How I learned to stop worrying and love the FORC method

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The first order reversal curve (FORC) technique has emerged as a uniquely powerful tool for exploring magnetic phenomena in nanopatterned systems, and natural or synthetic materials. Using the FORC technique, details including local and long-range interactions[1,2], magnetic coupling[3], intrinsic coercivity distributions and phase fractions[4,5], and magnetic reversal behavior[5,6] can be qualitatively and even quantitatively extracted. Despite recent successes, the FORC technique remains dramatically underutilized due to perceived issues including the non-trivial connection between physical reversal events and hysterons, the looming specter of negative features - which break with the standard Preisach model - and reversible features - which manifest only by the grace of 'made-up' data.

Here, I highlight four recent works which rely on reconciling these issues to elucidate qualitative and quantitative information about nanoscale physics. Starting simplistically, the reversal behavior of an $A1/L1_0$ mixed-phase $Fe_{39}Cu_{19}Pt_{45}$ (4 nm) thin-film is investigated as a prototype HAMR media[4]. The FORC measurements show largely reversible and irreversible features, representing the $A1$ and $L1_0$ phases, respectively. Integrating the FORC diagram, major- and phase separated hysteresis loops are reconstituted, as well as a quantitative phase fraction. Next, FORC measurements of an $AlO_x/GdO_x/Co$ (15 nm) magneto-ionic device with in-plane anisotropy are shown[7]. This FORC distribution shows similar features as the FeCuPt, suggesting a similar mixed-phase system. Re-enforcing the FORC's sensitivity to reversal mechanics, FORCs from a $Fe_{55}Pt_{45}$ (4 nm) thin-film are shown to be entirely different than the FeCuPt (4 nm) film[8]. The 'left-bending' boomerang feature in the FePt film identifies a domain growth reversal[9]; forming a perpendicularly coupled $L1_0$-FePt(4 nm)/$A1$-FePt(0-9 nm) bilayer causes the feature to evolve into a right-bending boomerang. Supplemental magnetic characterization suggests the left/right orientation identifies the interactions. Indeed, using micromagnetic modeling, we demonstrate the ability to transform the FORC distribution between left- and right-bending boomerangs and magnetizing or demagnetizing wishbones by leveraging the exchange coupling, dipolar coupling, and anisotropy distributions.

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