BW-12 Energy barriers in sub-micron magnetic islands prepared from alloyed and multilayered Co/Pt films.

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By means of Anomalous Hall Effect measurements, we investigated the thermal switching field distribution of individual magnetic thin film circular elements of 200 nm diameter with out-of-plane easy axis in a temperature range from 10K to 300K. We compared this behavior for elements prepared from $Co_{80}Pt_{20}$ alloyed thin films as well as Co/Pt multilayers, and show that the variation in energy barriers is significantly smaller for a 3 nm multilayered film than for a 20 nm multilayered or alloyed film.

Due to thermal energy, the switching field of an individual element fluctuates between reversal attempts. From statistics on thousands of hysteresis loops we obtain a thermal switching field distribution. This distribution can be fitted to an Arrhenius based model, assuming a known relation between the reduction of energy barrier and the externally applied field. From the model fit, we obtain the energy barrier against reversal as well as the switching field the element would have at room temperature, but in the absence of thermal energy. Note that this is not necessarily the same as the switching field at 0K, since the material properties are temperature dependent. In our multilayered films for instance the saturation magnetization increases by 7% and effective perpendicular anisotropy by 16% when decreasing the temperature down to 10 K. The statistical analysis was therefore performed for temperatures of 10 K and 300 K. This allowed us to compare the measured temperature dependence of the switching field of individual elements with predictions made from the statistical analysis, taking into account the variation in material properties with temperature.

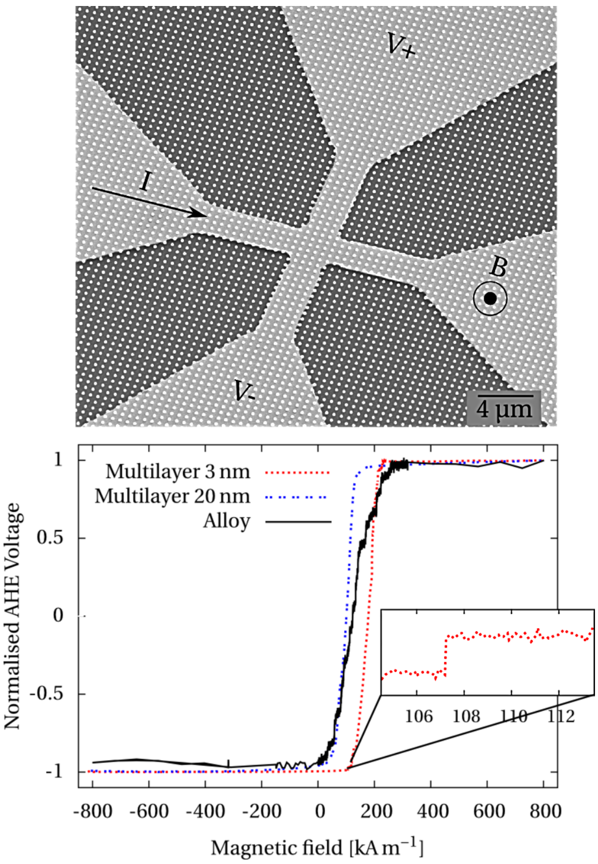
From our experiments we conclude in the first place that energy barrier as well as the theoretical switching field in the absence of thermal fluctuations are always larger for elements with higher switching fields at room temperature. This is in contradiction with our previous work (Engelen, 2010), where we found that for alloyed films prepared in a similar way, the energy barrier is independent of the switching field. The base films in that study however had a two to three times higher anisotropy, which might explain the difference.

Secondly, the switching field distribution of arrays based on multilayered films is lower than that of arrays based on alloyed films. The difference in energy barriers between weak and strong islands is larger for the 20 nm multilayer than for the 3 nm multilayer. This effect is less prominent for the switching field in absence of thermal fluctuations. The variation in energy barrier of elements prepared from the 20 nm multilayer, is larger than the variation for the alloy based elements.

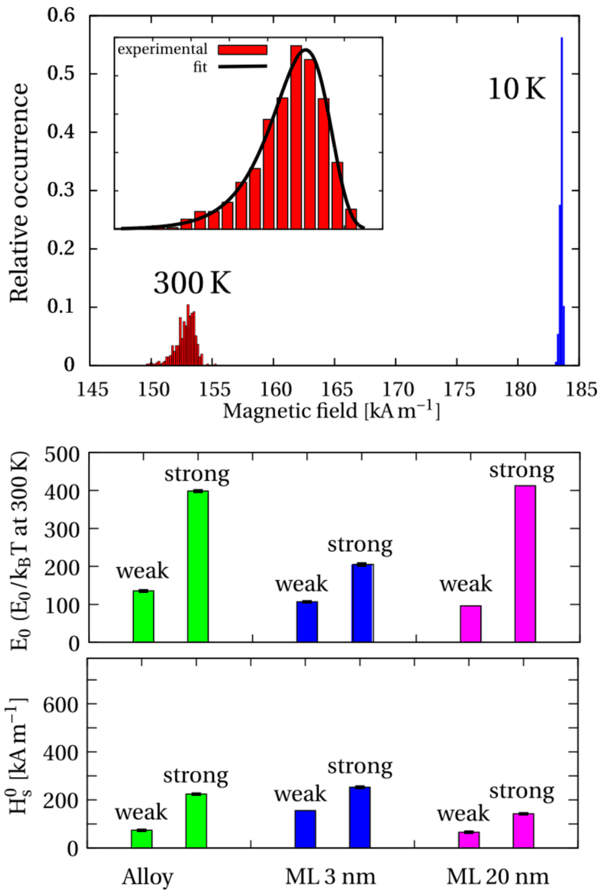
Finally, we conclude from the model fit in combination temperature dependent measurements of energy barriers and switching fields that an energy barrier model based fully on domain wall propagation model underestimates the dependence of energy barriers with temperature, whereas a coherent rotation model overestimates this dependence. We therefore suggest an intermediate model, based on work by Adam (2012), in which the domain nucleates at the edge of the element at reduced domain wall energy.

The results we present in this contribution enhance our understanding in the reversal and switching field distribution of sub-micron magnetic elements with perpendicular anisotropy, such as used in patterned magnetic recording media and MRAM memories.

Engelen et al "Thermally induced switching field distribution of a single CoPt dot in a large array" Nanotechnology 21 (2010) p. 035703
Adam et al "Magnetization reversal by confined droplet growth in soft/hard hybrid nanodisks with perpendicular anisotropy" Physical Review B 85, 214417



Left: Hall Cross with Co/Pt magnetic elements produced by Laser Interference Lithography. The sensitive area contains about 80 elements. Right: Anomalous Hall signals were obtained from alloyed and multilayered films. The inset shows reversal of individual islands.



Left: The distribution of the switching field of an individual island in the area is temperature dependent. The inset shows that the distribution can be accurately fitted by an Arrhenius model. From the model fit the energy barrier against reversal and the switching field in the absence of thermal fluctuation can be obtained. Right: For all films investigated, the energy barrier is larger for elements that switch at higher fields. The spread in energy barriers and SFD between elements is smallest for the 3 nm multilayer film.