Edge state of nanoscale magnetic tunnel junctions investigated by spin-wave resonance

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Magnetic state of pattern edge of nanoscale magnetic tunnel junctions (MTJs) affects their performance and its sensitive detection is highly demanded. In this work, we investigate the condition of the pattern edge using spin-wave resonance. We observed a distinctly different behavior in spin-wave resonance between two types of perpendicular CoFeB/MgO MTJs having different edge conditions.[1,2)] The results were reproduced by an analytical model considering different boundary conditions (fixed or free) and exchange stiffness.

We study two types of MTJs with various free-layer diameters D; step and standard MTJs, which are different in size of reference layer. They are prepared through different process conditions, leading to different edge condition (the details are described in our previous reports).[1)]

Homodyne-detected ferromagnetic resonance (FMR) spectra are measured by sweeping perpendicular magnetic field H_{perp} at various rf frequencies f_{rf} [1)]. We observe two resonance peaks at different external magnetic field, which can be identified by their azimuthal and radial mode indices (l, n). The most prominent peak observed with higher resonance field corresponds to uniform mode (0,0) and the other peak at lower resonance field corresponds to the first excited spin-wave mode (1,0). Difference between resonance fields for (0,0) and (1,0) modes is defined as $H_{00\text{-}10}$.

To understand the mechanism, we calculate the relation between $H_{00\text{-}10}$ and $1/D^2$ using an analytical model. We find that the results of standard MTJs, as in our previous work[2)], are well described by the free-edge boundary condition and exchange stiffness constant A_{S} =6.7 pJ/m reduced at the device edge to A_{S} = 0.67 pJ/m. On the other hand, the results for step MTJs are better described by a fixed-edge boundary condition and uniform A_{S} =6.7 pJ/m. These results indicate that spin-wave resonance can serve as a sensitive prober for edge states of nanoscale MTJs.

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