Supplementary Information

Ultrahigh-Speed Absolute Temperature Sensing Using Ferroelectric HfO_2 Enabled by Transient Negative Differential Capacitance

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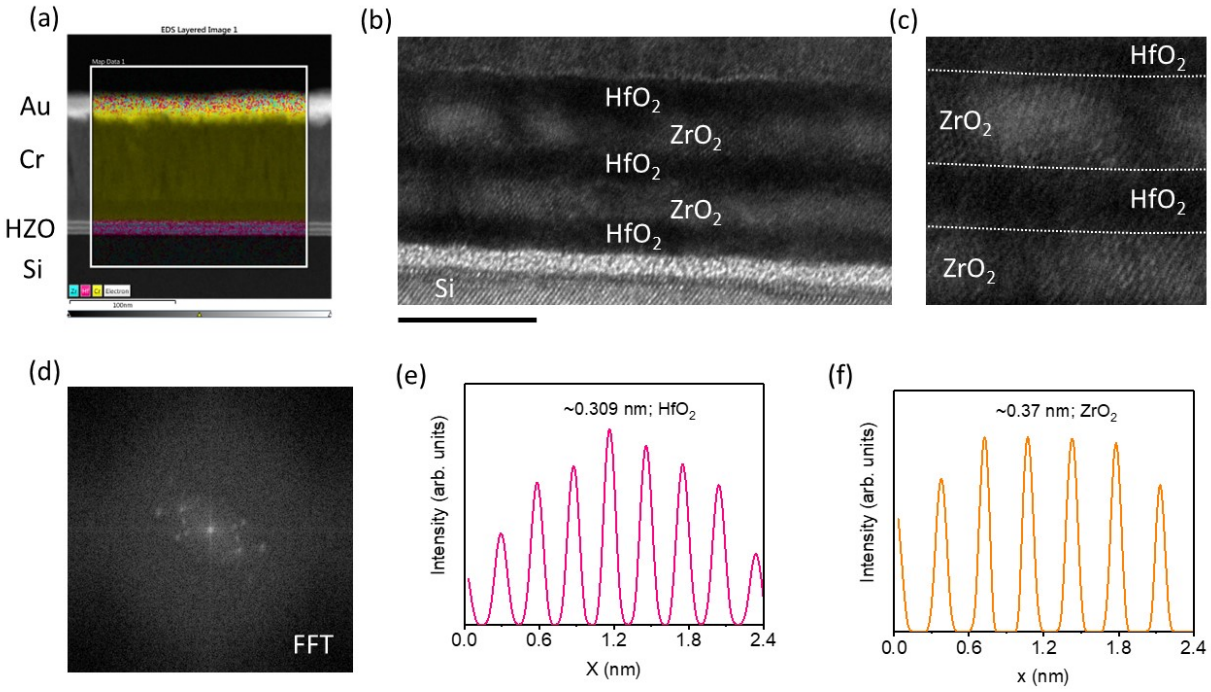

Fig. S1. Structural Characterization. (a) Cross-sectional EDS map of the device, showing HZO nanolaminate, Cr, and Au electrodes. (b) Cross-sectional TEM image of the HfO_2/ZrO_2 nanolaminate over SiO_2/Si. The scale bar for (b) is 10 nm. (c) Magnified view of the HfO_2/ZrO_2 interface, highlighted by white dotted lines. (d) FFT image extracted from panel (c). (e) Line profile obtained from the inverse FFT of the HfO_2 layer, showing an interfacial separation of 0.309 nm, corresponding to the orthorhombic structure of HfO_2. (f) Line profile obtained from the inverse FFT of the ZrO_2 layer, showing an interfacial separation of 0.37 nm, corresponding to the ZrO_2 plane of (111).

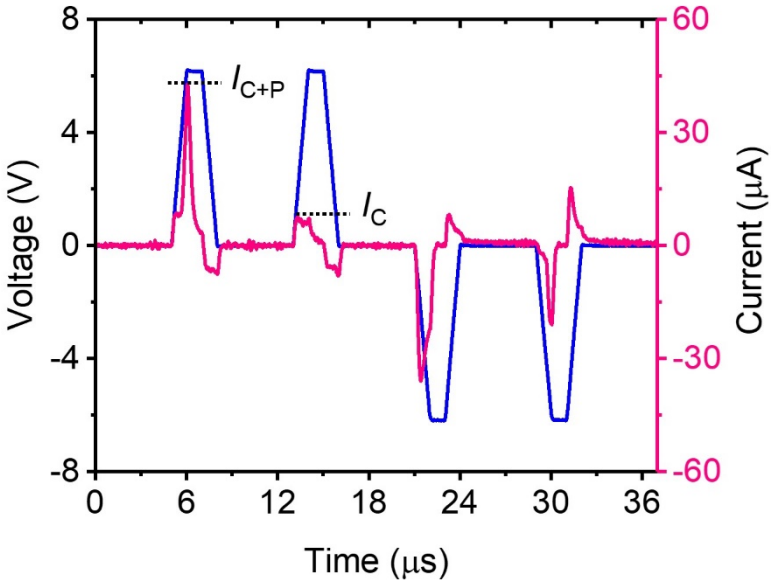

Fig. S2. Positive up and negative down response of the device

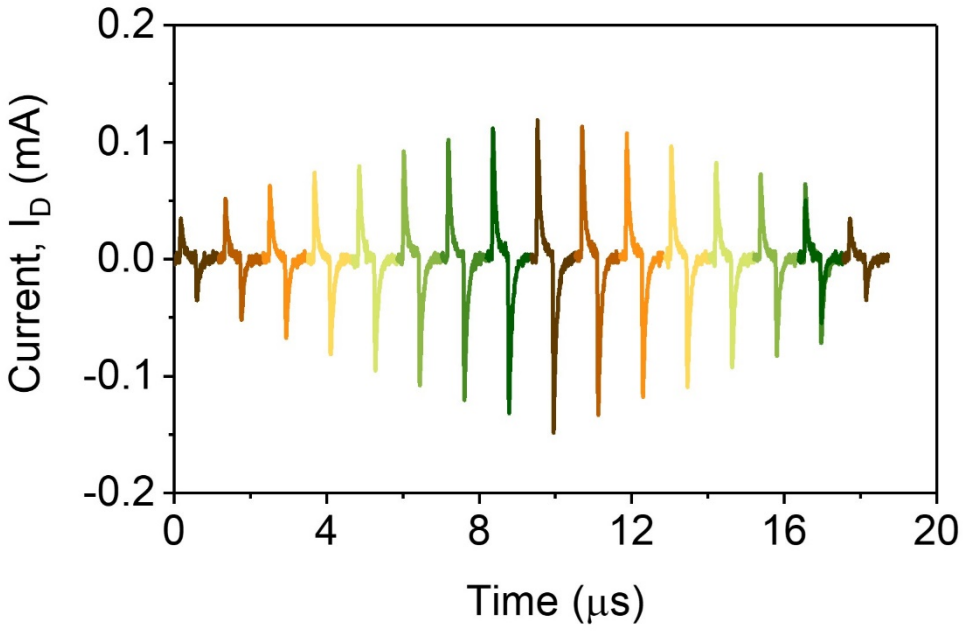

Fig. S3. Temperature-dependent transient response of the device. To ensure accuracy, the device was stabilized at a specific temperature for 30 minutes prior to measuring the I_D over 12 cycles. The distribution of peak I_D values is depicted in the main Fig. 2e.

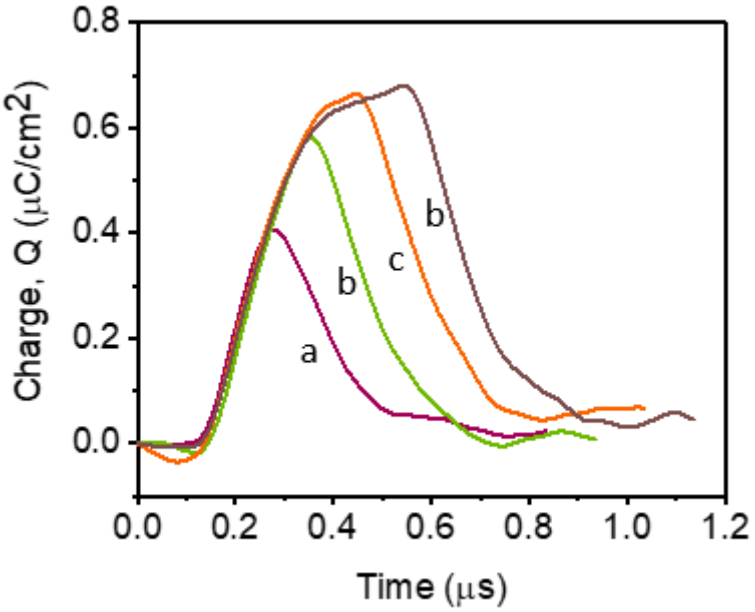

Fig. S4. The transient response of the device for different pulse durations of 32, 88, 180, and 320 nanoseconds. The charge storage capacity increases with time duration. (a) Charge versus time curve for 32 ns pulse. (b) Charge versus time curve for 88 ns pulse. (c) Charge versus time curve for 180 ns pulse. (d) Charge versus time curve for 320 ns pulse

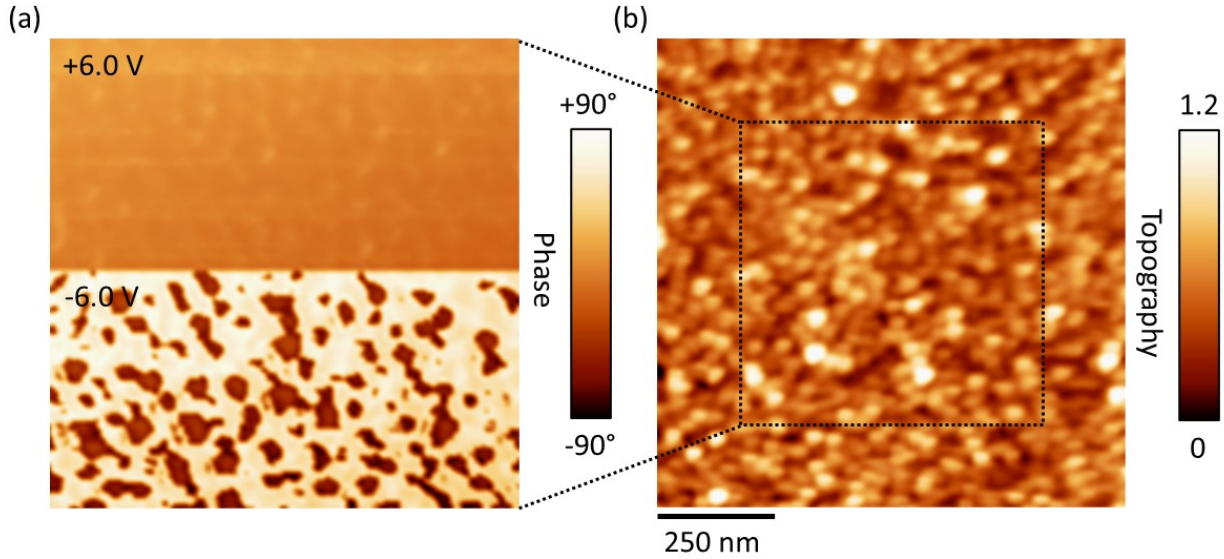

Fig. S5. (a) PFM phase map of the HZO/Si device with applied probe voltages of +6.0 V (top panel) and -6.0 V (bottom panel). The map shows a clear phase difference between the top and bottom panels, indicative of phase flipping. (b) Surface topography of the device, revealing the granular structure of the HZO. The black dotted square indicates the area where PFM mapping was performed. No change in surface features was observed, suggesting that the phase flipping is associated with ferroelectric polarization flipping.