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Micromagnetic study of pyramidal core-shell structures

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1) Motivation

Growth of complex nanostructures by new chemical self-assembly

- Shape and size distribution tunable
- Hysteresis properties of ferromagnetic structures can be analysed with micromagnetic model
- Due to complex shape: Generally only numerical treatment based on the finite element or an enhanced finite difference method possible

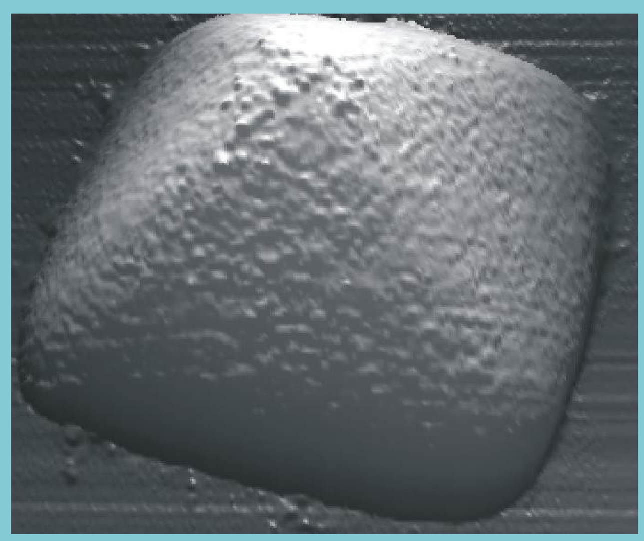


Figure 1: SEM image of a Nickel layer grown on a pyramidal Ag mesostructure (Nanoscience Group, Bath)

2) The micromagnetic method

Micromagnetic study of idealised pyramid core-shell structures

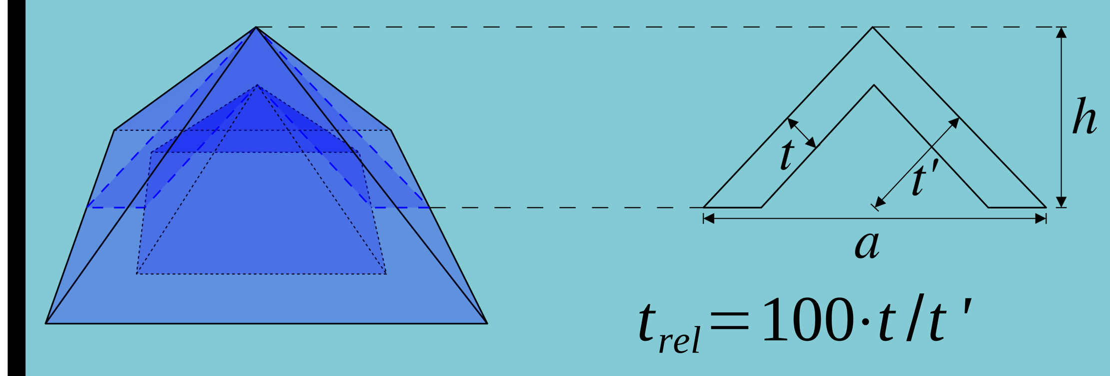
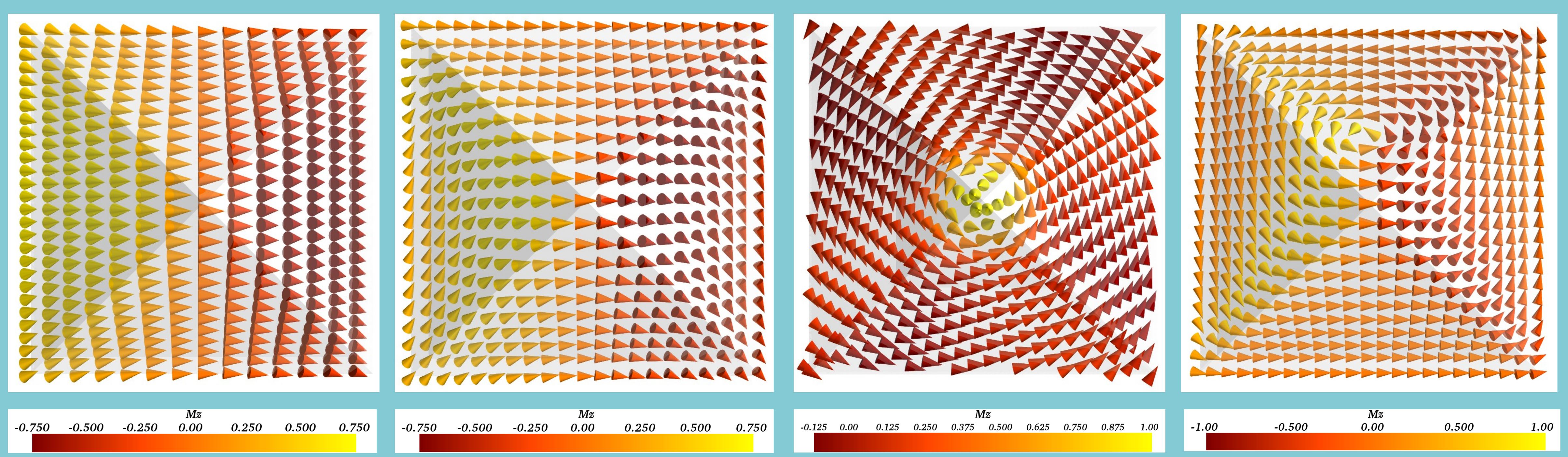


Figure 2: Idealised core-shell structure, two parameters: edge length a (size), rel. thickness height h set to a/2

- Use of FEM based code (Nmag)
- Model includes exchange, magnetostatic and external field contribution, anisotropy neglected
- Use of hierarchical matrices improves efficiency
- Stable configuration by relaxation of LLG equation

3) Results

Ground states occurring at different sizes and shapes (no external field!):



(a) Flower-state (b) C-state (c) Vortex with core at tip (d) Vortex with core on side face

Figure 3: Top view of different magnetic configurations. Those configurations are energetic ground states for different shapes (shell thicknesses) and sizes.

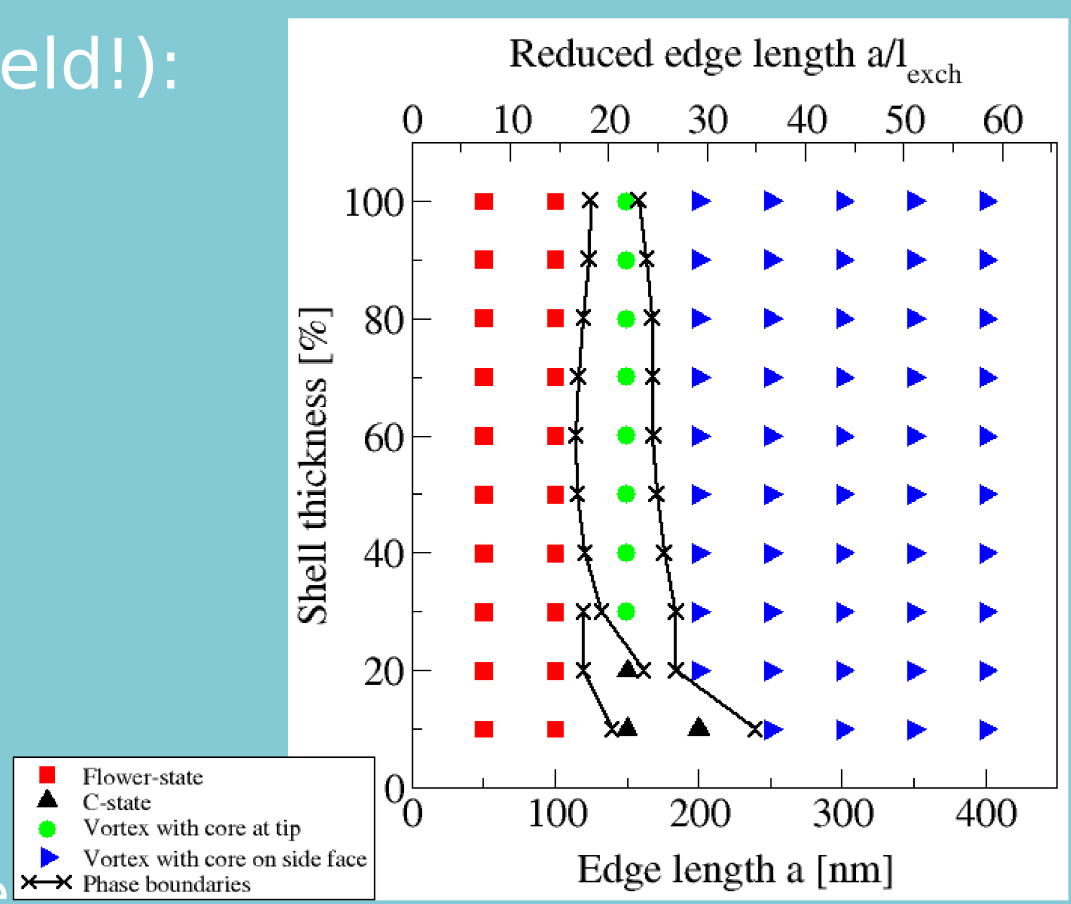
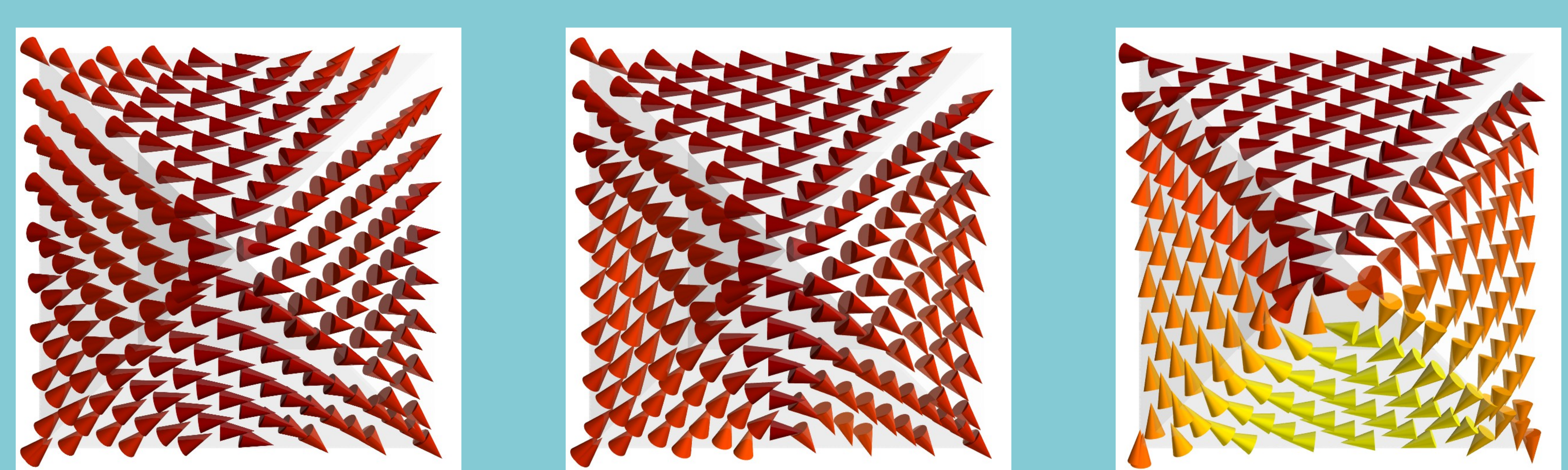
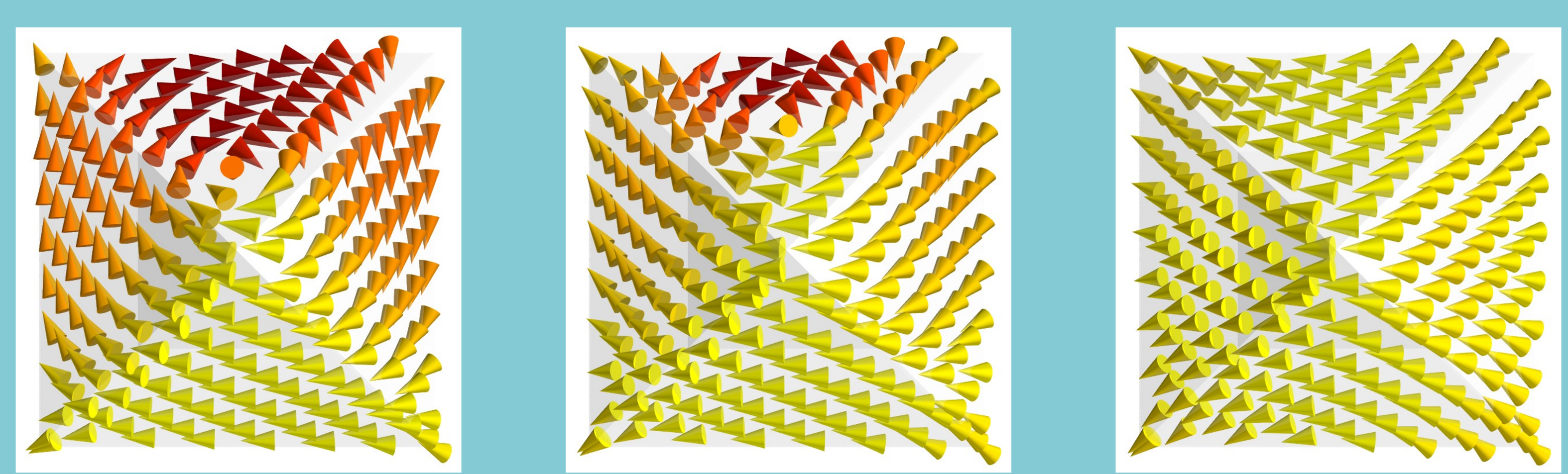


Figure4: Phase diagram showing energetic ground states for different pyramid sizes and shell thicknesses

Magnetic Reversal for pyramid shell with a=250nm and t_{rel}=50%:



(a) Flower-state (b) C-state (c) At H_x=0: Vortex-state with core on side face



(d) Vortex core moves over apex to opposite side (e) Vortex core moves down the side face (c) reversed Flower-state

Figure 5: Top view snapshots of reversal process (see figure 6). Positive x-direction:

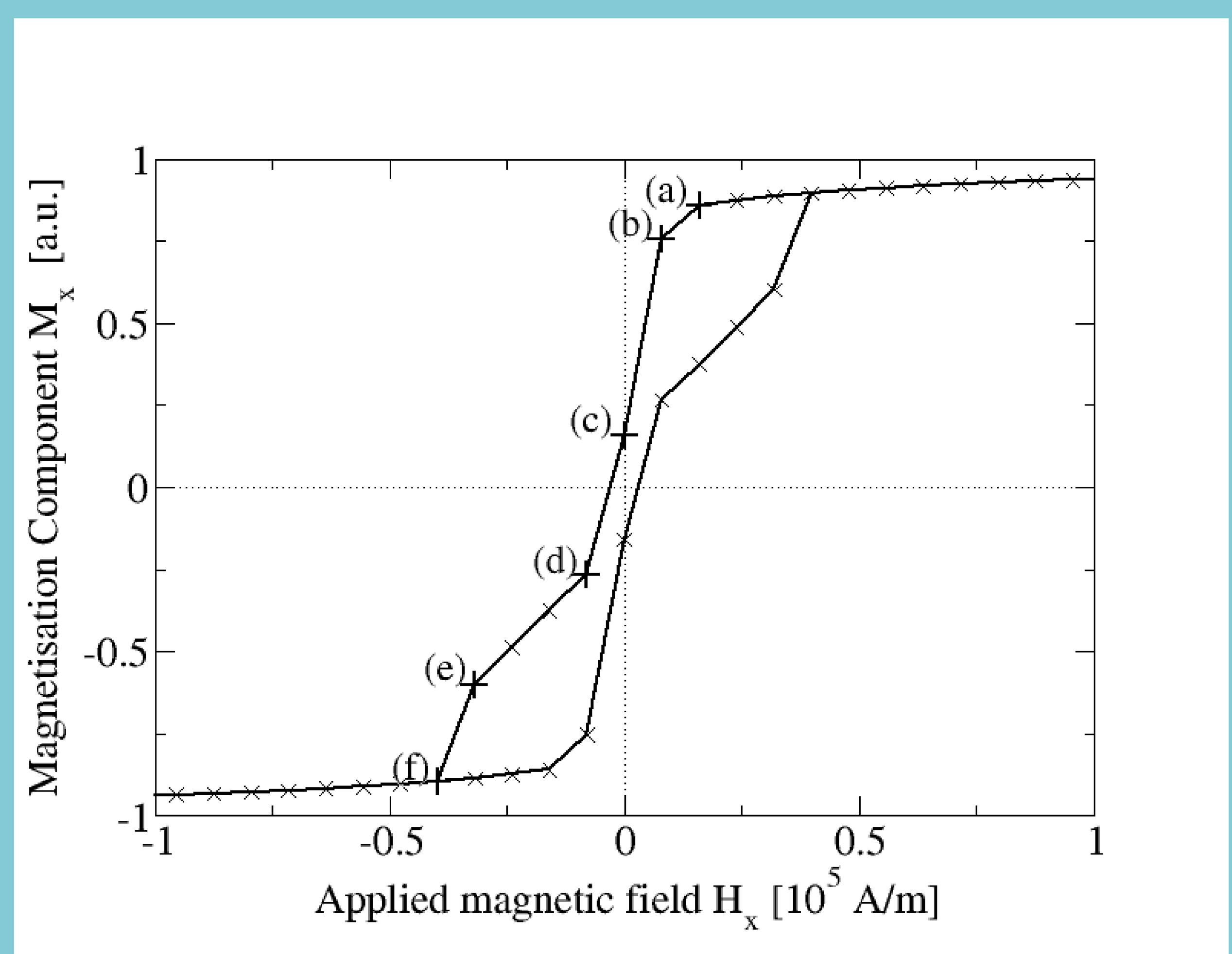


Figure 6: Hysteresis for a pyramid shell with a = 250 nm and t_{rel}= 50%. The external field varies along the x-direction, see also figure 5.

Conclusions: Micromagnetic analysis of pyramidal core-shell structure. Different physical behaviour for thin shell structures. Interesting reversal behaviour for the remanent state with a vortex core on a side face.