidized-black phosphorus *via* self-reduction in AlO_x atomic layer deposition

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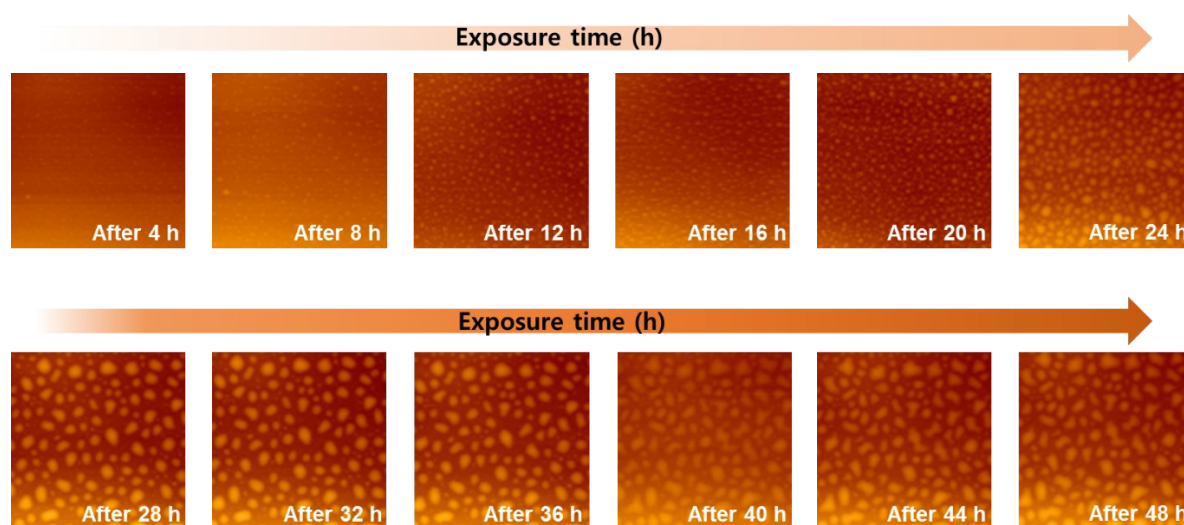


Fig. S1 Atomic force microscopy characteristics of oxidized black phosphorus (BP) as a function of air exposure time. Time-dependence AFM images of the exfoliated BP surface from 4 h to 48 h under ambient conditions.

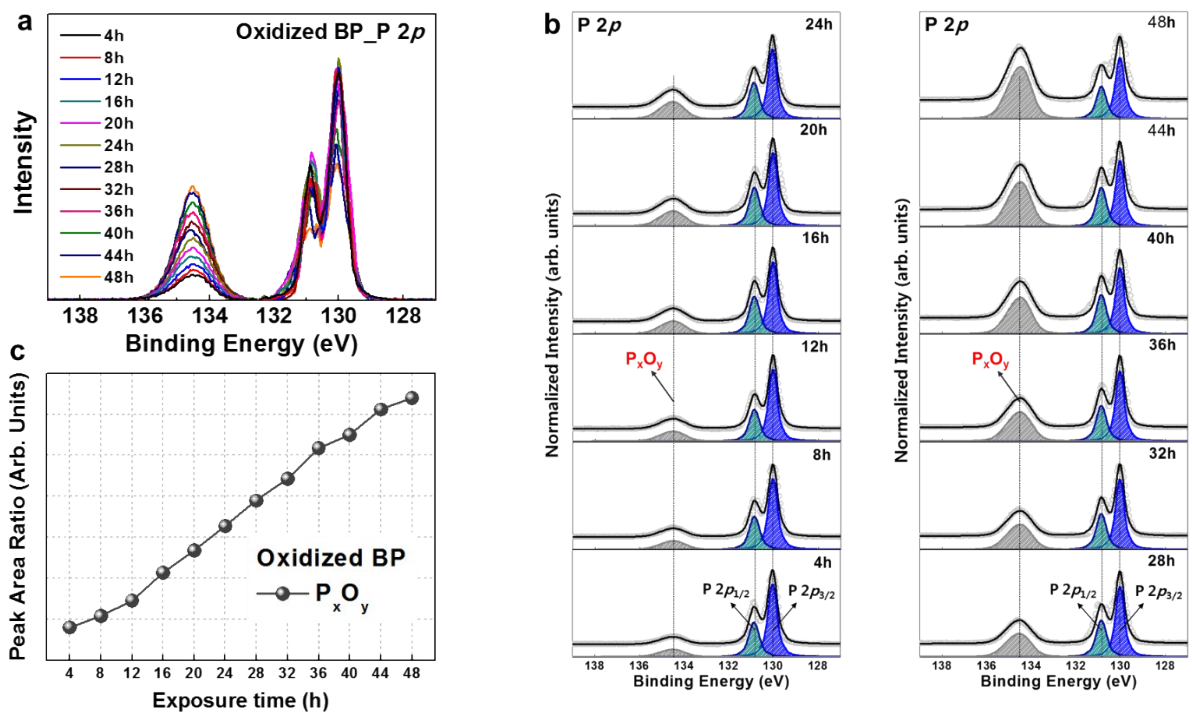


Fig. S2 X-ray photoelectron spectroscopy characteristics of oxidized BP as a function of air exposure time. Time-dependent XPS of (a) raw, and (b) fitted spectra of P 2p core level of oxidized BP as a function of air exposure time (4 h to 48 h); (c) The peak area ratio of P_xO_y from the fitted XPS spectra (b).

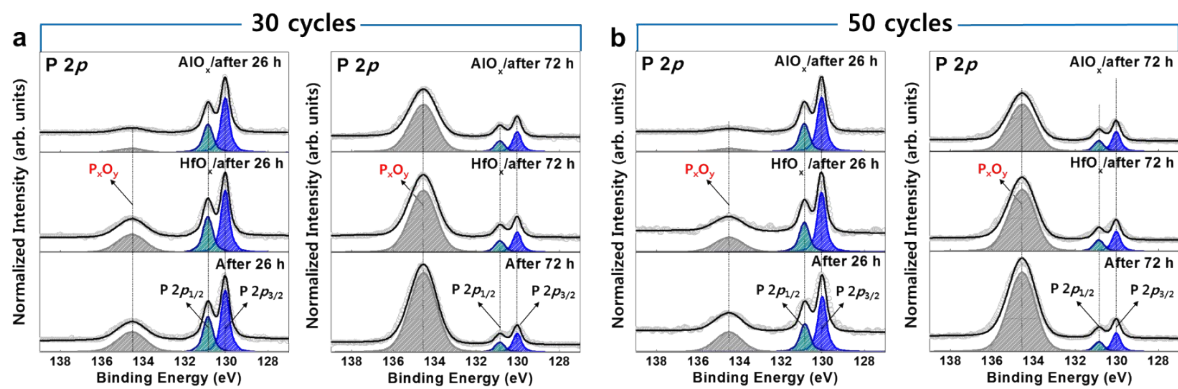


Fig. S3 Comparison of chemical states of ALD-AIO_x and HfO_x on oxidized BP at surface exposure times. The fitted XPS spectra of the P 2p core level prior to (oxidized BP) and following (a) 30 and (b) 50 deposition cycles as a function of air exposure time 26 h and 72 h.

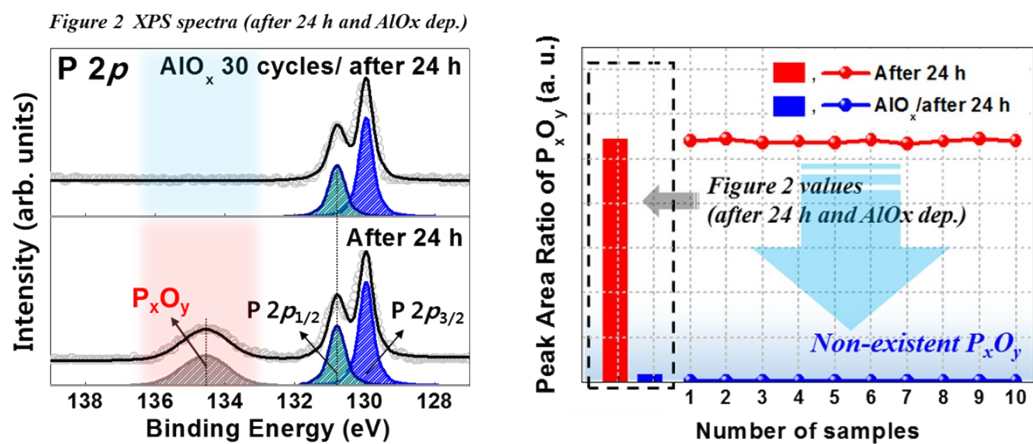


Fig. S4 The cumulative distribution of change in the oxidized phosphorus species (P_xO_y) measurements for statistical analysis in AlO_x grown on oxidized BP (24 h) under the same thickness (30 cycles).

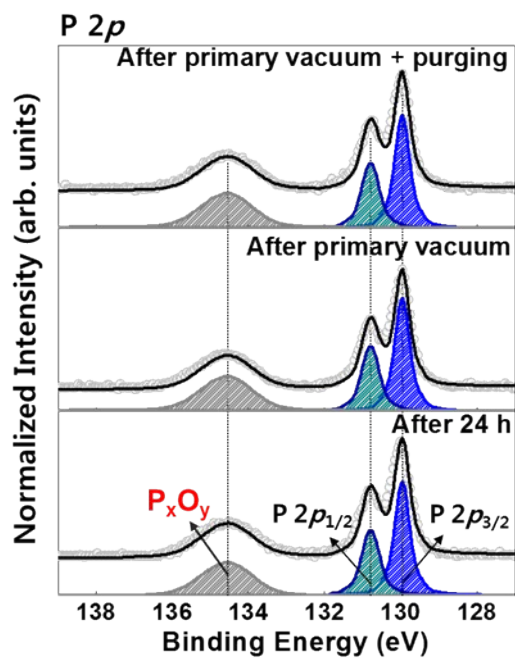


Fig. S5 The stoichiometry and chemical state of the P_xO_y before and after ALD process. After primary vacuum and N_2 purging process after primary vacuum in ALD, the binding energy and peak ratio of phosphorus species (P_xO_y) was not changed, compared with that of air exposure for 24 h.

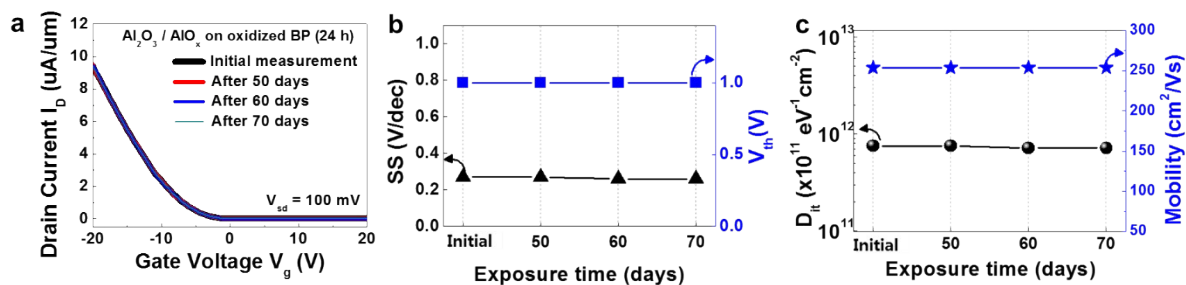


Fig. S6 Comparison of cumulative electrical measurement of $\text{Al}_2\text{O}_3/\text{AlO}_x/\text{oxidized BP}$ (24 h) FET device at different exposure time (after 50, 60 and 70 days). The (a) I_d - V_{gs} characteristics for the carrier transport data and other values (b), and (c) of extracted mobility, D_{it} , V_{th} , and SS are well consistent with those of initial measurement of FET device.

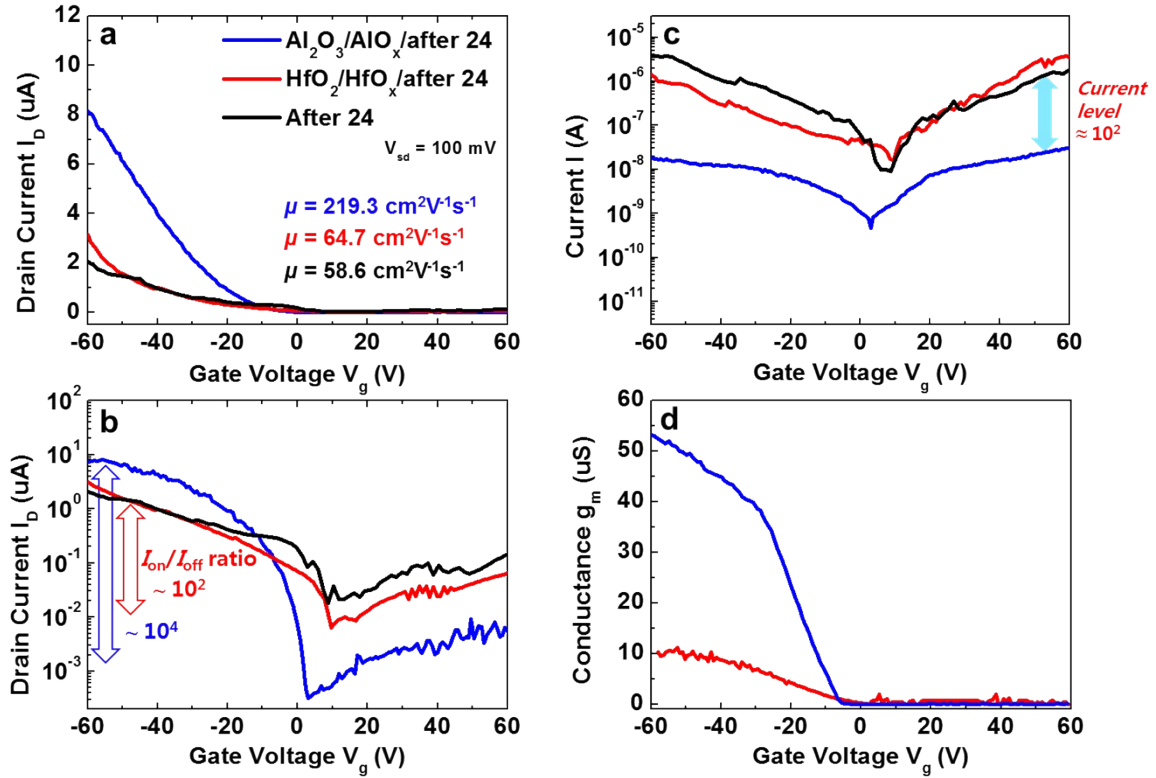


Fig. S7 Back gating electrical characteristics of the ALD- $\text{Al}_2\text{O}_3/\text{AlO}_x$ and $\text{HfO}_2/\text{HfO}_x$ on oxidized BP (surface exposed for 24 h)/ SiO_2 -300 nm/highly doped Si for field-effect transistors (FETs). The (a) and (b) I_d - V_{gs} transfer curves were obtained by back gating FET device (gate voltage (V_g) ranges of ± 60 V at a fixed drain voltage (V_{sd}) of 0.1 V) and (c) gate leakage current and (d) transconductance.