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**TITLE:** Low temperature coupling in [Co/Pd]/Cu/[Co/Ni] spin valves with perpendicular magnetic anisotropy\*

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**ABSTRACT BODY:** Pseudo spin-valves (PSVs) comprised of [Co/Pd] and [Co/Ni] multilayers (MLs) with perpendicular magnetic anisotropy have attracted attention due to their applications in spin torque technologies.<sup>1,2</sup> One limiting factor in their use is reduced magnetoresistance (MR) from coupling across the Cu spacer at the optimum GMR thickness. It was shown that this parasitic coupling is reduced at low temperatures.<sup>3</sup> We examine the nature of this coupling during field cycling in a [Co(6Å)/Pd(6Å)]<sub>5</sub>/Cu(30Å)/[Co(6Å)/Ni(6Å)]<sub>5</sub> PSV using first order reversal curve (FORC) measurements.<sup>4-6</sup> Fig.1 shows the FORCs and contour plots of the FORC distribution at 300K and 77K (top and bottom, respectively). At 300K the sample has a single-stepped major loop (Fig.1a). The FORC distribution (Fig.1b) is consistent with magnetization reversal by domain nucleation and propagation<sup>4</sup> through the entirety of the film; showing parasitic coupling. At 77K the major loop is bifurcated, indicating layer decoupling. The FORCs (Fig.1c) clearly trace out a minor loop from reversal of the [Co/Ni] ML. The contour plot has a localized peak at  $H_R = -0.25\text{kOe}$  coinciding with the minor loop, and is consistent with the reversal of the [Co/Ni] ML (Fig.1d). Once the [Co/Pd] ML begins to reverse additional features emerge. Of note is a large negative feature at  $H_R = -1\text{kOe}$  (Fig.1d, circled area). This feature coincides with the FORC curves deviating from the minor loop shape (Fig.1c, circled region). A similar feature has been observed in [Co/Pt]/Ru materials and is caused by recoupling of the layers.<sup>6</sup> Fig.2 shows representative FORCs taken at both temperatures. For  $H_R < -1\text{kOe}$  the FORCs are similar in shape, providing further evidence of the recoupling. The variation in coupling is also shown in the MR data (not shown). An increase in MR occurs with decreased temperature. Approaching saturation the MR traces all closely follow that of the 300K trace. The recoupling is from [Co/Pd] ML dipole fields re-nucleating domains in the [Co/Ni] ML.

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**KEYWORDS:** Perpendicular Magnetic Anisotropy, FORC, Spin Valve, GMR.

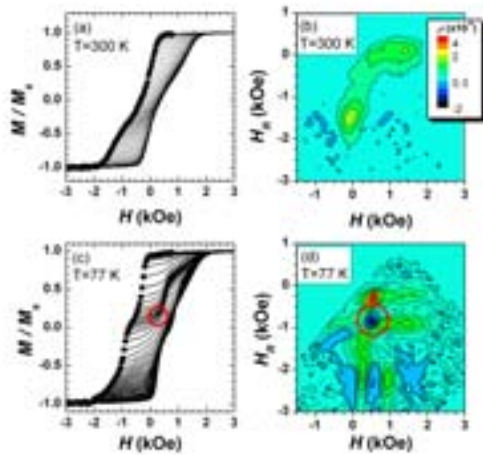


Figure 1- (Left) FORCs and (Right) contour plots of the FORC distribution for the [Co/Pd]/Cu/[Co/Ni] PSV at (top) 300 K and (bottom) 77 K.

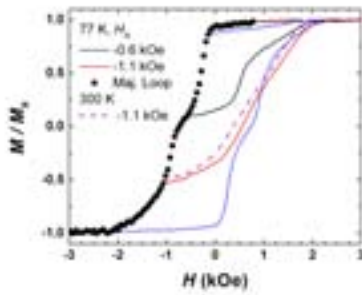


Figure 2 - Representative FORCs taken at (dashed lines) 300 K and (solid lines) 77 K.