Application Note RSMD009

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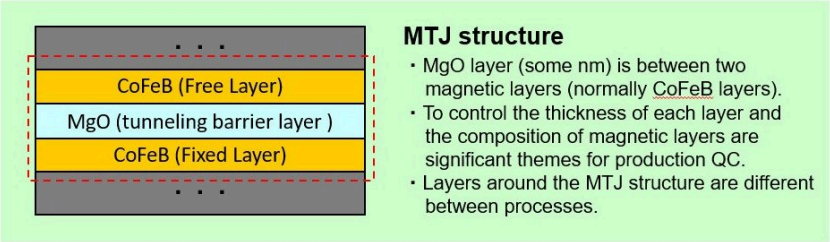
Semiconductor Metrology Application: Metrology for MTJ Layer Thickness & Composition

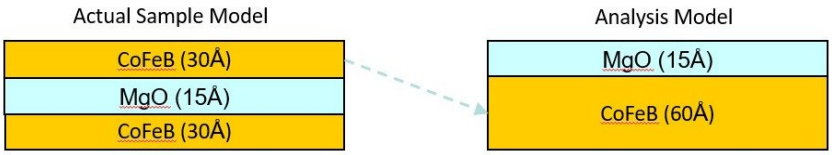
MTJ measurement: A key WDXRF measurement capability

An important structure of MRAM is the MTJ structure that contains light elements, such as B and Mg. Analysis of these elements are a specialty area of WDXRF. EDXRF and optical methods cannot analyze those light elements.



MTJ analysis concept

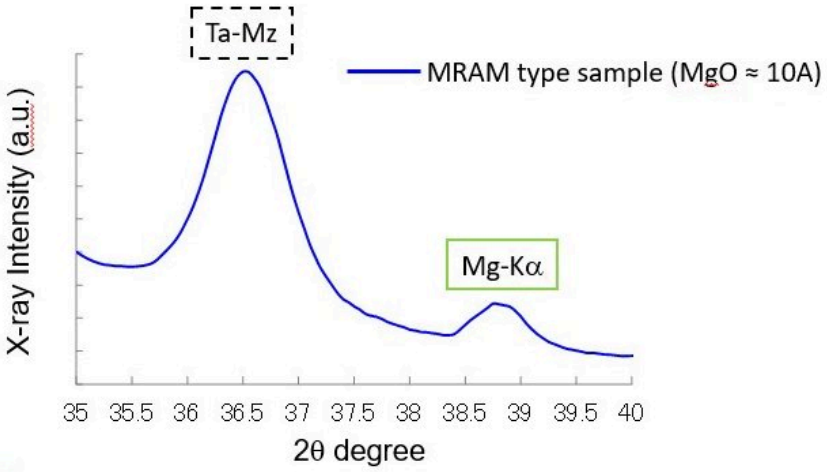
For the simultaneous analysis of MgO and CoFeB layers, the analysis model shown below at right is used (thicknesses of repeated layers are consolidated).



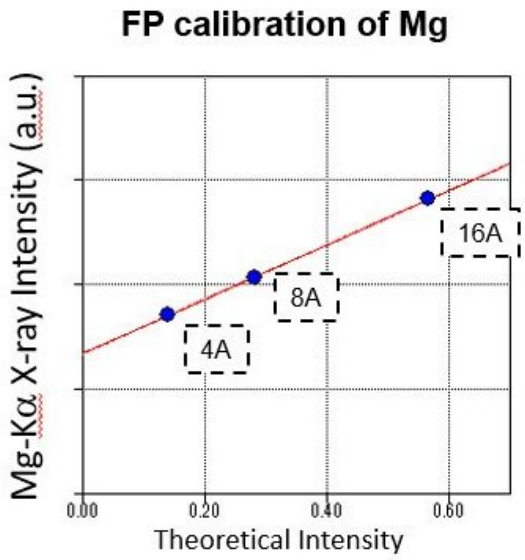
XRF systems are not well suited to distinguish the spectrum from different layers containing the same element. For the MTJ structure, the systems cannot separate two CoFeB layers. in this case, therefore, CoFeB layers should be analyzed as one layer. (The effects of absorption and excitation are minimal since the layers are thin.)

MgO thin film analysis by WDXRF tool

A Ta layer is often used as a cap and/or barrier around the MTJ structure. In this case, the Ta-Mz peak appears near Mg-Kα but it is definitely separated using a WDXRF system. This is one of the significant features of a WDXRF system, whose resolution capability is high. With an EDXRF system, a small Mg-Kα peak can be buried by the high background of Si-Kα and Ta-Mz.



For thin film multilayers, the FP method is generally used because it can calculate the absorption by other layers and the composition differences. FP calibrations are correlations between theoretical and measured intensities. It is possible to analyze with a few standard samples and apply other structures, such as single layers and/or pure metals.



MgO thin film analysis by WDXRF (AZX 400)

■Measurement Condition

Element Line	Mg Kα
kV-mA	40 - 75
Filter	OUT
Diameter	30 mm
Slit	S4
Analyzing Crystal	RX25
Detector	F-PC
Counting time Peak (sec)	100
BG(sec)	-

■10-time repeatability result

	MgO Thickness		
Target Thickness	4	8	16
Unit	A		
AVERAGE	4.0	8.0	16.0
MAX.	4.0	8.1	16.1
MIN.	3.9	8.0	16.0
RANGE	0.1	0.1	0.1
Std. Dev.	0.035	0.042	0.052
R.S.D.(%)	0.88	0.52	0.32

MgO thin film analysis by WDXRF (WaferX 310)

■Measurement Condition

Element Line	Mg Kα
kV-mA	40 - 90
Collimator	40 mm
Goniometer	Fixed
Analyzing Crystal	RX25
Detector	F-PC
Measurement Time (sec.)	100
APC	ON

■10-time repeatability result

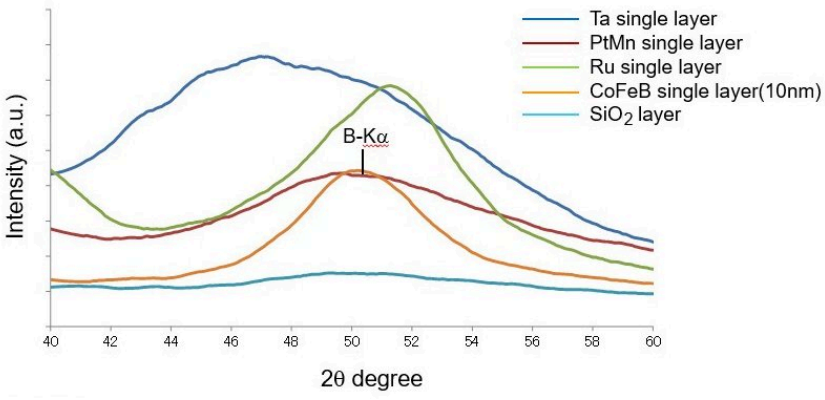
	MgO Thickness		
Target Thickness	4	8	16
Unit	A		
AVERAGE	4.0	7.9	16.0
MAX.	4.1	8.0	16.1
MIN.	4.0	7.9	16.0
RANGE	0.1	0.1	0.1
Std. Dev.	0.029	0.033	0.040
R.S.D.(%)	0.72	0.42	0.25

Precision values of different Collimator/ Counting time

	MgO Thickness				
Target Thickness	8 A				
Collimator	40mm	20mm	10mm	10mm	10mm
Measurement Time (s)	100	100	100	200	300
AVERAGE	7.9	7.9	8.0	8.0	8.0
MAX.	8.0	8.0	8.2	8.1	8.1
MIN.	7.9	7.8	7.8	7.9	7.9
RANGE	0.1	0.1	0.4	0.2	0.2
Std. Dev.	0.033	0.046	0.10	0.074	0.062
R.S.D.(%)	0.42	0.58	1.28	0.92	0.77

CoFeB thin film analysis by WDXRF

For the CoFeB layer, compositions are often analyzed, not just the thicknesses. In this case, measurements of B-Kα are required. However, when B-Kα is measured with stacked samples, spectra from Pt, Ta, Ru and W (if used, and possibly other elements) overlap it. Therefor, dummy single layer smaples of CoFeB should be used for the analyses.



CoFeB thin film analysis by WDXRF (AZX 400)

■Measurement Condition

Element Line	Co Kα	Fe Kα	B Kα
kV-mA	40 - 75		
Filter	OUT	F-Sn	OUT
Diameter	30 mm		
Slit	S4	S4	S8
Analyzing Crystal	LiF1	LiF1	RX75
Detector	SC	SC	F-PC
Counting time Peak (sec)	60	60	100
BG(sec)	-	-	-

■10-time repeatability result

	CoFeB THK.	Co Comp.	Fe Comp.	B Comp.
Target Thickness	1.5	20	60	20
Unit	nm	at%	at%	at%
AVERAGE	1.56	20.71	59.41	19.88
MAX.	1.57	21.10	59.94	20.46
MIN.	1.55	19.85	58.66	19.40
RANGE	0.02	1.26	1.28	1.06
Std. Dev.	0.0056	0.38	0.36	0.32
R.S.D.(%)	0.36	1.82	0.60	1.63

CoFeB thin film analysis by WDXRF (WaferX 310)

■Measurement Condition

Element Line	Co Kα	Fe Kα	B Kα
kV-mA	40 - 90		
Collimator	40 mm		
Goniometer	Fixed	Fixed	Fixed
Analyzing Crystal	LiF1	LiF1	RX75
Detector	S-PC	S-PC	F-PC
Counting Time (sec.)	100		
APC	ON		

■10-time repeatability result

	CoFeB THK.	Co Comp.	Fe Comp.	B Comp.
Target Thickness	1.5	20	60	20
Unit	nm	at%	at%	at%
AVERAGE	1.55	20.14	59.85	20.02
MAX.	1.56	20.52	60.21	20.28
MIN.	1.54	19.89	59.39	19.80
RANGE	0.01	0.63	0.82	0.48
Std. Dev.	0.0042	0.20	0.22	0.17
R.S.D.(%)	0.27	0.99	0.38	0.85

Analysis of stacked MRAM

For the analysis of stacked MRAM samples, the analysis model should set as shown below with summed thickness of repeated layers.

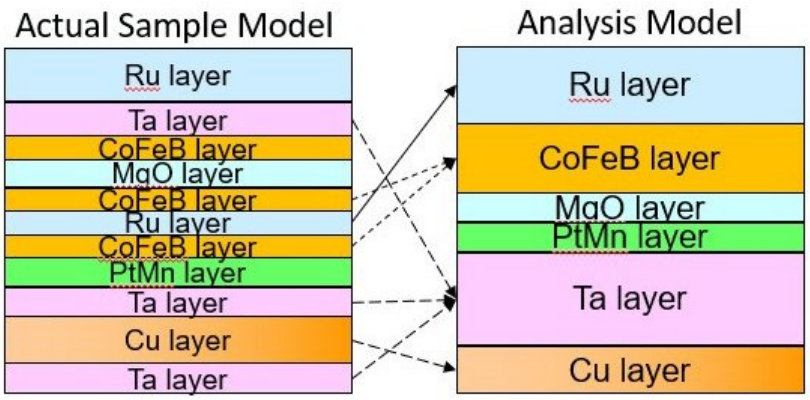


Table: 10-times repeatability analysis of an MRAM sample

	Ru *	CoFeB	MgO	PtMn	Ta	Cu
Target Value (angstrom)	80	50	15	120	200	400
Counting Time(sec)	20	10	60	30	10	10
Average	79.9	50.1	15.1	120.0	200.5	399.8
Range	0.9	0.6	0.2	1.5	2.5	3.3
Std. Dev.	0.30	0.25	0.08	0.57	0.98	1.14
R.S.D. (%)	0.37	0.49	0.54	0.48	0.49	0.28

* Thickness analysis of CoFeB is available for stacked MRAM.

Related products

WaferX 310

WDXRF simultaneous spectrometer for thickness and com
position measurements for up to 300 mm wafers