Electrical field-controlled ON-OFF ferromagnetism in metal oxide films

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In the context of Digital Agenda for Europe within the Horizon 2020 Programme, which stresses importance of energy efficiency, voltage control of magnetism is expected to realize ultra-low power magneto-electronics. Modern magneto-electronic devices are ultimately controlled by electric currents, inherently involving a significant energy loss by heat dissipation. Hence, even a partial substitution of electric currents by electric fields to manipulate such devices would already result in a remarkable energy saving [1]. Therefore, a stable, tunable, and non-volatile magneto-electric effect to tailor magnetism via electric fields is crucial for energy-efficient applications. The voltage-induced ionic motion (magneto-ionics) is attracting increasing interest driven by a possibility for an electrical modulation of magnetism to an extent never attained by any other magneto-electric coupling mechanisms [2]. We have recently investigated using positron annihilation spectroscopy and magnetometry techniques the electrolyte-gated and defect-mediated oxygen and cobalt migration in paramagnetic Co_3O_4, which allows for voltage-controlled ON-OFF room temperature ferromagnetism [3]. A negative voltage reduces Co_3O_4 to Co (ferromagnetism: ON), resulting in a graded material including Co- to O-rich regions. A positive bias reverses the process oxidizing Co back to Co_3O_4 (paramagnetism: OFF) [Fig. 1a]. These gate-induced O and Co migration processes are driven by complex vacancies (clusters of cobalt and oxygen vacancies; see Fig. 1b), whereas O transport is in addition assisted by grain boundaries, which may act as diffusion channels and allow for an exceedingly large incorporation of oxygen. The steady states as a function of bias as well as kinetics of defect-assisted ion migration will be discussed in detail.

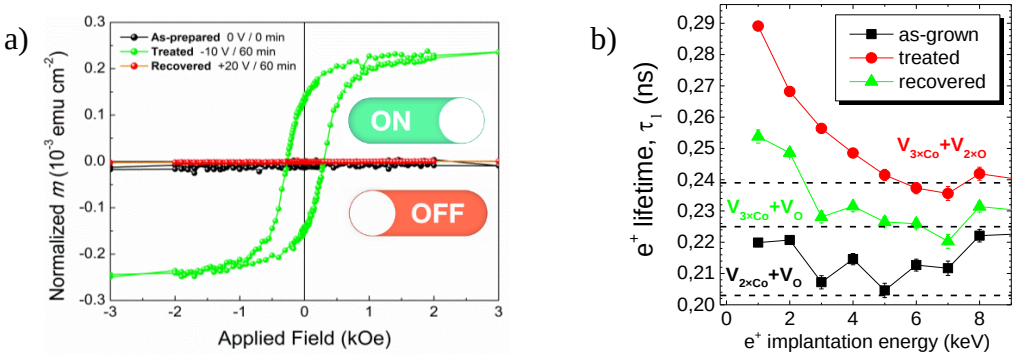

Figure 1 *Electrical fields induced magnetic switching (a) and corresponding defect structures calculated by ab-initio DFT (b) for the as-grown, treated with a negative, and a positive bias Co_3O_4 films.*

References

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