MAR08-2007-001227

Abstract for an Invited Paper
for the MAR08 Meeting of
the American Physical Society

Theory of Current-Induced Domain Wall Creep in (Ga,Mn)As.

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A magnetic domain wall (DW) can interact with electrical current and as a result its displacement is induced by the application of the current, showing the possible electrical control of the magnetization direction. Thus electrical current in this non-uniform spin texture is now drawing much attention from the technological point of view, in addition to the longstanding interests from the fundamental physics points of view. Recently, systematic experimental data of the dependence of DW velocity spanning five decades on current density have been obtained in a microstructure made from a ferromagnetic semiconductor (Ga,Mn)As, providing deep insight to outstanding physics of DW dynamics. The quantitative analyses showed that the current-driven motion in (Ga,Mn)As can be explained by spin-transfer mechanism under currents beyond a threshold value. The linear mobility tempts ones to expect there is always an equivalent magnetic field which has the same effect upon DWs as the current does. Here we make a detailed comparison between these two sources of drive but in the subthreshold, "creep," regime, where the velocity obeys an Arrhenius scaling law. The observed scaling law for the two drives is incompatibly different from each other, i.e., the effect of a driving current and field are not equivalent. We offer theory which explains the important features of experiment. When described by an Arrhenius law it is found that the barriers diverge as the drive approaches zero, manifesting the system is in a "glassy" state. While the field driven case is compatible with the random field universality class, the case of current induced creep is not to fit any known such class. The work reported is the result of collaborations with M. Yamanouchi, F. Matsukura, S. E. Barnes, S. Maekawa, and H. Ohno. [Ref. Science 317, 1726-1729 (2007).]