Dynamic electric-field-induced magnetic effects in cobalt oxide thin films: towards magneto-ionic synapses

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A- Experimental Setup

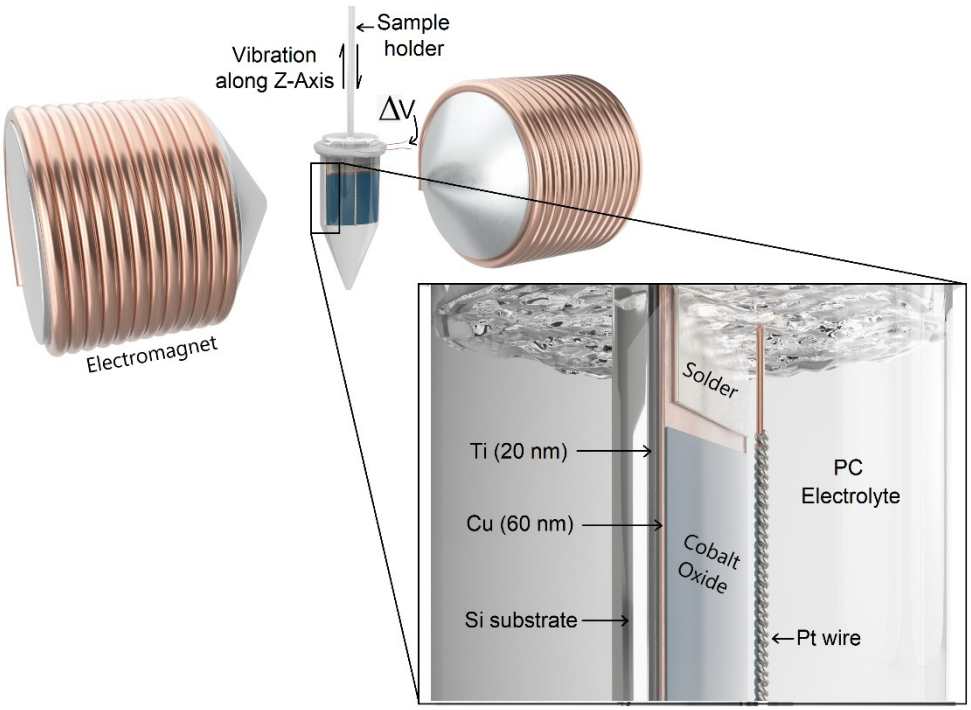

Fig. S1. Schematic showing the home-made electrolytic cell used for the of voltage actuation and magnetoelectric characterization by VSM.

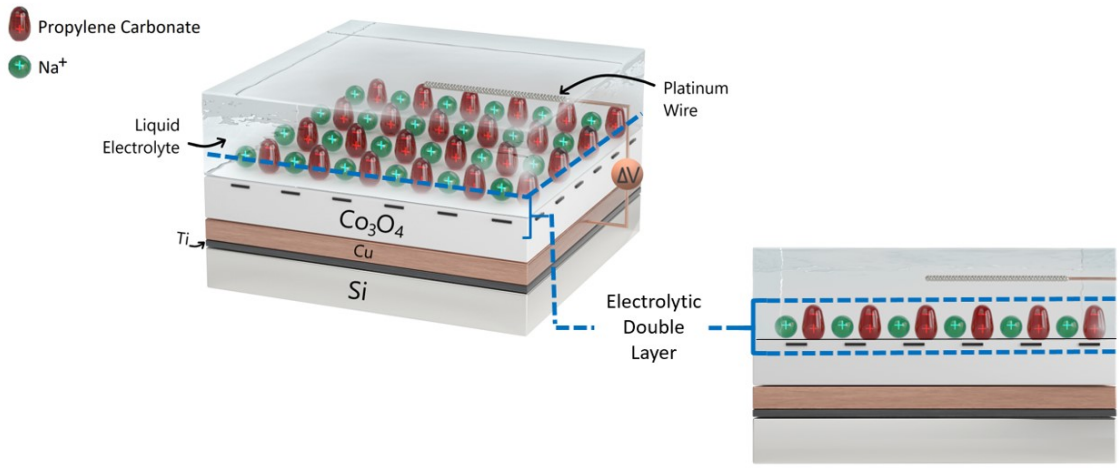

Fig. S2. Schematic of the EDL formation. Note that, for simplicity, the Na^+ ions and the propylene carbonate changes are drawn separately although, most likely, Na^+ ions become solvated when dissolved in the electrolyte.

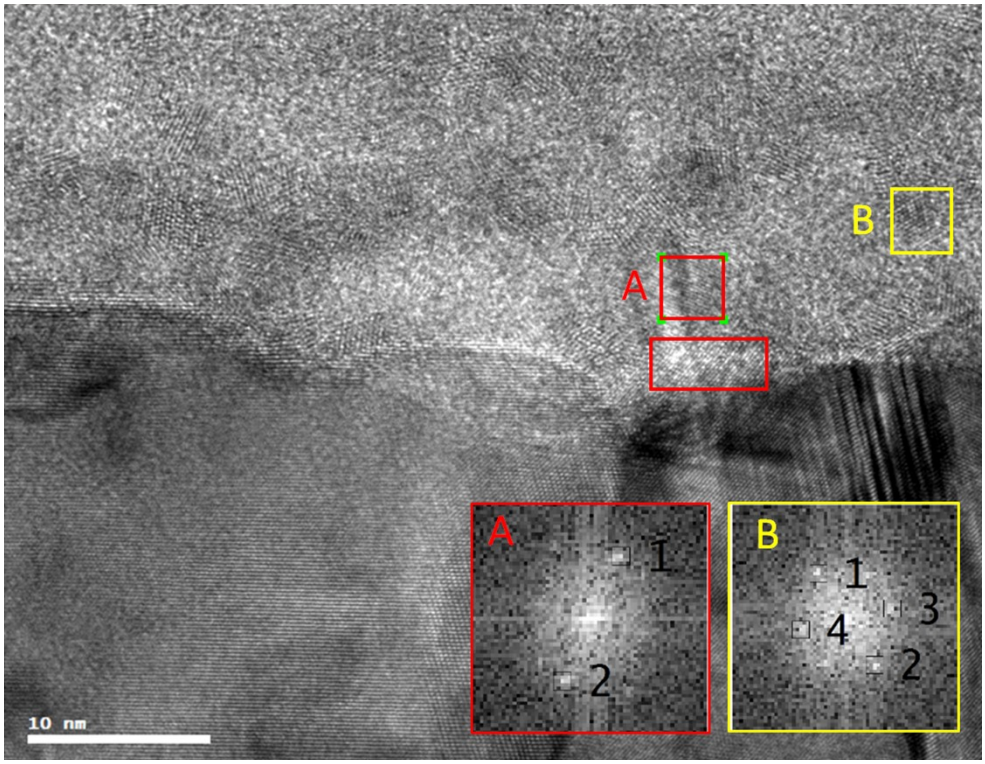

Fig S3. HRTEM image of a thin (25 nm) CoOx film treated with high negative voltage (–50 V) for 30 min. The squares A and B indicate crystallites whose lattice cell parameter matches the position of HCP-Co as evidenced by the fast Fourier transforms presented at the bottom left corner of the image: "1" and "2" represent an interplanar distance of 1.90 Å which matches the (101) direction of HCP-Co and "3" and "4" represent an interplanar distance of 2.15 Å which matches the (100) direction of HCP-Co. The majority of the other crystals seen by HRTEM correspond to either CoO or Co_3O_4.

B- Further Magnetoelectric measurements

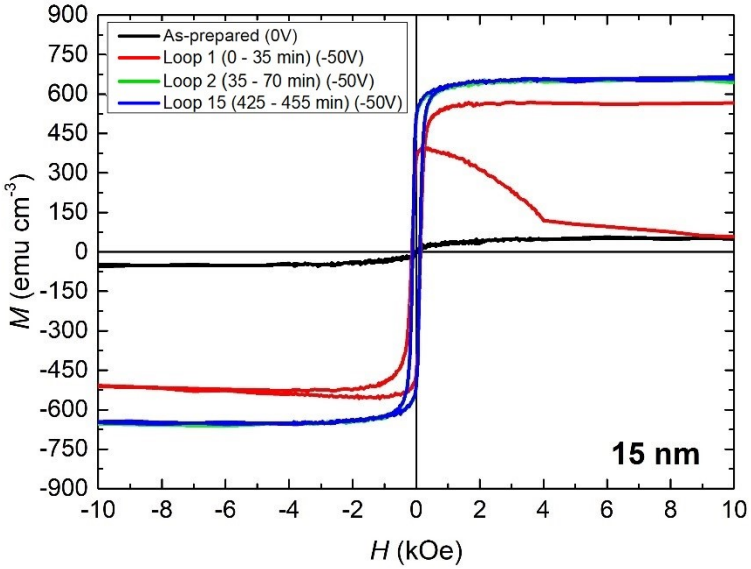

Fig. S4. Dependence of magneto-ionic effects on the cobalt oxide film thickness. Panels a–d show consecutive hysteresis loops corresponding to cobalt oxide films of 15 nm thickness, respectively, upon electrolyte gating (ΔV = –50 V) acquired using a vibrating sample magnetometer (magnetic field applied in-plane).

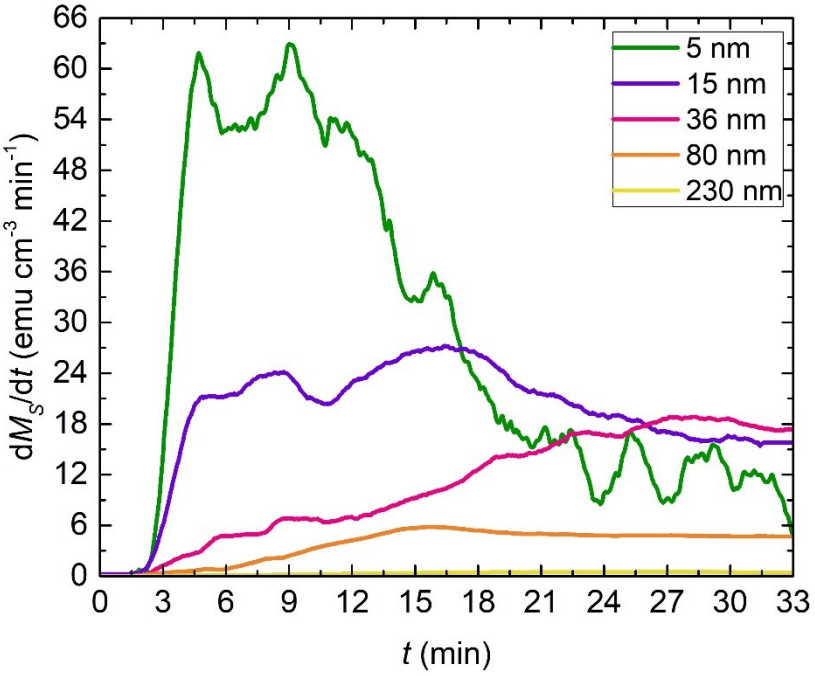

Fig. S5. (a) Time evolution of derivative of the saturation magnetization (dM_S/dt) as a function of the cobalt oxide film thickness, acquired while applying an in-plane magnetic field of 10 kOe.

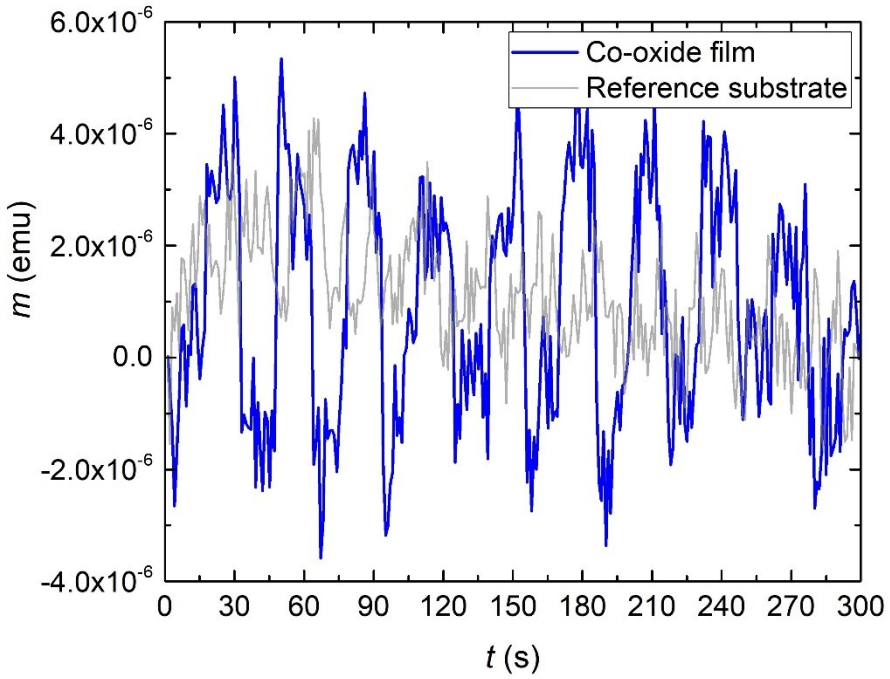

Fig. S6. Magnetic recovery effects evidenced by measuring two consecutive hysteresis loops after having actuated the cobalt oxide films for 1000 s using –50V/0V voltage pulses at frequencies of (a) 1 Hz, (b) 10 Hz and (c) 100 Hz. (d) the same recovery experiment after applying a DC voltage of –50V for 1000 s.