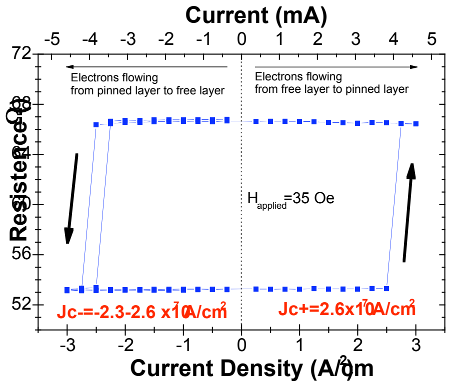
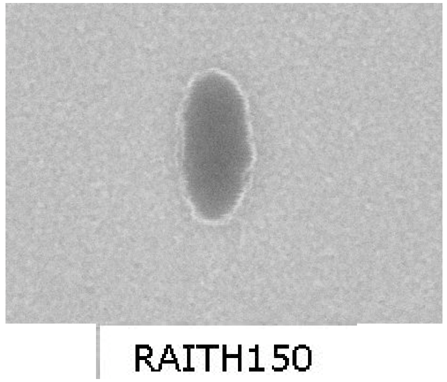




30 nm
Magnetic Tunnel Junction Fabrication

Overview and Applications

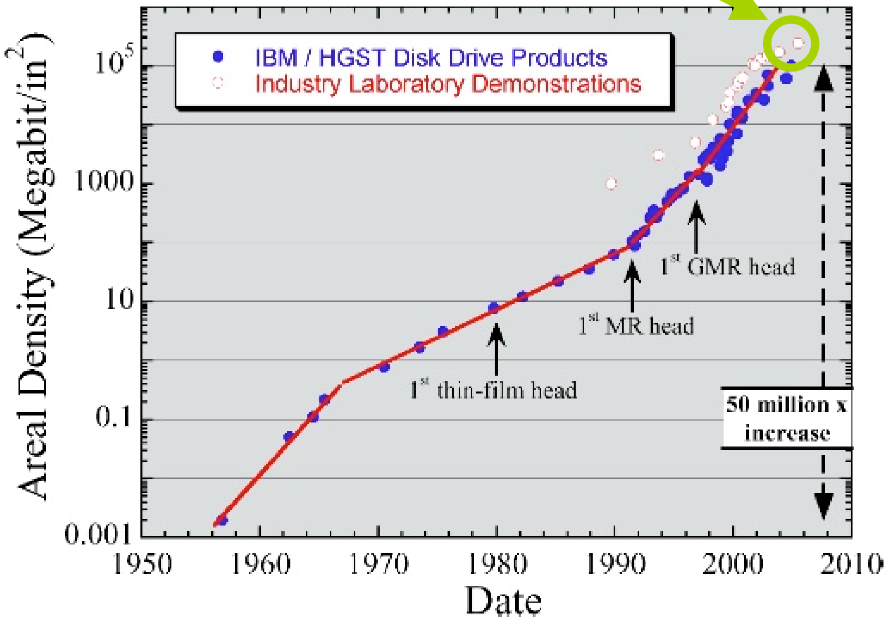
INESC MN

Microsistemas e Nanotecnologias

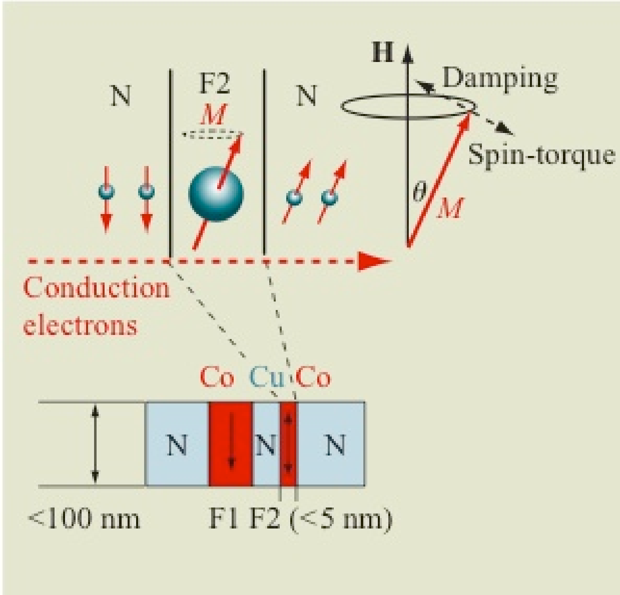
Rita Macedo,
R. Ferreira, S. Cardoso, P. P. Freitas

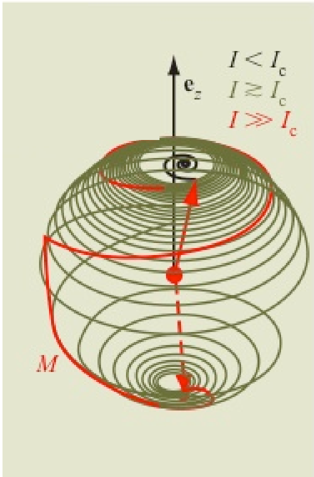
Read Head Technology

2008: Density Storage 1Tb ⟺ Bit Dimension ~ 30 nm



Spin Transfer MRAM





Challenges

- Reduce cell size
- Produce MTJ with low *Resistance Area* product (*RxA*)

Challenges

- Reduce cell size

Electron Beam Lithography Performance

- Beam Energy
- Electron Interaction Phenomena
- Resist Process

Strategy

- Use low-energy electron beam
  - Reduce the exposure dose
  - Avoid radiation damage caused by high energy electrons
  - E-Beam tool used is RAITH 150
- Reduce thickness of e-beam resist
  - Reduce electron interaction

	Electron Beam Resists		
Beam Energy	PMMA	ZEP-520	AR-7520.18
100 kV	10 nm	10 nm	n.a
10-20 kV	20 nm	25 nm	60 nm
Other Properties	•Positive •Low Sensitivity	•Positive •High Sensitivity • Good etch resistance	•Negative •High Sensitivity •Good etch resistance

E-Beam @ INESC-MN
Raith 150

- Direct Writing and SEM system
- Thermal assisted field emission
- Acceleration Voltage: **100V–30kV**
- Probe Current Range: 5 pA-20 nA
- Beam Size: 2 nm @ 30 KeV
- Lithography Resolution: **~ 20 nm**

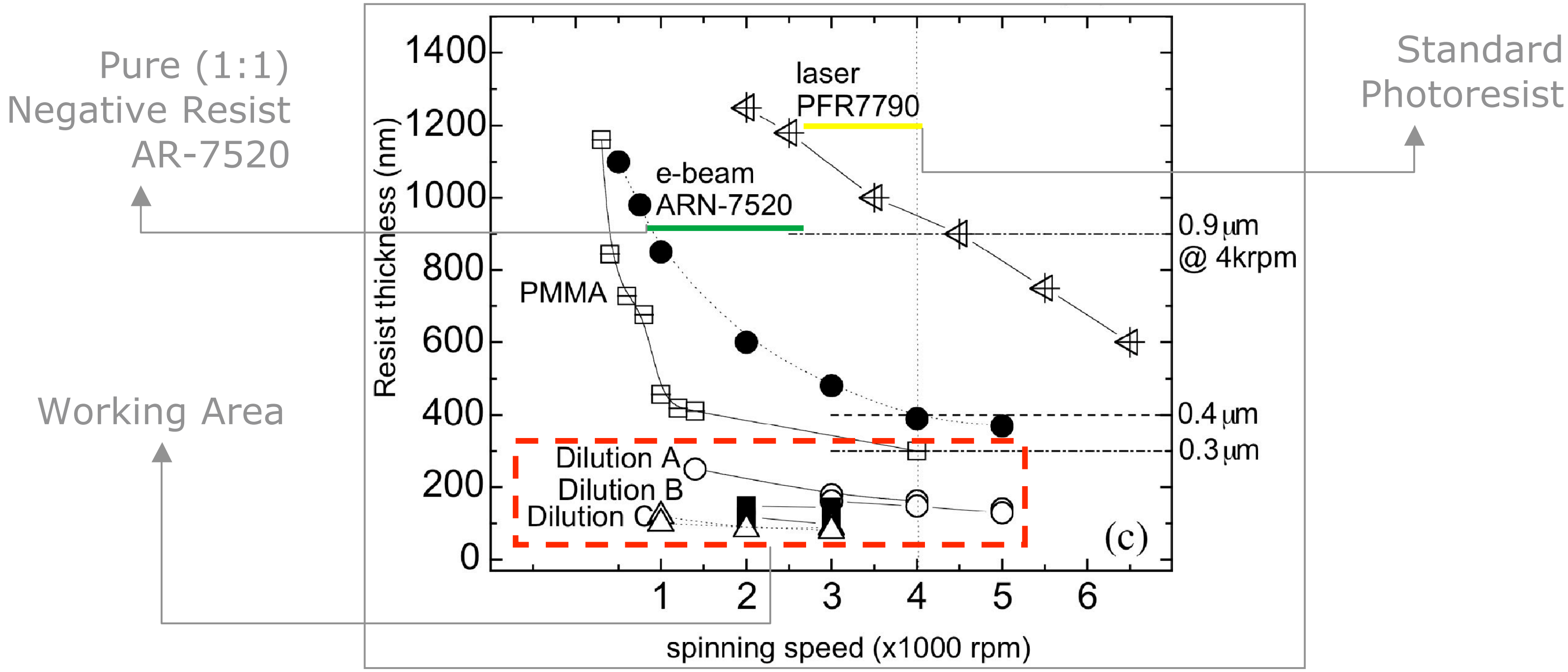
Objective

- Decrease Resist Thickness

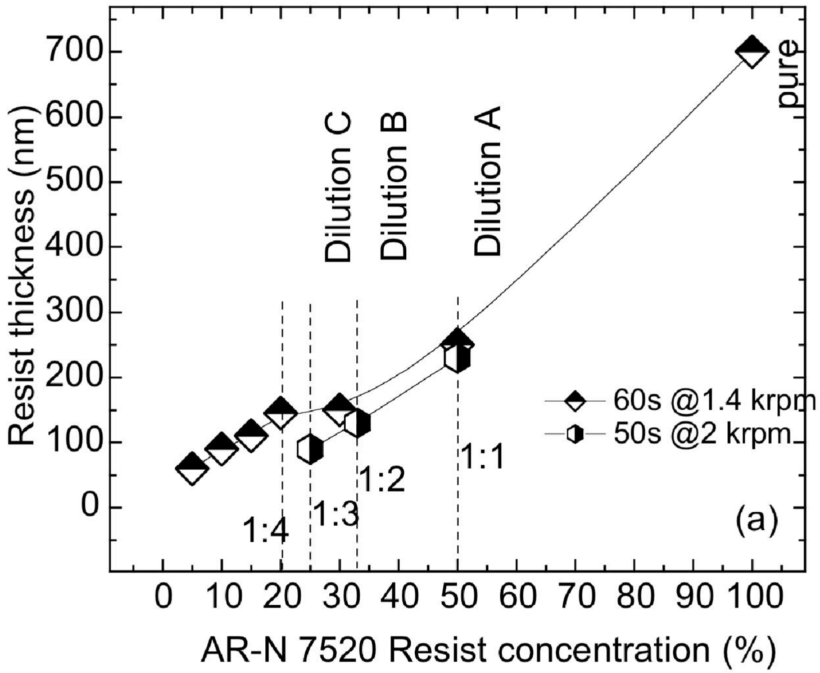
Study different Dilutions of AR-7520

- Solvent used is AR 300-12

- Comparation between AR-7520.18 and other resists used for microfabrication

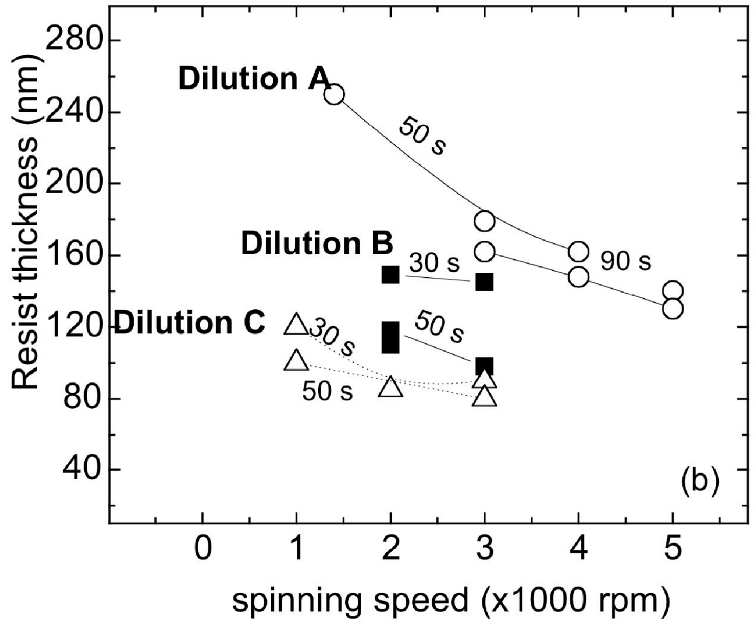


- AR-7520.18 resist thickness dependence on the dilution



	Dilution		
Results	A (1:1)	B (1:2)	C (1:3)
Small thickness	~130 nm	~100 nm	~80 nm
Coating Parameters	• 5 krpm • 90 s	• 3 krpm • 50 s	• 3 krpm • 30 s

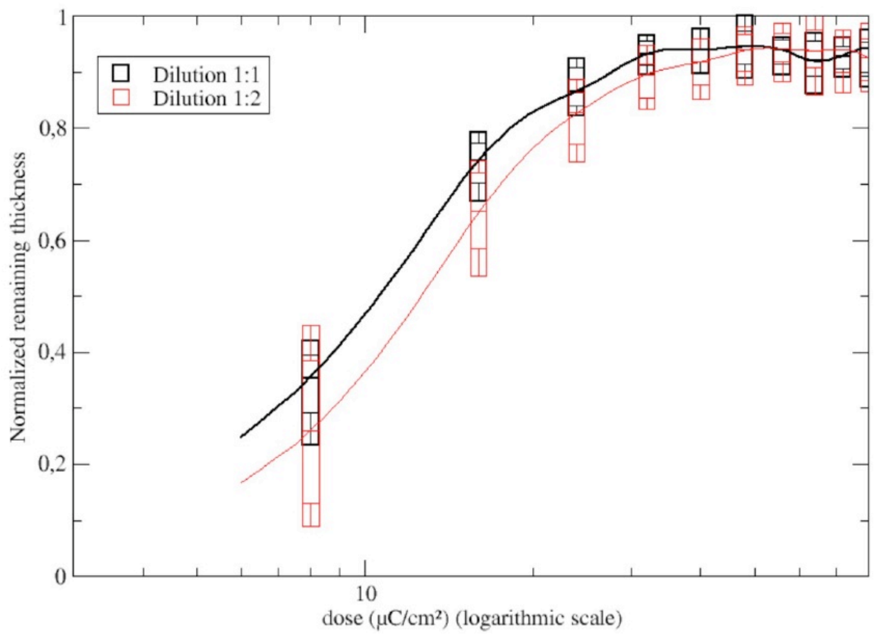
Dilutions 1:1 (A), 1:2 (B), 1:3 (C) were selected to investigate the influence of the spinning time and velocity



Critical Issues for the Electron Beam Resist

- High Sensitivity

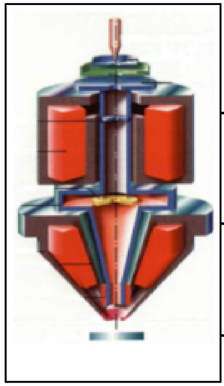
Contrast curves obtained for different resist concentratiob shows a *no critical changing in the sensitivity and contrast* for diluted resists.



- Good etch resistance

0.4 A/s of etch rate allows a safe working regime for processimg.

	E-Beam Resist AR-7520.18			PMMA	Laser resist PFR7790
	A (1:1)	B (1:2)	C (1:3)		
70º incidence	0.7 A/s	0.6 A/s	0.4 A/s	1.0 A/s	1.4 A.s

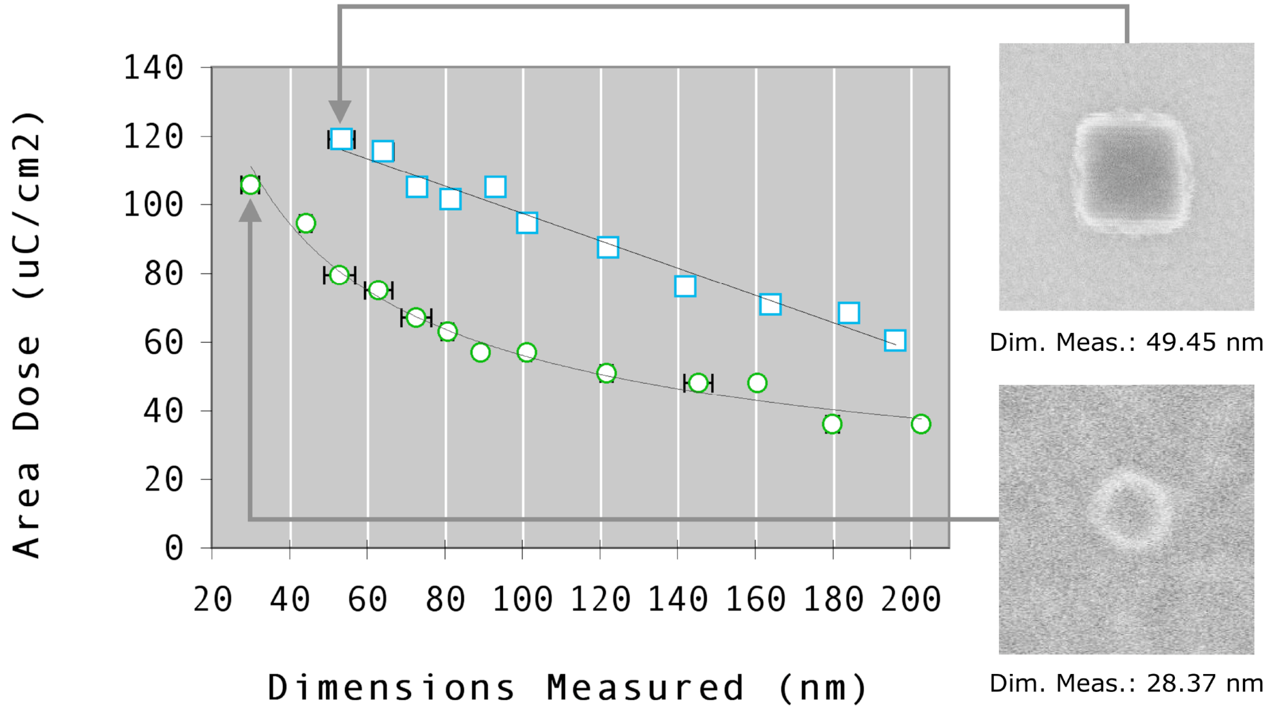


Resolution almost reaching the nominal limits of machine (*~ 20 nm*)

Low-Energy Electron Beam Parameters

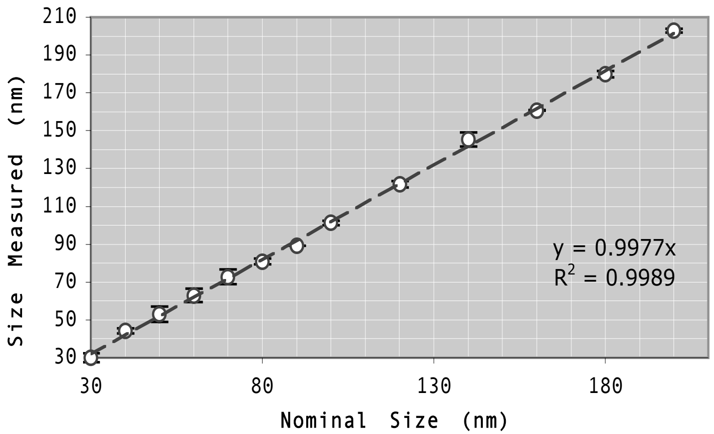
Acceleration Voltage	Current	Area Dose	Resolution
10-20 kV	20-35 pA	40-140 μC/cm^2	30 nm

Dose Optimization



Analysis of the optimization process

- By reducing the resist thickness the resolution limit increases
  - From 60 nm to 30 nm
- Lower resist thickness needs low area dose

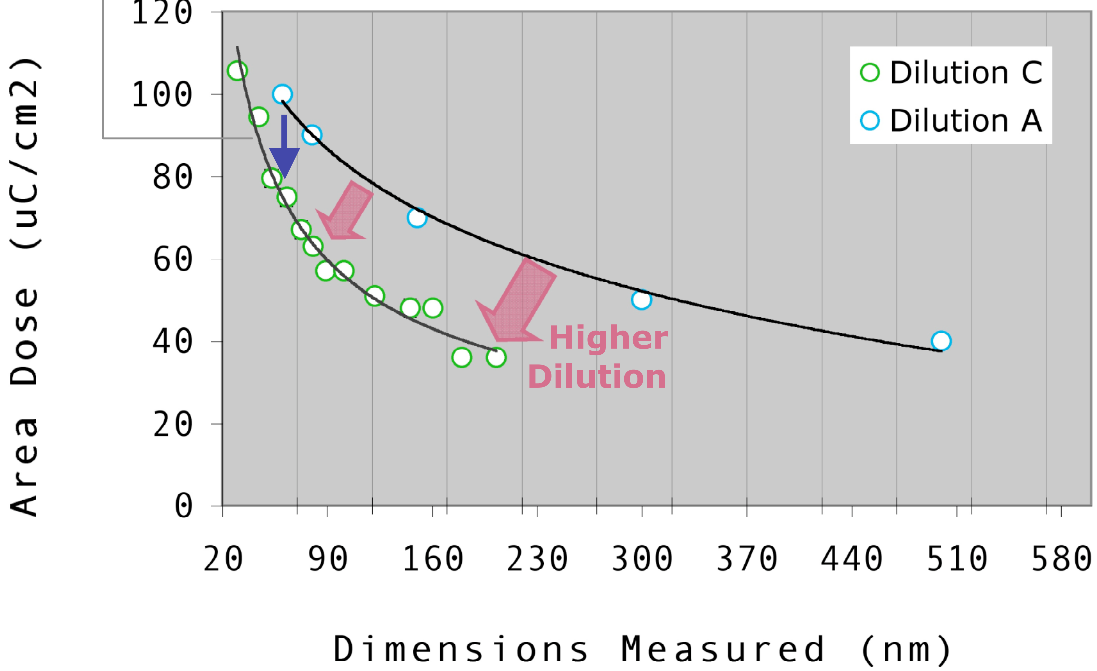


Previous work

Optimization

	Electron Beam Resists		
Dilution	Thickness	Dose	Dimensions
A	200 nm	35-100 µC/cm²	60 - 500 nm
C	80 nm	40-140 µC/cm²	30 - 200 nm

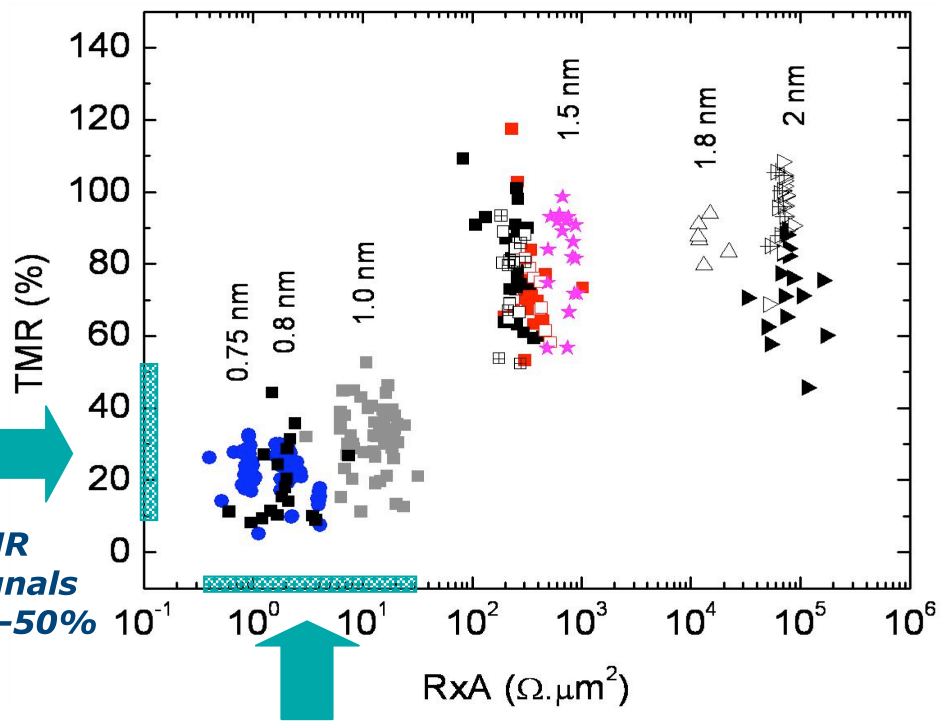
- Example: 60 nm, Dilution A ~ 100uC/cm²
  Dilution C ~ 80 uC/cm²



Challenges

- Produce MTJ with low *Resistance Area* product (*RxA*)

Achievements

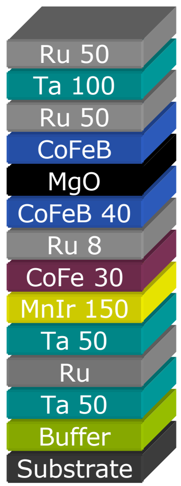


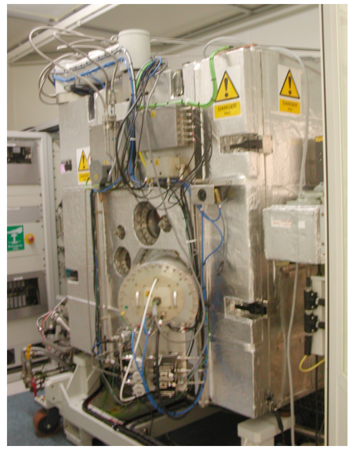
TMR signals 20-50%

Low RxA

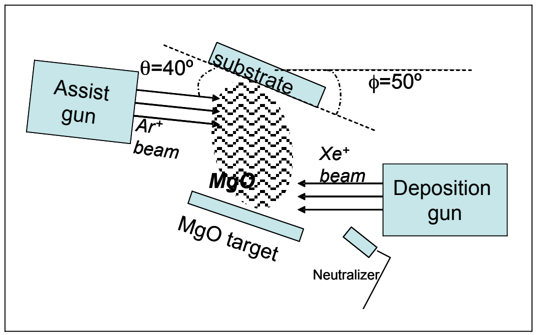
MgO-based MTJs are prepared by Ion beam assisted deposition (IBD)

- IBD system in a Nordiko 3600 tool
  - Base Pressure: $6x10^{-8}$ Torr
  - An assist beam is used for MgO deposition





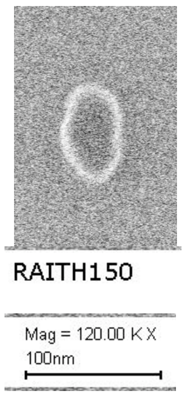
- Geometry used for MgO assisted deposition,



E-Beam Lithography + Materials

Sub-50nm pillars

Low RxA MTJ



Nanofabrication Process

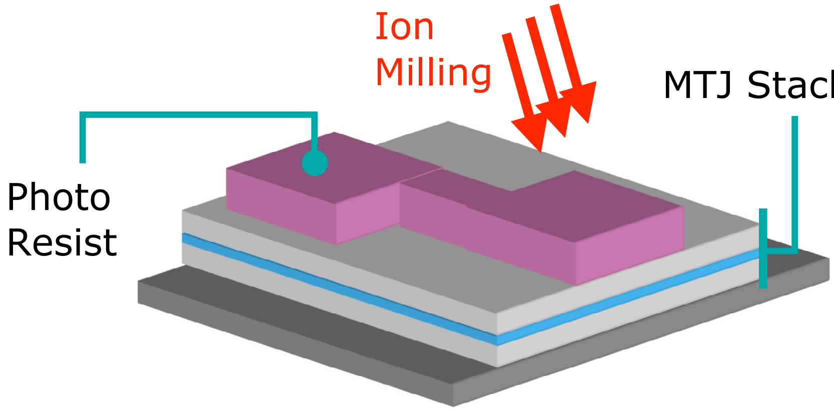
Challenges

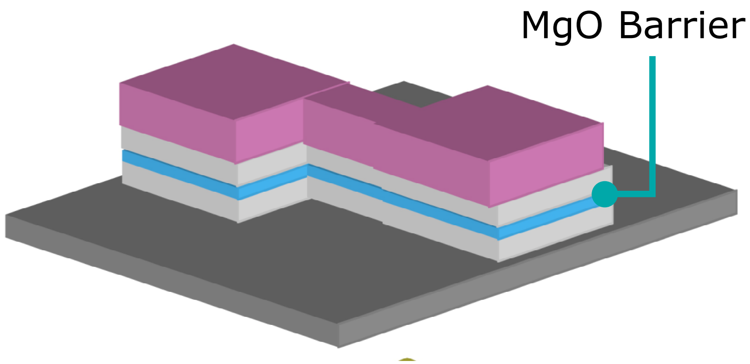
- How to establish contact to the top electrode of the nano-sized pillar?
- How to avoid side-wall issues due to redeposition during etching by ion milling?

Strategy

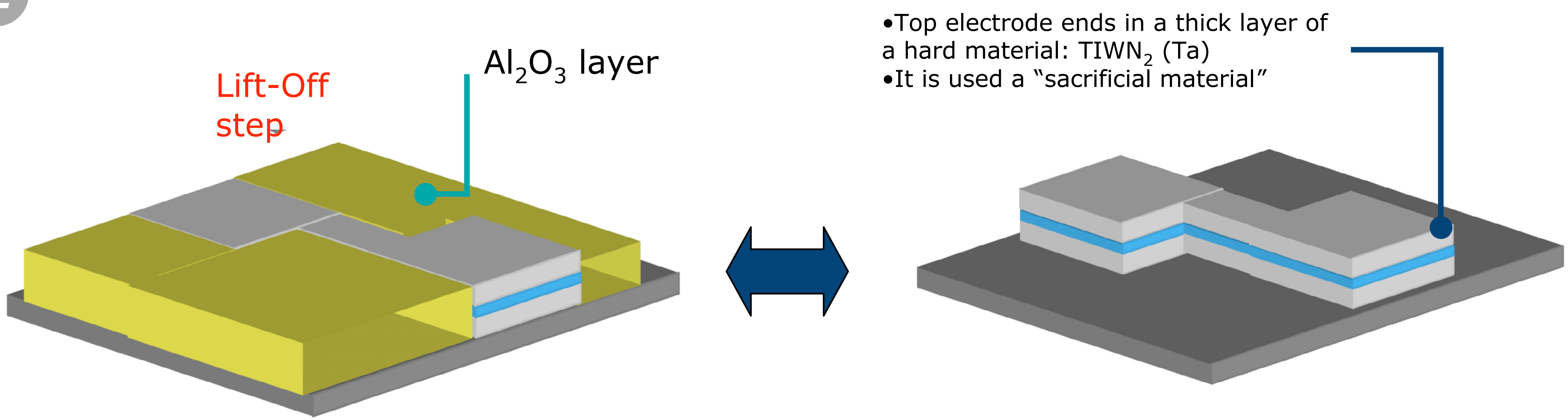
- E-Beam and etching by ion milling to define the pillar
- Chemical-Mechanical (CMP) to planarize the insulator layer and to open a top contact to the pillar

1 *Bottom Electrode Definition*

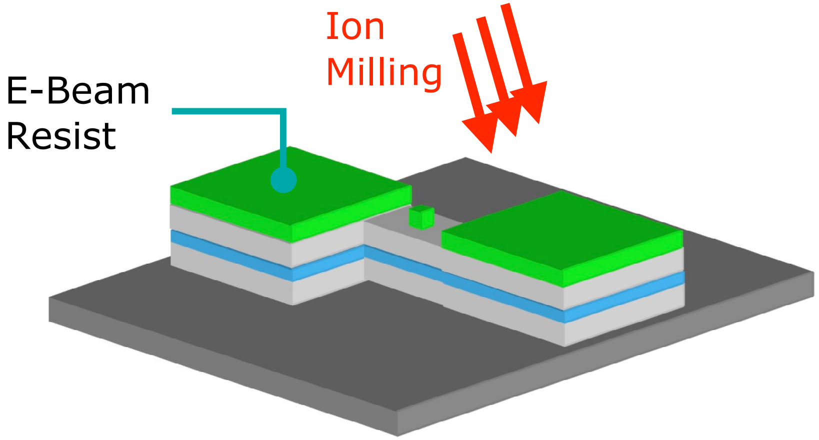


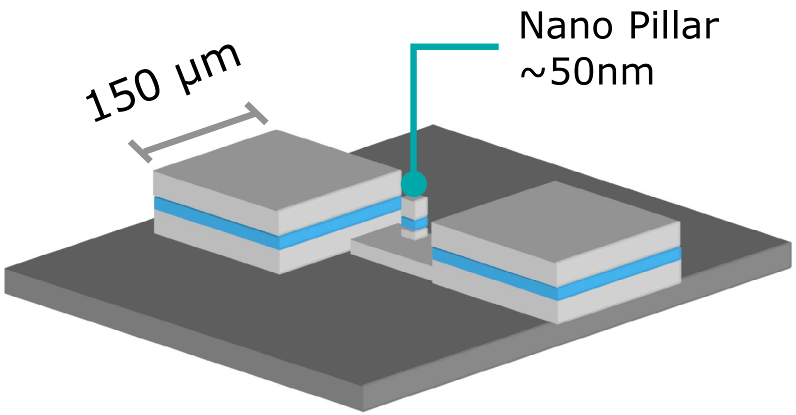


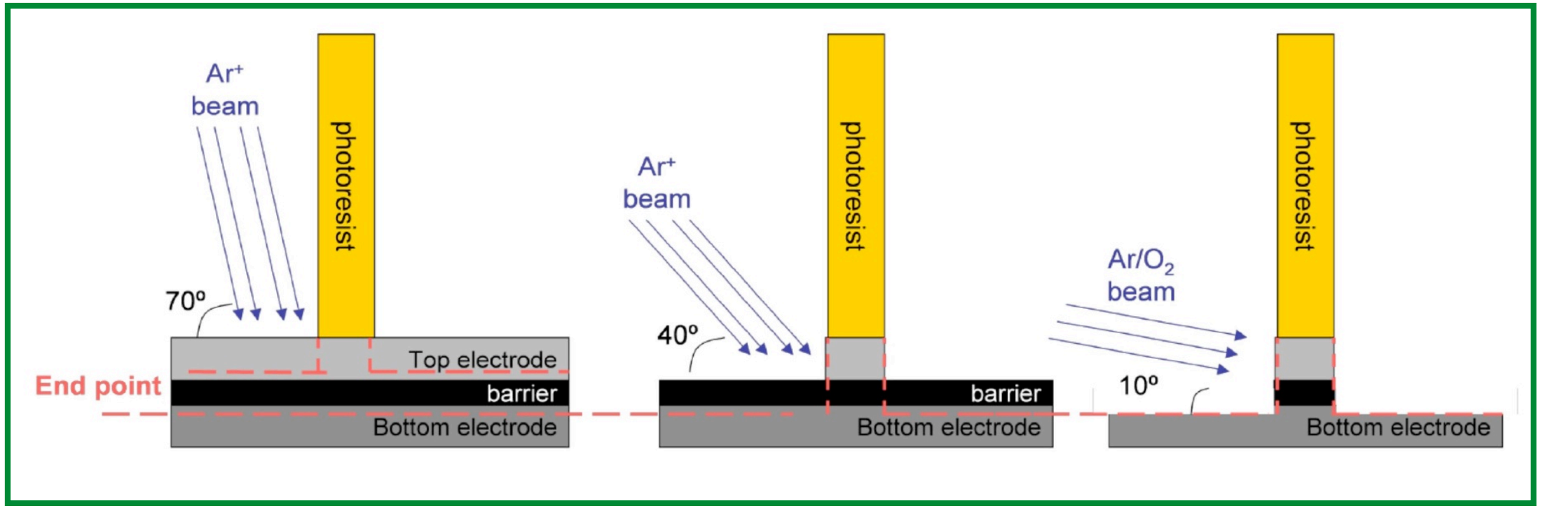
2 *Surface Planarization*



3 *Junction Definition*





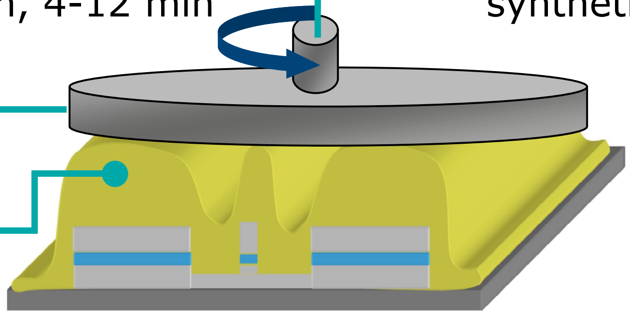


4 *Chemical Mechanical Polishing*

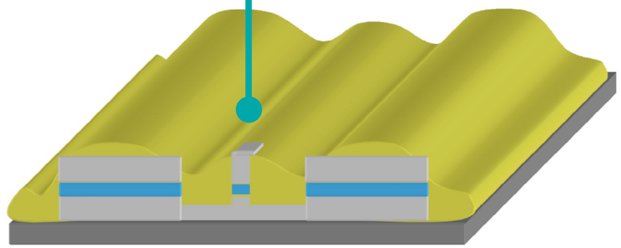
Lapmaster
Polishing tool
30rpm, 4-12 min

Coiloidal Ceria slurry
Porous soft-
synthetic pad

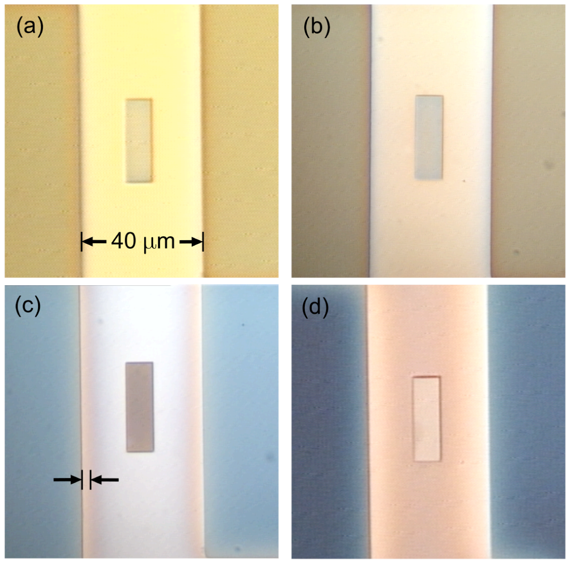
SiO_2



Opened top contact
to Nano Pillar

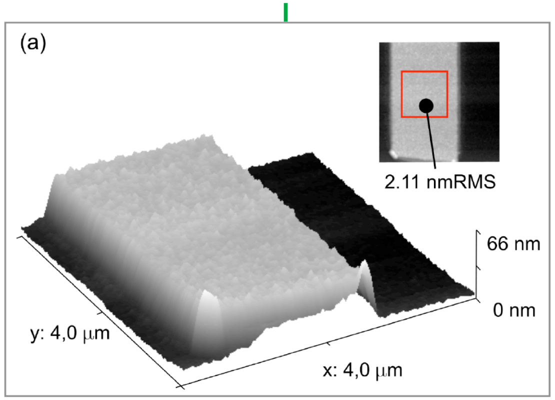


Optical Inspection

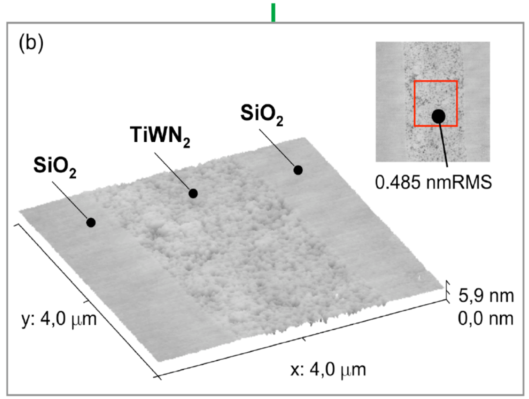


AFM Measurements

Before Polishing

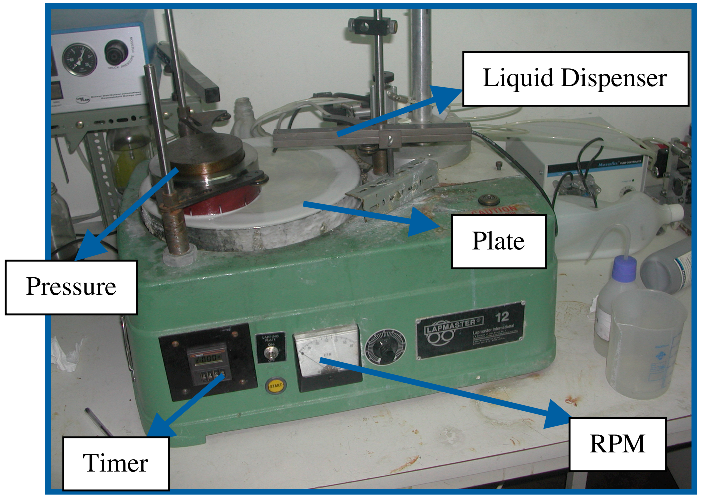


After Polishing



Advantages

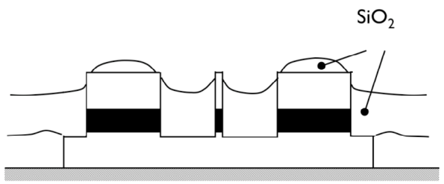
- Very adaptable polishing machine
  - o 1'' samples, 3'' wafers
  - o different slurries can be used
- Portable
- Small polishing time steps

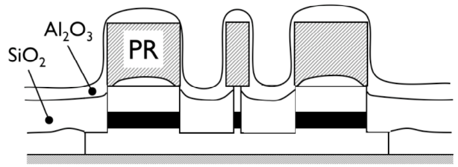


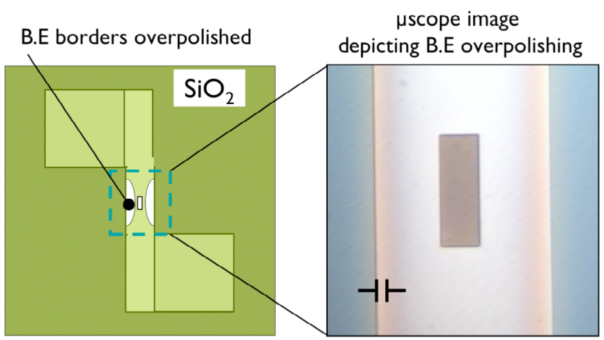
Disadvantages

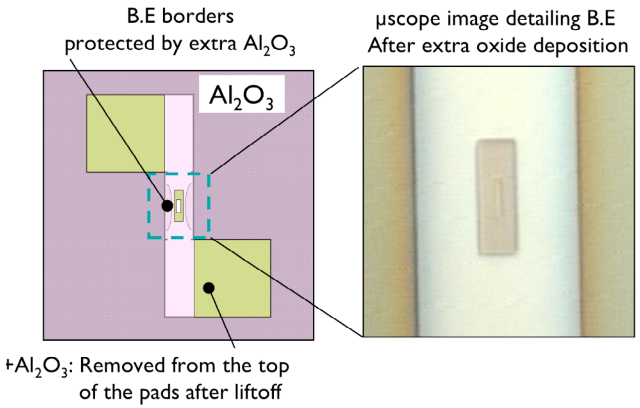
- Uniformity problems
- Polishing rate difficult to calibrate
- Process control not optimized

5 *Extra Oxide Deposition*

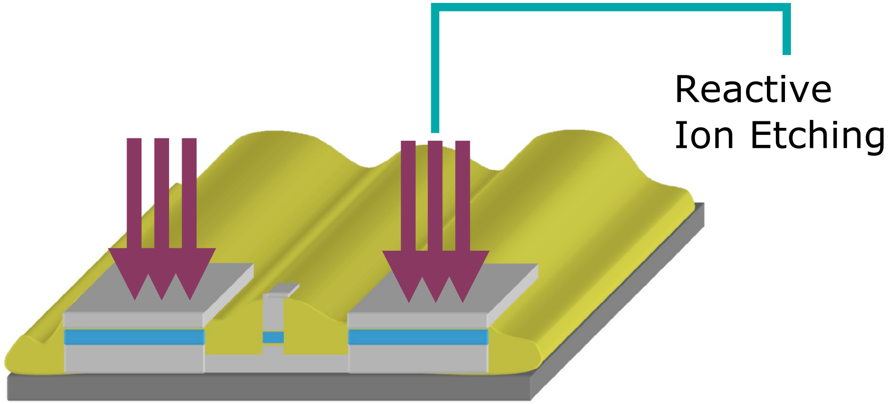


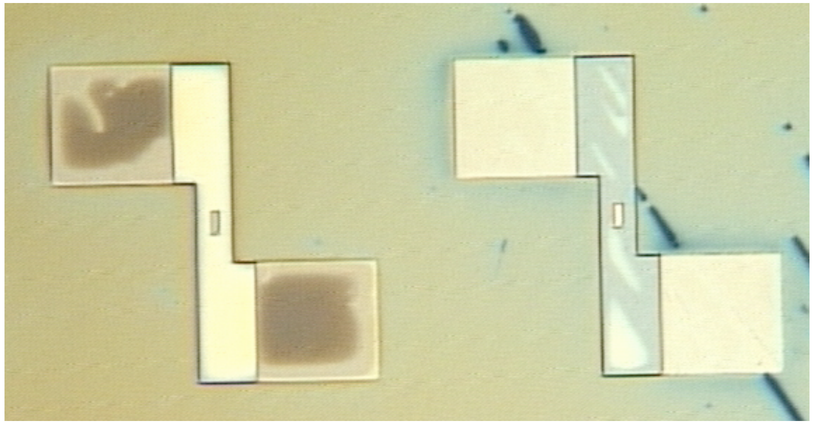




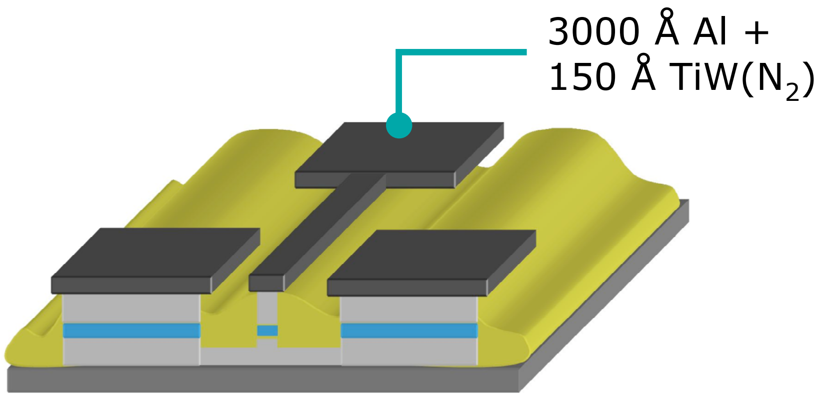


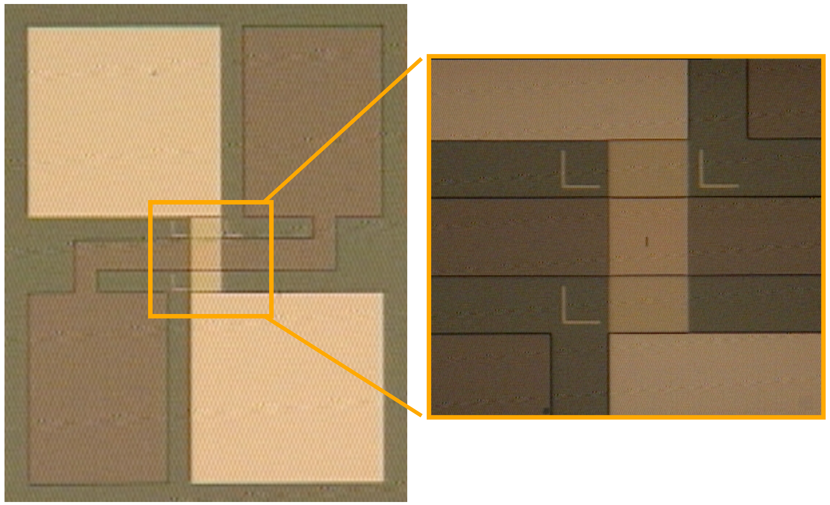
6 *Vias Opening*





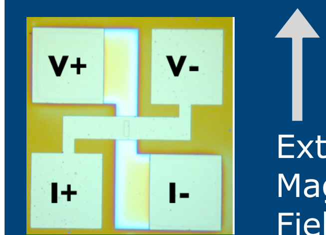
7 *Metallization*





Measurements

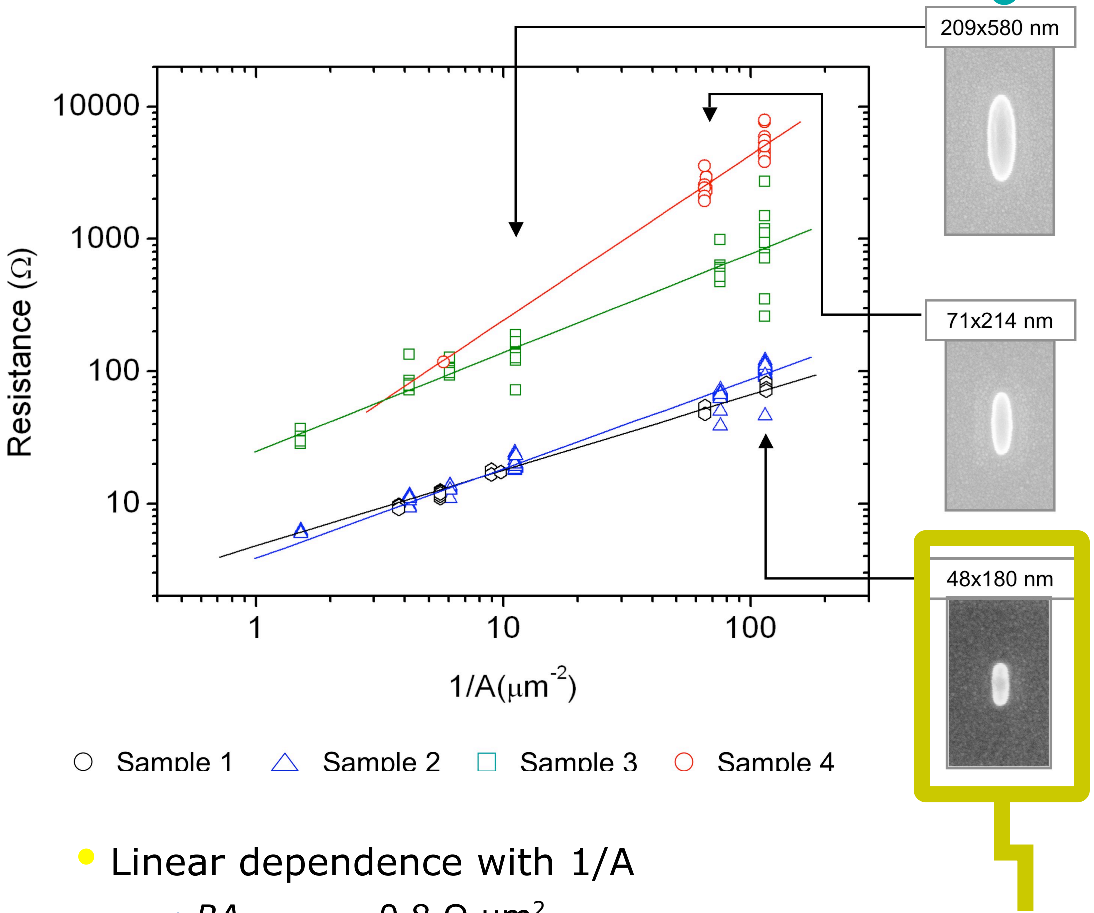
- Several devices were fabricated using this process and measured
- Samples were annealed
  - 1h @ 320 ºC
  - Cooling under field (*1 Tesla*)
- A four-probe geometry was used



External Magnetic Field

Results

Size of nanostructures integrated

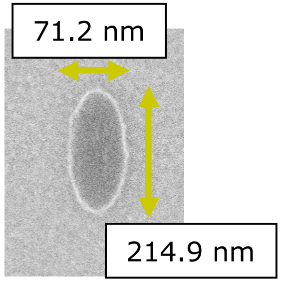


- Linear dependence with 1/A
  - $RA_{Sample1}$ ~ 0.8 Ω.μm²
  - $RA_{Sample2}$ ~ 1 Ω.μm²
  - $RA_{Sample3}$ ~ 15 Ω.μm²
  - $RA_{Sample4}$ ~ 50 Ω.μm²

Minimum critical size integrated: ~50 nm

Sample structure

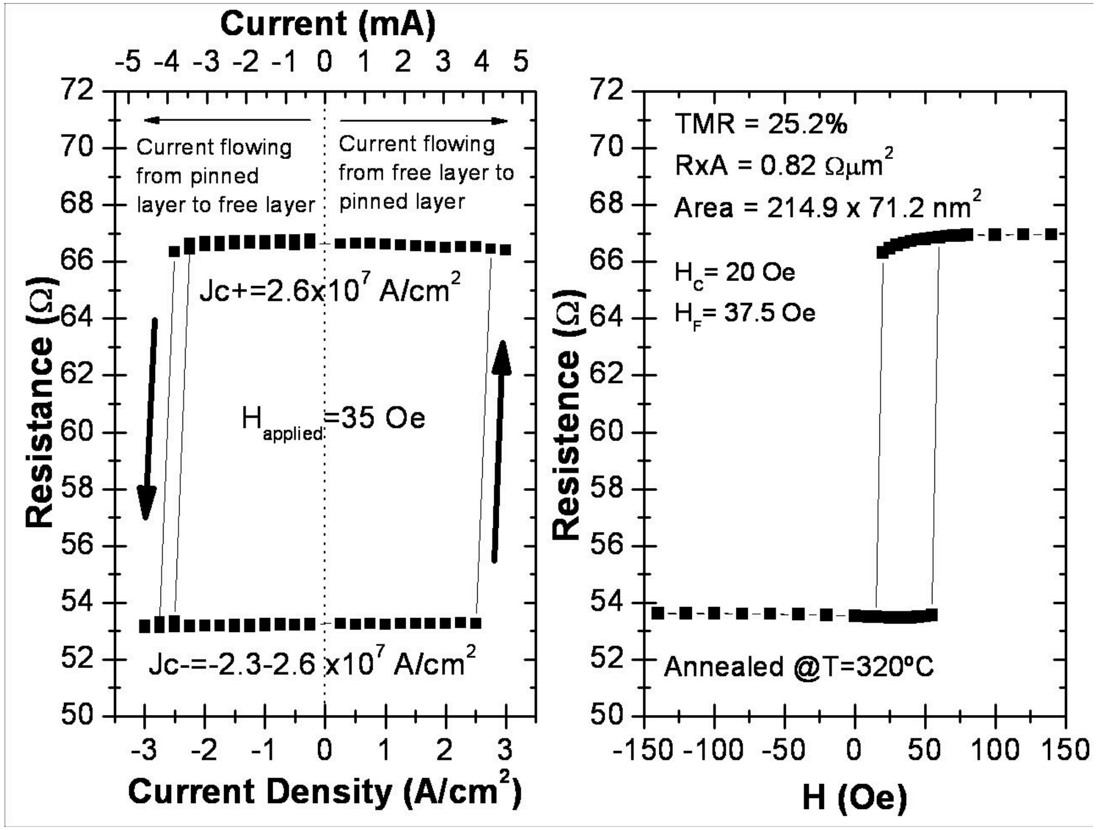
Low resistance devices are suitable for current induced switching

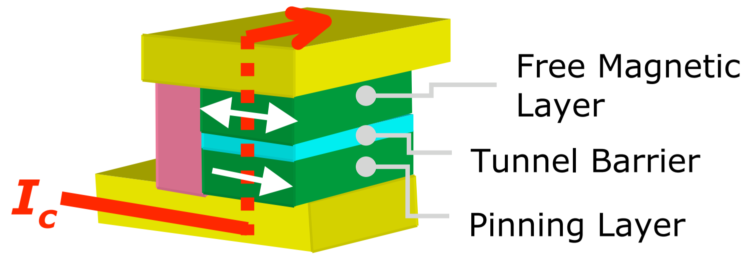


- Magnetic effect
  - Switching currents depend on applied magnetic field
- Full magnetization reversal
  - Same ΔR as in a transfer curve
- Current density still large
  - Critical current of $2.6x10^7$ A/cm^2
  - Should improve with higher TMR (current polarization)

Current Induced Switching

Magnetoresistance Curve





Achievements

- A new nanofabrication process was developed and sucessully tested
- A negative resist (AR-7520.18) was study aiming its thickness reduction
  - from 200 to 80 nm
- Electron Beam lithography performance was optimized
  - Minimun resolution **~30 nm**
  - Exposure dose tunned for diferent dimensions
- Low RxA MTJs (0.8-50 $\Omega.m^2$) with reasonable TMR signals were fabricated
  - Minimun size integrated **~50x180nm**
- Spin Transfer Measurements were done
  - Current induced switching observed for a critical current **~2.6x10^7 A/cm^2**

Future Work

- Optimize Chemical Mechanical Polishing Process aiming higher yield values
- Nanofabrication process of pillars of ~30nm
- Improve the TMR signals of Low RxA MTJs
- Decrease the critical current for current induced switching

THANK YOU!!