Preisach model and FORC based identification techniques applied to various hysteretic processes

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Preisach model was intensely used in recent years to simulate hysteretic processes. The identification technique based on a set of First-order Reversal Curves (FORC), developed initially only for systems correctly described by the Classical Preisach Model, is now extensively employed as an experimental tool for the characterization of various hysteretic processes [1]. In this talk we show our recent results in the study of hysteresis in a number of physical systems: ferromagnetic, ferroelectric and in materials with spin transition.

Ferromagnetic hysteresis studies will be presented with emphasis on the vectorial models and on the identification techniques and test problems. A set of rotational hysteresis curves are proposed as a very powerful tool to test the vectorial models and their ability to describe accurately complex magnetization processes [2]. In the case of scalar measurements the use of FORC distribution as Preisach distribution is only an approximation and higher order curves can be used to estimate the error. The well known deltaM curves and Henkel plots are second order curves and a generalized deltaM procedure can provide a Second-order Reversal Curve (SORC) distribution [3]. The differences between FORC and SORC distributions are due to both reversible and irreversible magnetization processes which are rather difficult to be estimated separately.

A FORC identification technique of the parameters in a Preisach-type model developed for ferroelectric materials is described in [4] and [5]. The experimental FORC distributions can be used as input in a Preisach-type model and the results are surprisingly well in agreement with higher order experimental curves. This technique is considered the best tool available to identify correctly the irreversible and reversible switching in ferroelectric materials used in applications. The FORC diagram technique has evidenced the aging effects in ferroelectric memories and could provide a more profound understanding of these processes that are a major technological problem.

A special attention will be given to a recent application of the Preisach model as a tool to understand the hysteretic behavior of a category of molecular magnets, the spin-transition materials. The molecules of these compounds can be found in one of the two states: low-spin (LS) or high-spin (HS). The molecules have different volumes in the two states and this phenomenon is at the origin of an inter-molecule interaction strongly dependent of the elastic properties of the crystal. The spin-transition compounds are diamagnetic in LS state and paramagnetic in HS state and show a multiple hysteretic behavior controlled by temperature, pressure and electromagnetic radiation. This intricate nonlinear phenomenon can be described with a reasonable accuracy with a special Preisach model developed by our group in recent years [6, 7].

In all the mentioned cases in order to understand the shape and the main features on the FORC distribution we have to use physical models. In ferromagnetic hysteresis, micromagnetics can provide valuable test problems and data that can illustrate the links between the parameters used in phenomenological models and the fundamental physical phenomena. Similar approach is needed in the other domains mentioned before (ferroelectric hysteresis and spin-transition materials). Models able to describe hysteresis in these systems are also presented and analyzed.

In each example, the difficulties encountered and the problems that remain unsolved are presented and discussed.

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