Morphological study of submicron elements FIB-patterned on ferromagnetic-antiferromagnetic Fe/NiO layers

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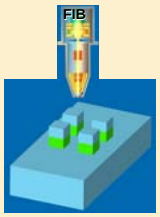
Patterning of magnetic materials

Ferromagnetic/Antiferromagnetic (FM/aFM) layers are currently employed in reading heads devices and are appealing for future devices such as magnetic RAMs. These new applications require a knowledge on how the magnetic properties change when size is confined to the nano-scale.

FIB offers a very flexible and easy tool for nano-patterning: material is removed by ion milling, leaving arrays of isolated features with the desired pattern.



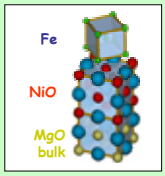
The Experiment

Magnetic properties can strongly depend on features' morphology, therefore we have studied the shape of patterned features as a function of two beam parameters: current(I) and dwell time (DT). Patterns consisted of 250 and 500 nm square islands.

Beam currents			Dwell Time	Energy
Nominal I	Nominal Ø	Actual I	1 µs	30 keV
50 pA	15 nm	60 pA	10 µs	
100 pA	20 nm	144 pA	100 µs	
300 pA	25 nm	398 pA		

The sample was a MgO/Fe/NiO/MgO multilayer, grown and characterized (chemically and structurally) in UHV.

MgO_{cap} 10 nm
Fe(100) 10 nm
NiO(100) 10 nm
MgO(100) bulk

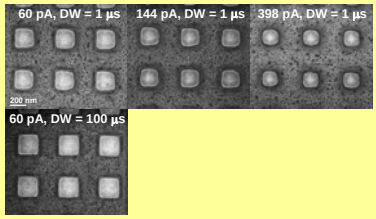


SEM Pattern Analysis

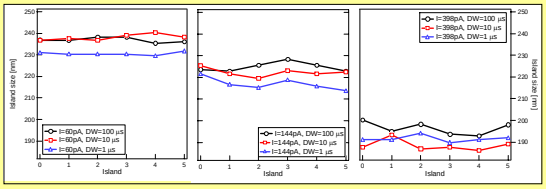
Dependence on I: Island size decreases as I increases, shape rounds

Dependence on DT: At a given I shape is better defined the higher DT (lower repetitions)

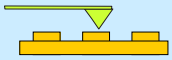
250 nm Islands



Island size



AFM Pattern Analysis

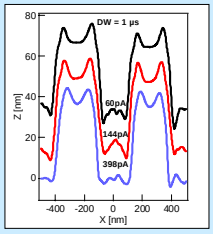


Dependence on I and DT: confirms SEM observations

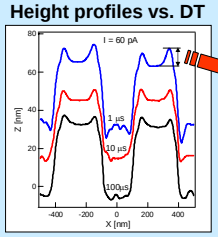
Edge bending: A pronounced bending-up occurs at the edges. As size decreases with I, bended edges overlap at the center of the island.

Tip heights vs. I and DT: Edge bending strongly reduces when DT increases at a given I

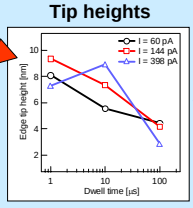
Height profiles vs. I



Height profiles vs. DT



Tip heights

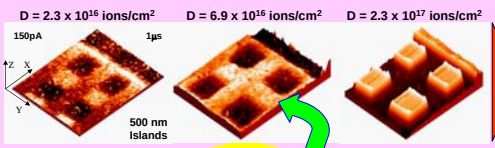


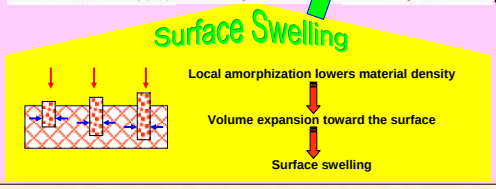
The origin of edge bending: SURFACE SWELLING

To investigate the origin of edge bending we have patterned 500nm island at **increasing ion dose**.

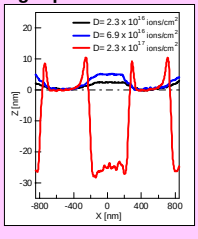
Surface swelling: At low doses, before erosion starts, swelling is observed where the beam hits the surface. Surface is 5 nm-elevated with respect to untouched areas.

We explain bended edges as the tails of swelled areas.





Height profiles vs. Dose



CONCLUSIONS

1) Increasing I (beam size): Island size decreases, roundness increases.

2) Increasing Dwell Time (lower repetitions): sharper shapes.

3) AFM analysis revealed edge bending of island surface.

4) Edge bending originates from surface swelling at the beginning of the pattern (low ion dose).

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