

# Experimental and theoretical analysis of the upper critical field in ferromagnet-superconductor-ferromagnet trilayers

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## Abstract

The upper critical magnetic field  $H_{c2}$  in thin film ferromagnet-superconductor-ferromagnet trilayer spin-valve cores is studied experimentally and theoretically in geometries perpendicular and parallel to the heterostructure surface. The series of samples with variable thicknesses  $d_{F1}$  of the bottom and  $d_{F2}$  of the top Cu<sub>41</sub>Ni<sub>59</sub> ferromagnet (F) layers are prepared in a single run, utilizing a wedge deposition technique. The critical field  $H_{c2}$  is measured in the temperature range 0.4-8 K and for magnetic fields up to 9 T. A transition from oscillatory to reentrant behavior of the superconducting transition temperature versus F-layer thickness, induced by an external magnetic field, has been observed for the first time. In order to properly interpret the experimental data, we develop a quasiclassical theory, enabling one to evaluate the temperature dependence of the critical field and the superconducting transition temperature for an arbitrary set of system parameters. A fairly good agreement between our experimental data and theoretical predictions is demonstrated for all samples, using a single set of fit parameters. This confirms the adequacy of the Fulde-Ferrell-Larkin-Ovchinnikov (FFLO) physics in determining the unusual superconducting properties of the studied Cu<sub>41</sub>Ni<sub>59</sub>/Nb/ Cu<sub>41</sub>Ni<sub>59</sub> spin-valve core trilayers. © 2013 IOP Publishing Ltd.

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