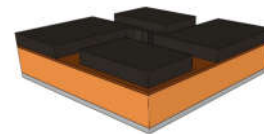
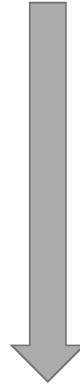
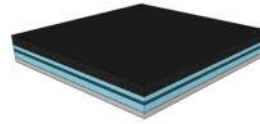


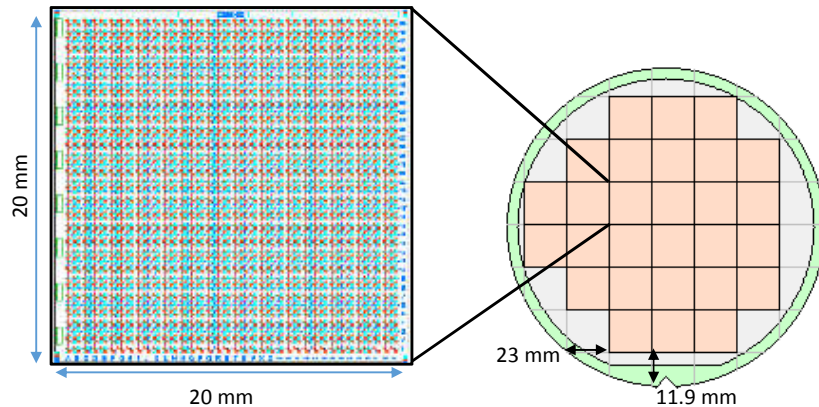
Batch Name		Date	
Comments		Responsible	

PROCESS OVERVIEW

0. MTJ stack deposition
1. Cap Layer deposition – 30 nm Ta (Nordiko 3600)
2. 1st Lithography DWL for BE
 - a. PR coating
 - b. Exposure
 - c. Development
3. 1st Etch by Ion Milling until substrate
4. PR Strip
5. 1st Lithography E-beam for pillars (<100 nm)
 - a. E-beam resist coating
 - b. Exposure
 - c. Development
6. 2nd Etch by Ion Milling until 0.33 of Mnlr (two-step)
7. 300 nm SiO₂ deposition by PECVD (Electrotech)
8. E-beam contrast layer deposition – 5 nm Ta (Nordiko 3600)
9. 2nd Lithography E-beam for Nano-vias (500 μm)
 - a. PMMA coating
 - b. Exposure
 - c. Development
10. 3rd Etch by Ion Milling for Ta removal (5 nm)
11. 1st Reactive Ion Etching until top pillar
12. PMMA removal
13. 4th Etch by Ion Milling for Ta removal (5 nm)
14. 2nd Lithography DWL for Vias to pads
 - a. PR coating
 - b. Exposure
 - c. Development
15. 2nd Reactive Ion Etching until BE
16. PR Strip
17. 3rd Lithography DWL for TE
 - a. PR coating
 - b. Pre-development
 - c. Exposure
 - d. Development
18. 40 nm Ru deposition (Nordiko 3600)
19. 300 nm Al + 15 nm TiWN₂ deposition (Nordiko 7000)
20. Metal lift-off



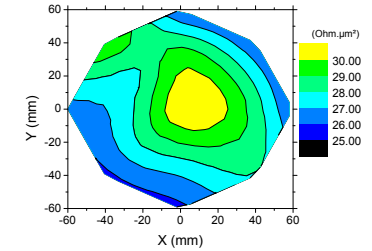
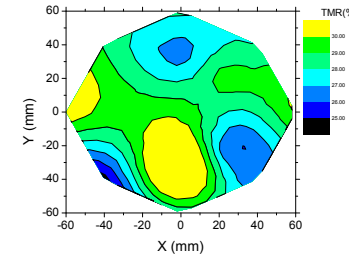
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Step 0	Junction Stack	Date	
		Responsible	

Machine: Nordiko 3000

ID	Stack	Total thickness
TJ 1587	Si// AlOx/Ru 50/ Al 20/ Ru 150/ Al 20/ Ru 150/ IrMn 180/ CoFe 30/ Ru 6/ CoFeB 40/ AlOx 6/ CoFeB 30/ Ru 150	832 Å 1132 Å (w/ cap layer)
CIPT current in plane tunneling	TMR ≈ 30% RxA ≈ 30 Ω.μm ²	



Step 1	Ta cap layer deposition	Date	
		Responsible	

Sample	Total to deposit	Total deposition Time	Observations
	30 nm Ta		

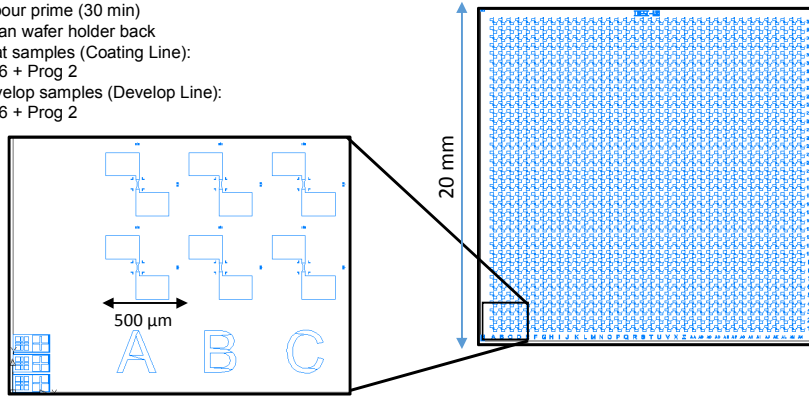
Machine:	Nordiko 3600	B.P.=7.5x10 ⁻⁸
Process steps:		

Read Values	RF Power (W)	V1 (V)	I1 (mA)	V2 (V)	I2 (mA)	Gas Flux (sccm)	Working Pressure (Torr)
Assist. Gun	123	986.6	119.9	270.0	1.6	4.1 Xe	1.8x10 ⁻⁶

Ready for the next Step: _____

Step 2	1st DWL Exposure for Bottom Electrodes Definition	Date	
		Responsible	

- Vapour prime (30 min)
- Clean wafer holder back
- Coat samples (Coating Line):
Prog 6 + Prog 2
- Develop samples (Develop Line):
Prog 6 + Prog 2



Machine:	DWL				
Map:	Wafer_20mmdies	Mask:	nanoMTJ_20mm_L1		
Nr. Dies	28	1 st Cross [from (0;0) mm of map]	(168;54) µm (19946;54) µm (168;19946) µm (19946;19946) µm	1 st Die (D _y)	11900 µm from flat notch
Focus	-20	Energy	80	1 st Die (D _x)	23000 µm from wafer border

V	Optical Inspection	Comments

Ready for the next Step: _____

Step 3	1st Etch by Ion Milling until substrate	Date	
		Responsible	

Clean etching holder with acetone before etching + back of sample to remove unwanted PR that can cause PR to burn. Be careful with the acetone not to go on top of the sample

Done

Sample	Total to etch (1 st)	Total etching Time	Observations
	60 degrees		Etch all 1132 Å height until substrate + 10% overetch Clean border of wafer with acetone carefully for full etch check (resistance)

Machine:	Nordiko 3600	B.P.= 7.5x10 ⁻⁸
Batch recipe:		
Wafer Recipe:		
Process steps:		

Read Values	RF Power (W)	V1 (V)	I1 (mA)	V2 (V)	I2 (mA)	Gas Flux (sccm)	Working Pressure (Torr)
Assist. Gun	191	723.8	104.4	344.3	3.2	11.2 Ar	1.38x10 ⁻⁴

(Check with multimeter) Ready for the next Step: _____

Step 4	PR removing	Date	
		Responsible	

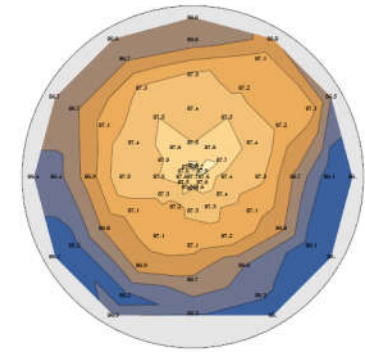
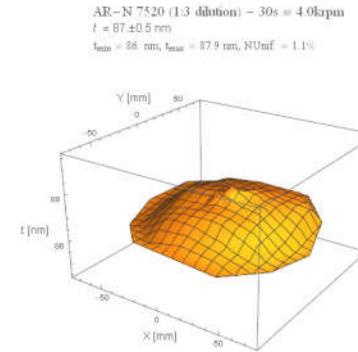
Start @:	End @:	Total Time:	
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Ready for the next Step: _____

(if stack has CuN donot use microstrip, only acetone without temperature)

Step 5	1st Lithography E-beam for pillars definition (< 100 nm)	Date	
		Responsible	

- 120s pre-bake at 110°C (Manual-Program 2, Develop Line)
- Fill syringe with AR-N 7520 (1:3 dilution) (≈5 mL for each wafer)
- Purge manually
- Coat samples (Automatic, Coating Line)
- 30s spin at 4 krpm (Prog 2) + 60s soft-bake at 85°C (Prog 2)
- Run a dummy wafer before wafer sample
- Run wafer sample
- Clean syringe and coat lines with N₂ (Manual-Program 9, Coating Line)



Check list for e-beam exposure:

- Load wafer sample on the 150mm wafer holder;
- Set 20 kV acceleration voltage // 10 µm Aperture size // Z=17 mm// WD≈7.2 mm
- Wafer sample surface level
- Choose 6" wafermap layout and adjust perimeter and deskew marks
- Map: multilvlmisalig.csf, choose layers: automatic marks (61), pillar exposure (04) and nonius exposure ER (03)
- Focus, adjust stigmation, aperture alignment and write field alignment (500 µm). Focus again
- 3-Point Alignment with die map. Write field alignment and focus again
- Set parameters for exposure (Area dose: 300 µC/cm² (factor: 0.4); Dot dose: 0.005 pC (factor: 8) (for ø55-65 nm)
- Set Control Focus by Stage and start exposure

Note: Do not expose dot on 1st line of each die from (column A-E, K-O, etc... [in each 5 elements])

Machine		Raith 150					
Read Values	Current (pA)	Area dose (uC/cm ²)	A. step size (nm)	A. Dwell Time (us)	Beam speed (mm/s)	Dot dose (pC)	D. Dwell Time (ms)
E-beam		300				0.005	

Develop wafer sample:

- 120s pre-bake at 85°C (Manual-Program 4, Coating Line)
- Cool sample manually
- 70s develop using developer for 80nm thick resist (2:1 dilution with H₂O) (Manual-Program 1, Developing Line). Pour developer when it stops rotating (≈50mL is enough)

Step 6	2nd Etch by Ion Milling until 0.33 of MnIr (2 steps)	Date	
		Responsible	

Clean etching holder with acetone before etching + back of sample to remove unwanted PR that can cause PR to burn. Be careful with the acetone not to go on top of the sample

Done

Sample	Total to etch (1 st)	Total etching Time	Observations
	60 degrees (until AlOx barrier) 30 degrees (until 0.66 of MnIr)		Etch 486 Å until barrier (60 degrees) + 136 Å until 0.33 of MnIr (30 degrees) Use calibration glass sample with stack until AlOx to check etch until barrier (glass// CoFeB 30/ Ru 150/ Ta 300)

Machine:	Nordiko 3600	B.P.= 7.5x10 ⁻⁸
Batch recipe:		
Wafer Recipe:		
Process steps:		

Read Values	RF Power (W)	V1 (V)	I1 (mA)	V2 (V)	I2 (mA)	Gas Flux (sccm)	Working Pressure (Torr)
Assist. Gun	191	723.8	104.4	344.3	3.2	11.2 Ar	1.38x10 ⁻⁴

Step 7	Oxide Deposition	Date	
		Responsible	

Use of calibration sample (Si substrate)
Si substrate w/ pen line

Ink line on top of the sample

Done

Total to deposit:		3000 Å (nominal value)	Total deposition time:		15s	
Machine:		Electrotech				
Read v.	Base Pressure (T)	P before plasma (mT)	P working (mT)	Turbo Pump freq. (Hz)	Gas flux (sccm)	Power - Fwd/Ref (W)
	0.7				125 SiH4 2500 NO2	
Comments		Cover with ink the edges of each dies to protect alignment marks and borders of the dies from oxide (to be easier to SEM the samples on e-beam). Only remove ink after Ta deposition. Cover the bottom of some dies (1 st elements line in a die) to be possible to SEM pillars at the end of the process. Only remove ink after Ta deposition. Cover with ink a line on the borders of the wafer. Remove ink after oxide deposition. Measure on profilometer oxide deposited. Measure on ellipsometer SiO ₂ thickness deposited				

Step 8	5nm Ta deposition	Date	
		Responsible	

Sample	Total to deposit	Total deposition Time	Observations
	5 nm Ta		

Machine:	Nordiko 3600	B.P.= 7.5x10 ⁻⁸
Process steps:		

Read Values	RF Power (W)	V1 (V)	I1 (mA)	V2 (V)	I2 (mA)	Gas Flux (sccm)	Working Pressure (Torr)
Assist. Gun	123	986.6	119.9	270.0	1.6	4.1 Xe	1.8x10 ⁻⁶

Ready for the next Step: _____

Step 9	2nd Lithography E-beam for nano-vias definition (500 nm)	Date	
		Responsible	

- 120s pre-bake at 110°C (Manual-Program 2, Develop Line)
- Coat samples (Manual, Coating Line)
- 30s spin at 3 krpm (Prog 3) + 4 min soft-bake at 160°C (hot plate)

Check list for e-beam exposure:

- Load wafer sample on the 150mm wafer holder;
- Set 10 kV acceleration voltage // 10 µm Aperture size // Z=17 mm// WD≈7.2 mm
- Wafer sample surface level
- Choose 6" wafermap layout and adjust perimeter and deskew marks
- Map: multivimialig.csf, choose layers: automatic marks (61), pmma holes (05) and nonius exposure PMMA (06)
- Focus, adjust stigmation, aperture alignment and write field alignment (500 µm). Focus again
- 3-Point Alignment with die map. Write field alignment and focus again
- Set parameters for exposure (Area dose: 100 µC/cm² (factor: 1.3 for nonius and 1.5 for holes)
- Set Control Focus by Stage and start exposure

Machine:		Raith 150				
Read Values	Current (pA)	Area dose (uC/cm ²)	A. step size (nm)	A. Dwell Time (us)	Beam speed (mm/s)	
E-beam		100				

Develop wafer sample:

- 80s develop using AR 600-55 (MIBK). Use IPA as stopper for developing process

Step 10	3rd Etch by Ion Milling for Ta removal (5 nm)	Date	
		Responsible	

Clean etching holder with acetone before etching + back of sample to remove unwanted PR that can cause PR to burn. Be careful with the acetone not to go on top of the sample

Done

Sample	Total to etch (1 st)	Total etching Time	Observations
	60 degrees (for 5 nm Ta removal)		Etch enough for 5 nm Ta removal

Machine:	Nordiko 3600	B.P.= 7.5x10 ⁻⁸
Batch recipe:		
Wafer Recipe:		
Process steps:		

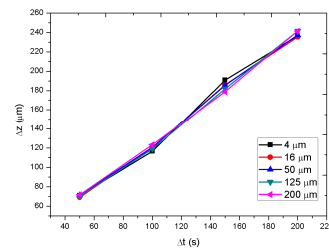
Read Values	RF Power (W)	V1 (V)	I1 (mA)	V2 (V)	I2 (mA)	Gas Flux (sccm)	Working Pressure (Torr)
Assist. Gun	191	723.8	104.4	344.3	3.2	11.2 Ar	1.38x10 ⁻⁴

V

Step 11	1st Reactive Ion Etching until top pillar	Date	
		Responsible	

Machine	Rainbow Lam 4500						
Recipe	Low power no O2						
Read Values	RF Power (W)	Ar flow (sccm)	CF4 flow (sccm)	Pressure (mTorr)	Wap	Clamp	
	100	200	100	140		1.3	
Notes	Etch the SiO2 accordingly to the measurement values of the oxide deposited and to the etch depth for different RIE etch steps (table and graph)						

Hole (μm)	Δz (nm)			
	Δt=50s	Δt=100s	Δt=150s	Δt=200s
4	72.4	118.3	174.1	239.3
16	72.5	116.0	170.9	234.2
50	70.2	117.0	171.8	235.5
125	71.1	117.8	171.3	233.6
200	73.6	117.4	171.6	234.5



Etch depth for different RIE etch step on SiO2 (PECVD)

Step 12	PMMA removal	Date	
		Responsible	

Start @:		End @:		Temperature	60°C
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Remover: AR 300-72

Step 13	4th Etch by Ion Milling for Ta removal (5 nm)	Date	
		Responsible	

Clean etching holder with acetone before etching + back of sample to remove unwanted PR that can cause PR to burn. Be careful with the acetone not to go on top of the sample

Done

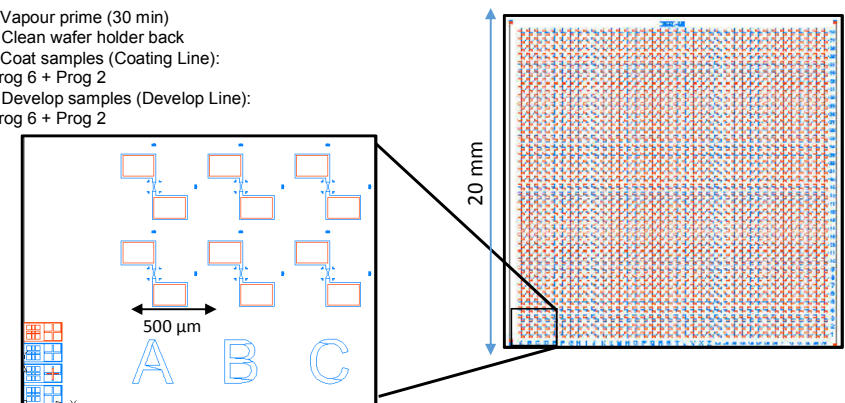
Sample	Total to etch (1 st)	Total etching Time	Observations
	60 degrees (for 5 nm Ta removal)		Etch enough for 5 nm Ta removal

Machine:	Nordiko 3600	B.P.= 7.5x10 ⁻⁸
Batch recipe:		
Wafer Recipe:		
Process steps:		

Read Values	RF Power (W)	V1 (V)	I1 (mA)	V2 (V)	I2 (mA)	Gas Flux (sccm)	Working Pressure (Torr)
Assist. Gun	191	723.8	104.4	344.3	3.2	11.2 Ar	1.38x10 ⁻⁴

Step 14	2nd DWL Exposure for Vias to Pads Definition	Date	
		Responsible	

- Vapour prime (30 min)
- Clean wafer holder back
- Coat samples (Coating Line): Prog 6 + Prog 2
- Develop samples (Develop Line): Prog 6 + Prog 2



Machine:	DWL				
Map:	Wafer_20mmdies	Mask:	nanoMTJ_20mm_L2		
Nr. Dies	28	1 st Cross [from (0;0) mm of map]	(168;54) um (19946;54) um (168;19946) um (19946;19946) um	1 st Die (D _y)	11900 um from flat notch
Focus	-20	Energy	80	1 st Die (D _x)	23000 um from wafer border

Optical Inspection	Comments
Ready for the next Step: _____	

Machine:	DWL				
Map:	Wafer_20mmdies	Mask:	nanoMTJ_20mm_L3		
Nr. Dies	28	1 st Cross [from (0;0) mm of map]	(168;54) um (19946;54) um (168;19946) um (19946;19946) um	1 st Die (D _y)	11900 um from flat notch
Focus	-20	Energy	90	1 st Die (D _x)	23000 um from wafer border

Optical Inspection	Comments
Ready for the next Step: _____	

Step 15	2nd Reactive Ion Etching until BE	Date	
		Responsible	

Step 18	40 nm Ru layer deposition	Date	
		Responsible	

Machine	Rainbow Lam 4500						
Recipe	Low power no O2						
Read Values	RF Power (W)	Ar flow (sccm)	CF4 flow (sccm)	Pressure (mTorr)	Wap	Clamp	
	100	200	100	140		1.3	
Notes	Etch the SiO2 accordingly to the measurement values of the oxide deposited and to the etch depth for different RIE etch steps (table and graph)						

Sample	Total to deposit	Total deposition Time	Observations
	40 nm Ru		

Machine:	Nordiko 3600	B.P.=	
Process steps:			

Read Values	RF Power (W)	V1 (V)	I1 (mA)	V2 (V)	I2 (mA)	Gas Flux (sccm)	Working Pressure (Torr)
Assist. Gun							

Ready for the next Step: _____

Step 16	PR removing (Lift-off)	Date	
		Responsible	

Step 19	Contact Leads Deposition	Date	
		Responsible	

Start @:		End @:		Total Lift-Off Time:	
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(check on profilometer for rabbit ears)

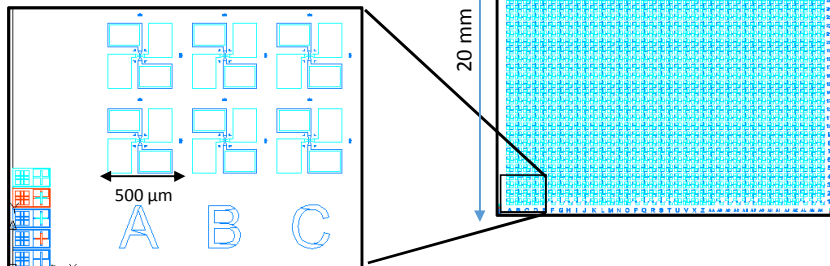
Ready for the next Step: _____

Step 17	3rd DWL Exposure for TE Definition	Date	
		Responsible	

Machine: Nordiko 7000

Seq.48 (svpad) – mod.2 – f.9 (1' soft sputter etch) P=60W/40W, p=3mTorr, 50 sccm Ar
 mod.4 – f.1 (3000A Al, 80'') P=2 kW, 3mTorr, 50 sccm Ar
 mod 3 – f.19 (150A TiWN₂, 27'') P=0.5 kW, 3mTorr, 50sccm Ar + 10 sccm N₂

- Vapour prime (30 min)
- Clean wafer holder back
- Coat samples (Coating Line):
Prog 6 + Prog 2
- Develop samples (Develop Line):
Prog 6 + Prog 2



Readings – Module 2				
Run#	Power1	Power2	Gas flux	Pressure

Readings – Module 4					
Run#	Power	Voltage	Current	Gas flux	Pressure
	2kW				

Readings – Module 3					
Run#	Power	Voltage	Current	Gas flux	Pressure
	0.5kW				

Step 20	PR removing (Lift-off)	Date	
		Responsible	

Start @:		End @:		Total Lift-Off Time:	
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Ready for the next Step: _____