Investigation of spin transport in Ta by magnetic damping of Py|Ta and Py|Ta|(Py|Fe)

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We report on magnetic damping measurements in sputter deposited, magnetic single and double layer heterostructures, Py|Ta and Py|Ta|(Py|Fe) respectively, where Py = Ni\textsubscript{80}Fe\textsubscript{20}, see Figure below. Under ferromagnetic precession of Py, a spin accumulation is developed inside of Ta, leading to a spin current. The spin current is transported through Ta and is either reflected at the Ta|Air interface or absorbed into an exchange coupled bilayer of Py|Fe, depending on the structure.

Spin transport in Ta films is studied by varying the Ta films thickness and evaluating the changes in damping in the Py layer due to spin pumping and spin sink effects. The structure of the Ta films is determined using x-ray diffraction and transmission electron microscopy. Magnetic damping data is interpreted using established spin pumping/spin diffusion theory \cite{1} with the following variations: a) \(\rho\) (resistivity) of Ta at the thin-film thicknesses (~1 nm) and \(\lambda\) (spin diffusion length) are constants with respect to Ta thickness, b) \(\rho\) is fixed at bulk resistivity and \(\lambda\) is a constant fitting parameter, c) \(\rho(x)\) is inversely proportional to \(\lambda(x)\), and both are thickness dependent and d) \(\lambda\) is constant while \(\rho(x)\) is thickness dependent \cite{2}. We find models a) and c) to be in best agreement with our data.

Additionally, an investigation of total damping, \(\alpha\), of Py|Fe shows a linear reduction in damping (8.0 x\textsuperscript{–}3 to 4.7 x\textsuperscript{–}3) as the ratio of Py to Py|Fe is reduced (1.0 to 0.25) while keeping the thickness of the entire structure constant at 6 nm. If contribution to damping due to spin pumping is taken into account, the intrinsic damping is estimated to be \(\alpha = 3.9x\textsuperscript{–}3\), for the Py(1.5 nm)|Fe(4.5 nm). This structure shows low zero frequency offset, ~1.2 Oe, indicating that the exchange coupling averages out the contribution from the anisotropy fields due to the polycrystalline nature of the sample. However, growing the structure in reverse order, Fe then Py, leads to a significant increase in damping (x2) and a large zero frequency offset, ~19 Oe.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure1.png}
\caption{Damping due to spin pumping into Ta as a function of tantalum thickness. Top blue data represents the spin pumping induced damping in Py|Ta|Py|Fe. The bottom, red data, represents the spin pumping induced damping of the Py|Ta structure. Data is fit using the models mentioned in the text.}
\end{figure}
