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Perpendicular ferromagnetic resonance measurements of damping and the Landé g-factor in sputtered $(Co_2Mn)_{(1-x)}Ge_x$thin films

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We analyzed vector network analyzer-ferromagnetic resonance data for sputtered polycrystalline $(Co_2Mn)_{(1-x)}Ge_x$ thin films measured in a perpendicular configuration to minimize two magnon scattering. The films were grown with varying Ge content and subjected to post-deposition annealing at 200, 245, and 300°C. We can adequately fit the data with the slow relaxing impurity model for damping, similar to what was successfully used to explain enhanced damping in RE- doped Permalloy films. However, it was required to generalize the theory to include coherence effects that modify the original fluctuating field correlation function from a damped exponential to an exponentially damping cosine. We find that the spectroscopic splitting factor g is a clearly decreasing function of Ge content for 245 and 300°C anneal samples. Analysis of the content dependence for g provides strong evidence of a significant negative spin polarization between -0.15 and -0.35 spins at the Ge sites. This is consistent with our analysis of magnetometry data in the context of generalized Slater Pauling (GSP) theory, which presumes that the minority band density of states has a deep minimum at the Fermi energy. GSP analysis yields a spin polarization of -0.25 at the Ge sites. The substantial antiferromagnetic spin polarization of the Ge sites, in addition to the correlation of the slow relaxing damping strength with Ge content, suggests that Ge atoms, perhaps in the form of point defects in the Co sub-lattice, are acting as the slow relaxing impurities. Finally, successful fitting of linewidth data with a model that includes coherence during the relaxation process indicates slight transverse as well as longitudinal exchange coupling between the Ge "impurities" and the magnetization, giving rise to mixing of the electronic energy levels responsible for the relaxation process.