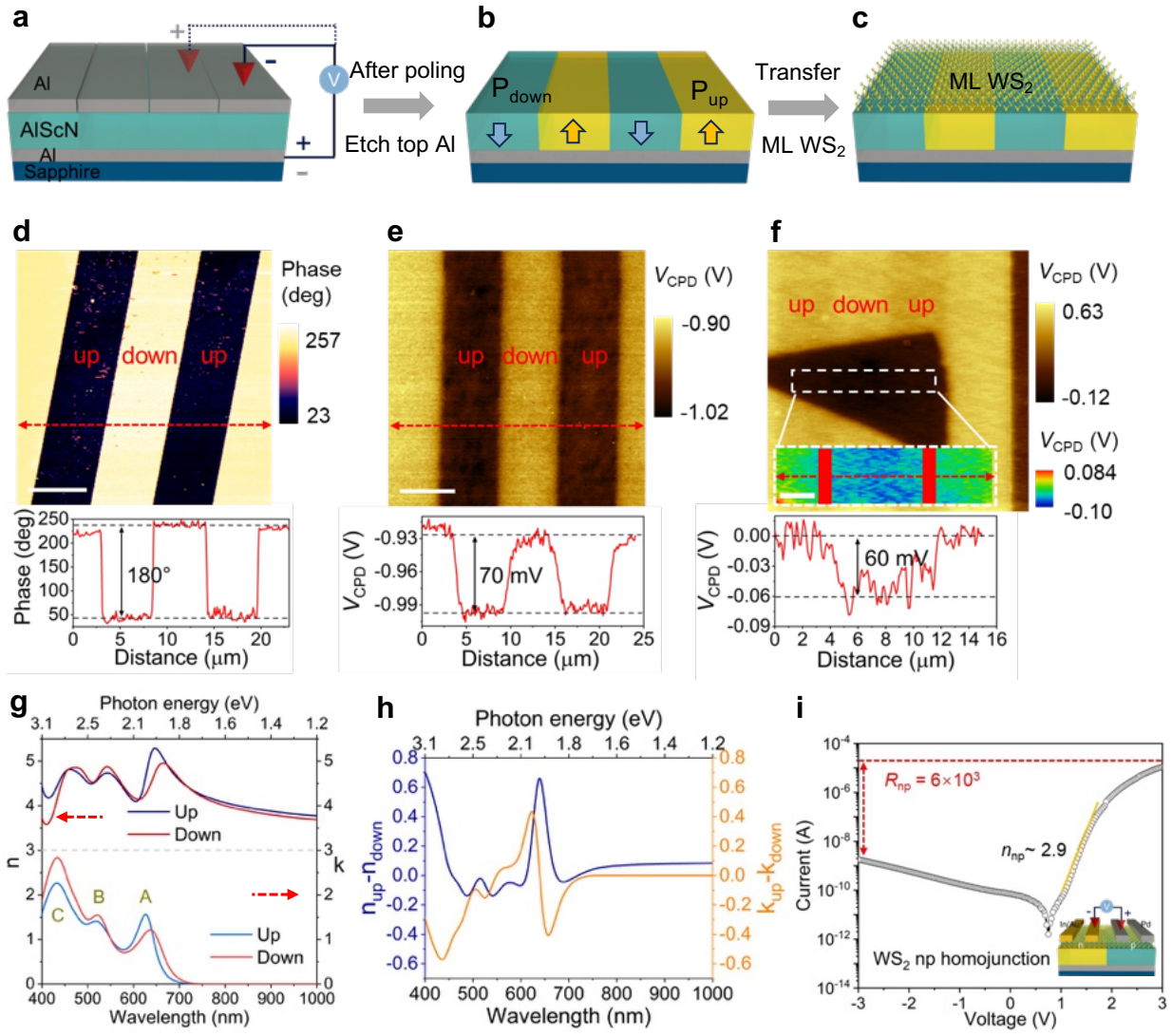

Fig. a, Schematic of AlScN ferroelectric domains locally polarized up and down by applying opposite voltages to the separated Al electrodes. **b,** Schematic of the AlScN pattern after poling and etching Al electrodes. Upward and downward arrows represent AlScN poling up (P_{up}) and down (P_{down}) states, respectively. **c,** Schematic of the ML WS_2/AlScN device after transferring ML WS_2 onto the patterned AlScN surface with defined polarization domains. **d,** PFM image of the poled AlScN surface. Regions labeled "up" and "down" correspond to P_{up} and P_{down} states, respectively. The bottom curve shows the phase profile along the red dashed line, indicating a 180° phase difference between domains. **e,** SKPM image of the poled AlScN surface. The bottom line profile shows a ~70 meV potential difference along the red dashed line on poled AlScN surface. **f,** SKPM image taken of ML WS_2 on the patterned AlScN. The inset shows a zoomed-in view of the white dashed box. The bottom line profile reveals a ~60 meV potential difference across the red dashed line on the WS_2 surface. Scale bars, 5 μm. **g.** Fitted real part n (top) and imaginary part k (bottom) of the refractive index under different polarization states (P_{up} and P_{down}). **h.** Calculated tunable range of optical constants n_{up}-n_{down} (Δn) and k_{up}-k_{down} (Δk) between P_{up} and P_{down} states, demonstrating significant modulation near the A exciton. **i.** Semi-log plot of the I–V curve for the n-p homojunction, with a Shockley diode model fit shown in yellow. The extracted ideality factor is n_{np} ~ 2.9, and the rectification ratio at $V = \pm 3$ V is $R_{np} = 6\times10^3$.