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The regular pattern formation in ferromagnetic films under influence of spin-polarized current

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Process of the saturation of a thin isotropic ferromagnetic film in transverse direction by strong spin-polarized current is studied theoretically. It is shown that the critical current of saturation J_c increases with the film thickness increasing: quadratically for thin films and linearly for thick ones (comparing with the exchange length). We show that appearance of stable *square vortex-antivortex superlattices* (crystals) precedes the saturation. Spatial period of the superlattice weakly decreases with the current increasing. With the current decreasing the transition from crystal phase into "fluid" phase occurs, where the long-range order in the superlattice is destroyed but the short-range order is preserved. The micromagnetic simulations confirms our analytical results with a high accuracy.
The phenomenon of vortex-antivortex superlattices formation was studied in detail both numerically [1,2] and analytically [2]. Our numerical study was based on computer micromagnetic simulations using OOMMF code [3] and our analytical approach was based on the discrete Landau-Lifshitz-Slonczewski equation [4]. The linear analysis of stability of the saturated state enable us to obtain the value of the saturation current J_c as function of material parameters and the film thickness. The weakly nonlinear analysis proves the possibility of stable square vortex-antivortex superlattices in the pre-saturated regime. The transition from crystal phase into fluid phase was studied only numerically. We show that parameter Λ (it describes the mismatch between spacer and ferromagnet resistance in the pillar structure) does not influence the saturation current J_c, and influence of Λ on the dynamics of the vortex-antivortex superlattice is very weak. But the critical current J_{fc} of the transition fluid phase – crystal phase, and consequently the current range of the crystal phase $[J_{fc}, J_c]$, depends on the parameter Λ significantly: the crystal region vanishes when $\Lambda \to 1$ and it is constant for $\Lambda \gg 1$.

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