# Piezoelectromagnetic effect in ferromagnetic (Ga,Mn)N layers

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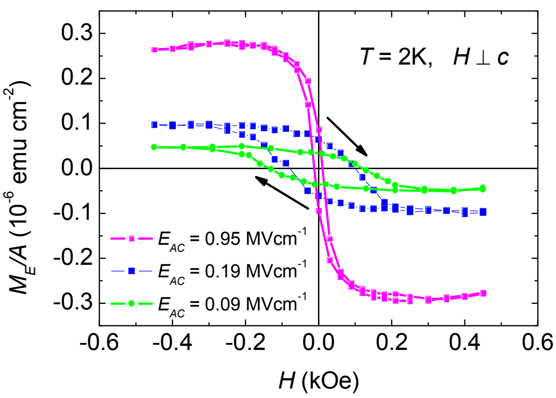
Switching of magnetization direction between two stable states separated by an energy barrier is one of the most important processes for magnetic recording and information storage [1]. This is conventionally done by applying an external magnetic field or spin polarized currents. One way to reduce the energy required for magnetization switching while maintaining sufficiently high magnetic anisotropy energy is to control the magnetization direction by other means than the external magnetic field or charge current. An electric field-control of magnetic anisotropy is a promising candidate. We anticipate that this can be accomplished in (Ga,Mn)N-based structures, in which the magnitude and the sign of magnetic anisotropy can be changed by appropriate material engineering and by an electric field. Recently, we have shown that a strong coupling between piezoelectricity and magnetism exists in paramagnetic $Ga_{1-x}Mn_xN$ with $x = 0.025$ [2]. Now, by using molecular beam epitaxy grown structures we investigate the magnetoelectric effect at $T \geq 2$ K in the ferromagnetic state. We observe an electric field-induced decrease of coercivity, shown in the figure, and a non-reversible magnetization switching for magnetic fields close to the coercive field (not shown). The data are interpreted within the theory of the precessional magnetization switching adapted to (Ga,Mn)N by allowing for the control of the magnitude of trigonal deformation along the wurtzite *c* axis by the applied electric field [2]. Experimental data are compared to theoretical results obtained from the Landau-Lifshitz-Gilbert equation that describes how the magnetization direction evolves towards its new equilibrium orientation after a change of an effective magnetic field. The calculations are supplemented by density functional theory simulations.




Areal density of the in-plane magnetic moment amplitude $M_E/A$ induced by electric fields $E_{AC}$ applied to $Ga_{0.93}Mn_{0.07}N$ layer.

[1] D. Chiba, T. Ono, F. Matsukura, and H. Ohno, *Appl. Phys. Lett.* 103, 142418 (2013)
[2] D. Sztenkiel *et al.*, *Nature Comm.* **7**, 13232 (2016)

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