Organic dielectrics toward green energy storage

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Organic ferroelectric thin films possess great potential for future electronic devices due to certain advantages over their inorganic counterparts: being environmentally benign, less expensive, bio-compatible, easier and simpler to fabricate. As organic material, they are naturally lead-free and thus can be considered in the context of eliminating toxic substances from electronic devices as a lead-free alternative to inorganic ferroelectrics.

Ferroelectrics and antiferroelectrics are interesting for energy storage, in particular because dielectric capacitors exhibit high power density, so that in the past two decades, enormous efforts have been made to improve their energy-storage performances [SUN19].

We propose to investigate the energy storage potential of capacitors based on two oxocarbon acids, croconic acid and squaric acid (fig 1). The ferroelectric properties of these materials were only discovered recently [HOR10, HOR18] and their potential has to be explored further, in particular as thin films. These materials are promising in particular because, in its crystal form, croconic acid has the highest room-temperature polarization among organic ferroelectrics, on par with standard inorganic materials; and for squaric acid because antiferroelectric materials are capable of displaying higher energy densities than ferroelectric ones [LIU18]

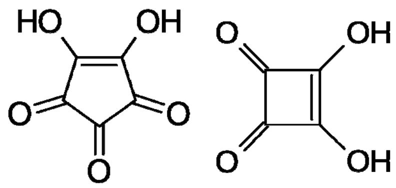

Figure 1 : Croconic acid (left) and squaric acid molecule (right).

The PhD work will be divided in three steps : i) thin film fabrication under ultra-high vacuum with sublimation on several substrates (Au, Co…), ii) study of their local ferroelectric properties by piezo force microscopy (fig. 2, MOH20) and iii) incorporation in submicrometer devices thanks to a homemade lithographic process [KAT21].

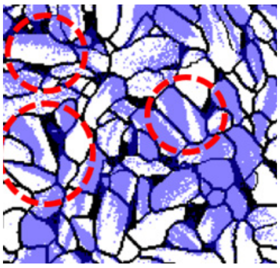

Figure 2 Ferroelectric characterization of a 200-nm thick croconic acid film on ferromagnetic cobalt. Topography contours superimposed on the ferroelectric contrast obtained using piezo-force microscopy. Black lines represent the grain boundaries. CA films of thickness 200 nm deposited on cobalt. Red dashed circles in shows some multi-domain grains. Area of ~1 μmx1 μm [MOH20].

Applicants should have (or expect to be awarded) a first class master's degree with sufficiently high grades in a relevant science subject (e.g. condensed matter physics, materials science, physics, etc.).

Bibliography :
[HOR10] Horiuchi *et al.* Nature **463** (2010) 798.
[HOR18] Horiuchi *et al.* Chem. Sci. **9** (2018) 425.
[KAT21] Katcko *et al*. Adv. Funct. Mater. 31 (2021) 2009467.
[LIU18] Liu *et al.* Adv. Mater. Technol. (2018) 1800111
[MOH20] Mohapatra *et al.* Mater. Adv. **1** (2020) 415–420.
[SUN19] Zixiong Sun *et al.* Adv. Electron. Mater. (2019) 1900698.