Progress in X-ray magnetic circular dichroism and reflection anisotropy spectroscopy Kerr effect studies of capped magnetic nanowires

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Abstract/Introduction:

Aligned cobalt nanowires of 1, 2, 3 and 6 atoms wide, were grown on platinum(997) surfaces under UHV conditions and capped with 5, 6 or 9 ML of gold. It has been shown previously that capping with Au raises the Curie temperature and favours perpendicular magnetization of Co nanowires grown on Pt, both of which are of technological significance[1]. X-ray magnetic circular dichroism (XMCD) measurements were performed at the $L_{3,2}$ edges of Co. Element specific hysteresis loops were measured as a function of temperature and coercivities were extracted. The easy axis of magnetization was confirmed to be perpendicular to the (111) terrace for all samples. The observed temperature dependence of the coercivity, which varies by an order-of-magnitude over a 100 K temperature range, is compared to the predictions of several theoretical models[2]–[5], including the "barrier plot" model[3], [4], based on an energy barrier distribution function, and the Gaunt "strong" and "weak" domain wall pinning models [5].

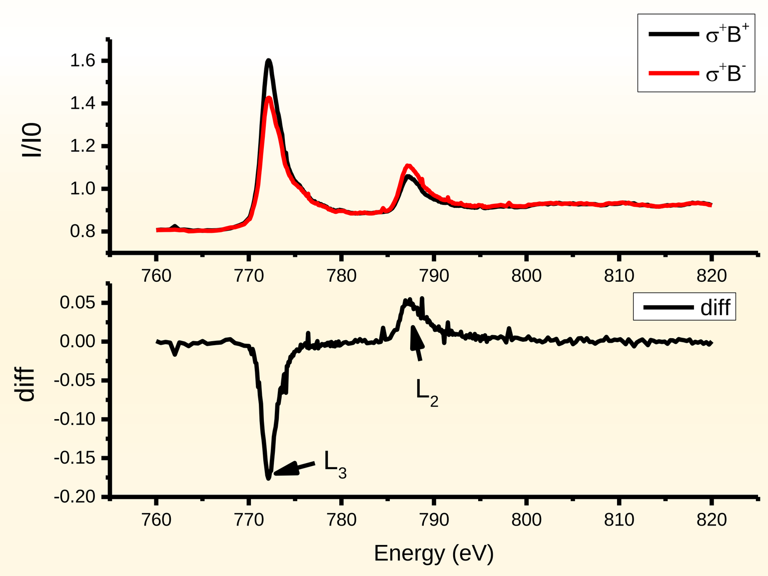
Sample preparation:

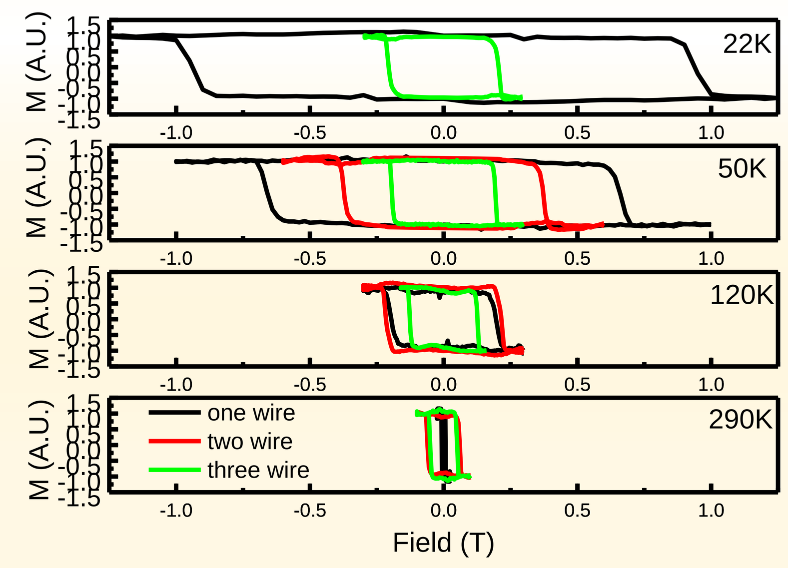
The Pt 997 surfaces were prepared in ultra high vacuum by repeated hot sputter annealing cycles at 750 K and 850 K respectively with a ion energy of 500V. Coverages were controlled with a quartz microbalance, where 0.13 monolayer of Co corresponds to a 1-atom-wide wire. At room temperature the Co self-assembles into wires at the step edge. The surface was then capped with Au to protect the Co wires from oxidation when being transferred to *ex situ* measurement chambers, while also modifying their magnetic properties. A sample was grown with composition Au(5ML)/Co(0.13/0.26/0.39ML)/Pt(997), corresponding to 1-, 2- and 3-atom-wide wires

Experimental details:

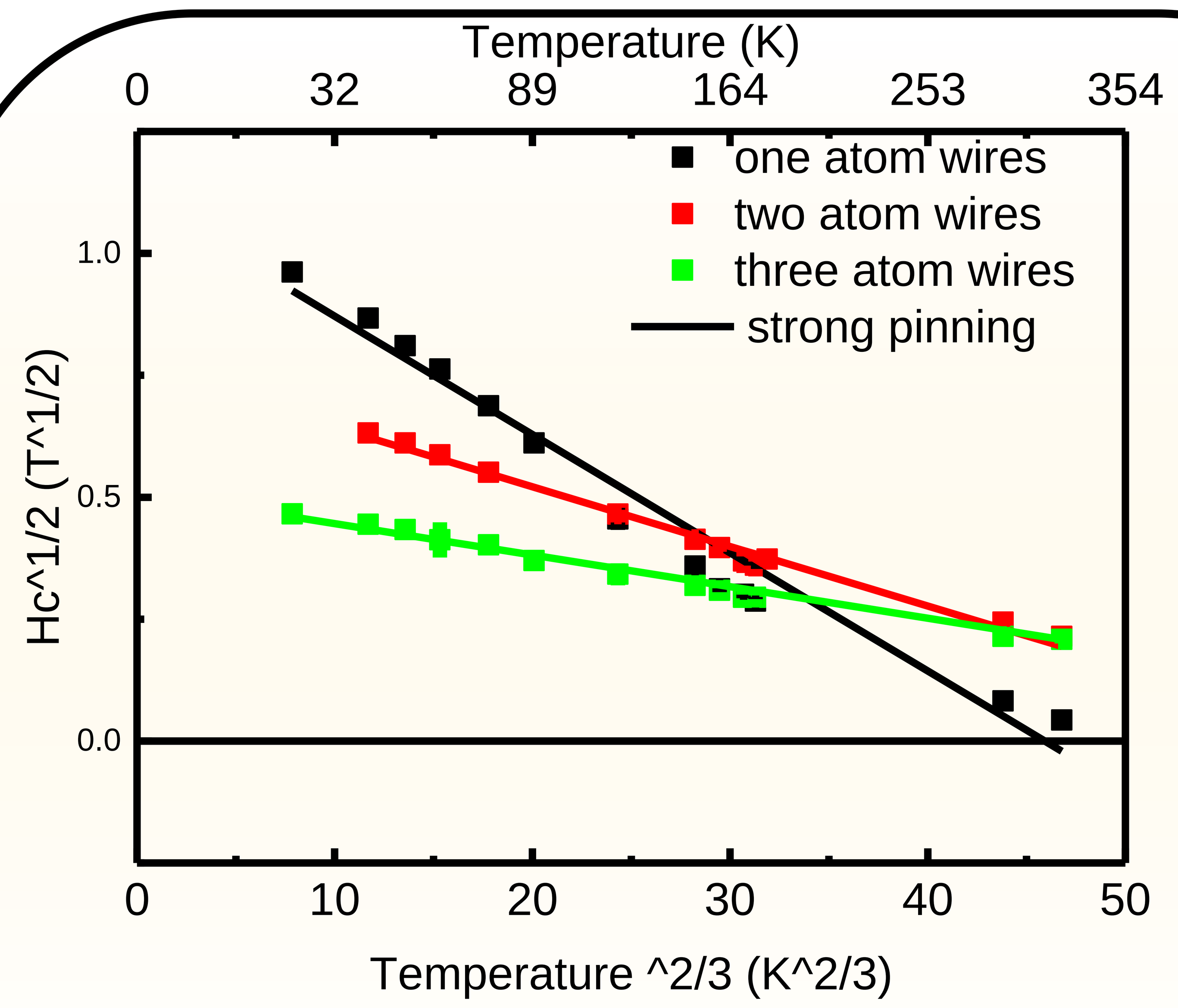
XMCD was performed on the capped Co wires, at Beamline 6.3.1 at ALS. XMCD is a element specific technique, due to its use of core level transitions. Hysteresis loops were measured by monitoring the Co L_3 intensity while ramping the field and reversing the polarization after each cycle.. Loops were collected at various temperatures from 20 K-320 K

Results





Models to explain temperature dependent magnetisation reversal



Gaunt strong and weak pinning models

•Weak ($H_c \propto T$): $\frac{H_c}{H_0} = 1 - \frac{25 k_B T}{2\pi N \gamma b^2}$

•Strong ($H_c^{1/2} \propto T^{2/3}$): $\left(\frac{H_c}{H_0}\right)^{1/2} = 1 - \left(\frac{75 k_B T}{4bf}\right)^{2/3}$

☑Model works

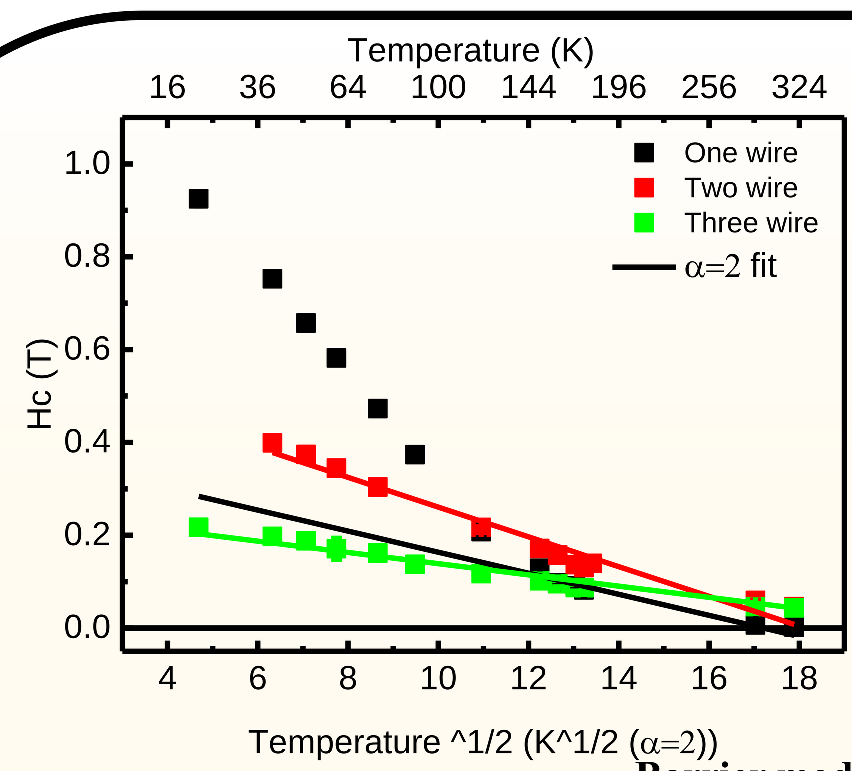
•Different Gaunt models apply depending on pinning site density

Gaunt strong pinning model

•The Gaunt strong pinning model provides the best fits for the system for all wire widths

•The success of this model indicates that the domain walls are pinned at defects such as step edge kinks

•Demagnetization energies of the order of eV extracted from fits, which could indicate that the capping layer is enabling increased coupling between the wires through the RKKY interaction and could triple the size of the spin block compared to the uncapped wires



☒Model not appropriate

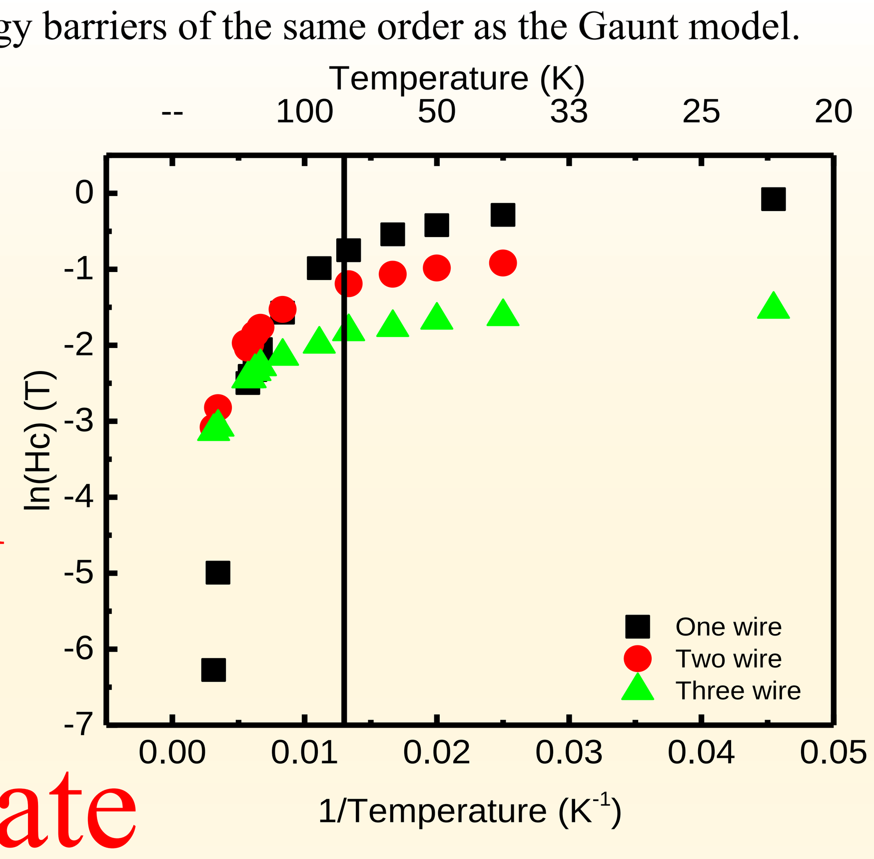
Barrier model

•Magnetic states switched between equivalent states by transitioning over a barrier

• $H_c \propto T^{1/\alpha}$ with different values of alpha for different switching mechanisms ($\alpha = 2$ for rotation in unison and $\alpha = 3/2$ for domain wall nucleation): $\frac{H_c}{H_0} = 1 - \left(\frac{k_B T \ln(\Gamma_0 t_e)}{U_0}\right)^{1/\alpha}$

•Rotation in unison model provides the best fit for this model but it fails to describe the 1-atom-wide wire behaviour.

•Demagnetization energy barriers of the same order as the Gaunt model.



☒Model not appropriate

Cheng model

•Model proposed by Cheng with low frequency magnetic hysteresis: $\frac{H_c}{H_0} = \omega \tau_0 \exp\left(\frac{T_K}{T} N(T)\right)$

•Linear fit for $\ln(H_c)$ versus $1/T$

•Model breaks down at low temperatures (below original author preformed work)

•Fails to describe the behaviour of any of the wires

References:

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Conclusion

•The Gaunt strong pinning model provides the best fit for our system for all wire widths
•The Barrier model does not describe the observed behaviour as well and fails to describe the 1-atom-wide wire behaviour
•The Cheng model breaks down at low temperature
•The Gaunt model indicates that the interaction between wires has increased from the uncapped case and the spin block size has increased