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Impacts of highly charged ions as seeds in a magneto-structural phase transition of magnetocaloric thin films

S. Cervera¹, M. Trassinelli², M. Marangolo, L. Bernard-Carlsson, M. Eddrief, V.H. Etgens, V. Gafton, S. Hidki, E. Lacaze, E. Lamour, C. Prigent, J.-P. Rozet, S. Steydli, Y. Zheng and D. Vernhet

CNRS, UMR 7588, Institut des NanoSciences de Paris (INSP), 4 Place Jussieu, 75005 Paris, France
Sorbonne Universités, UPMC Univ. Paris 06, INSP, UMR 7588, F-75005 Paris, France,

Synopsis Investigation on modifications of structural and magnetic properties of magnetocaloric thin films induced by slow highly charged ions bombardment under well-controlled conditions is presented. The ions induce defects/constraints that facilitate nucleation of one phase with respect to the other in the first-order magneto-structural MnAs, with a consequent suppression of thermal hysteresis, but without any significant perturbation on the other structural and magnetic properties.

Modifications of material properties by ion impact, and in particular changes in magnetic features, have been extensively studied in the last decades. Nevertheless, previous studies on the effect of ion impact were focused mostly on materials exhibiting a second-order magnetic transition and with singly charged ions whilst, here, we investigate thin film presenting a first-order magneto-structural transition, namely MnAs, irradiated with slow highly charged ions, i.e. 90 keV ($v=0.4$ a.u.) Ne^{9+} [1, 2]. Indeed, MnAs is one of the most promising candidates for developing magnetic refrigeration since it exhibits giant magnetocaloric effect (GMCE) associated to its phase transition close to room temperature (at $T_c=40^\circ$). Up to now, the practical use of GMCE materials for real refrigerator systems is blocked by the presence of a large thermal hysteresis in the magnetization cycle, which is typical of first-order transition materials (fig. 1, solid lines). Differently from other technics applied previously to reduce the thermal hysteresis (like doping, external strains, ...) [3–5], ion collisions induce defects that act as seeds for the nucleation of one phase with the other during the transition. Consequently, the thermal hysteresis is entirely suppressed (fig. 1, dashed lines) whereas other structural and magnetic properties are only slightly affected. In particular, the large refrigeration power of MnAs thin films related to GMCE is preserved. At present, we extend our investigations using different collision conditions and other samples that are relevant for the magnetic refrigeration (FeRh, compounds based on Fe_2P , etc.). The goal is to provide new insights on the fundamental processes that play a major role in the suppression of the thermal hysteresis in order to get a full understanding on this effect.

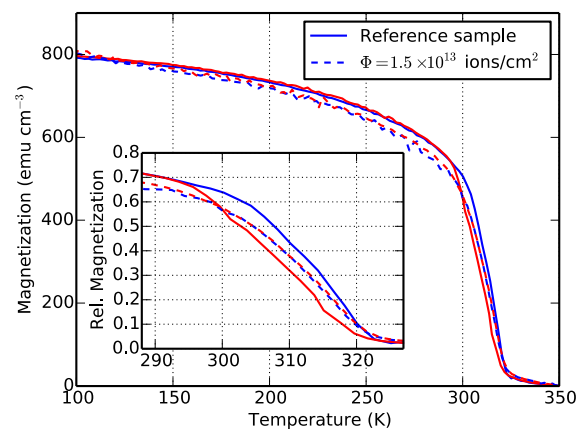


Figure 1. (color online) Magnetization as a function of temperature for the reference (solid lines) and for the irradiated samples (dashed lines). Data obtained by a temperature increase (from colder temperatures) and decrease (from hotter temperatures) are presented in blue and red, respectively.

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¹E-mail: sophie.cervera@insp.jussieu.fr

²E-mail: martino.trassinelli@insp.jussieu.fr