TMEC
Thai Microelectronics Center
Integrate Ideas Into Reality

Sensor production and test at TMEC

Jirawat Prabket

Thai Microelectronics Center (TMEC)

4th ALICE ITS upgrade, MFT and O2 Asian Workshop 2014 @ Pusan
Haeundae Grand Hotel, Pusan, South Korea, Dec 15-16, 2014

ALICE
PUSAN NATIONAL UNIVERSITY · TRUTH LIBERTY DEVOTION ·
PNU-Supercomputing Center
KiSTi www.kisti.re.kr
NECTEC a member of NSTDA

Outline

- TMEC's Overview
- Our participates in the ITS upgrade
- Incoming wafer QA: status & results
- Summary

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- **TMEC's Overview**
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TMEC is ready

Our main office and facility is located in Chachoengsao province, approximately 70 km east of Bangkok.

- 1,000 sq. m. (10,764 sq. ft.) of class 100 and 10,000 cleanroom space with additional support area.
- 6" Wafer production line
- 500 wafer starts per month capacity

TMEC process line

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CMOS process line is the heart of TMEC work.

Cleaning Process

Furnace

Photolithography

Implanter

Down to 0.5µm CMOS Technology

Metrology

Dry Etching

Plasma CVD

Sputtering

Standard
340 steps

TMEC R&D services

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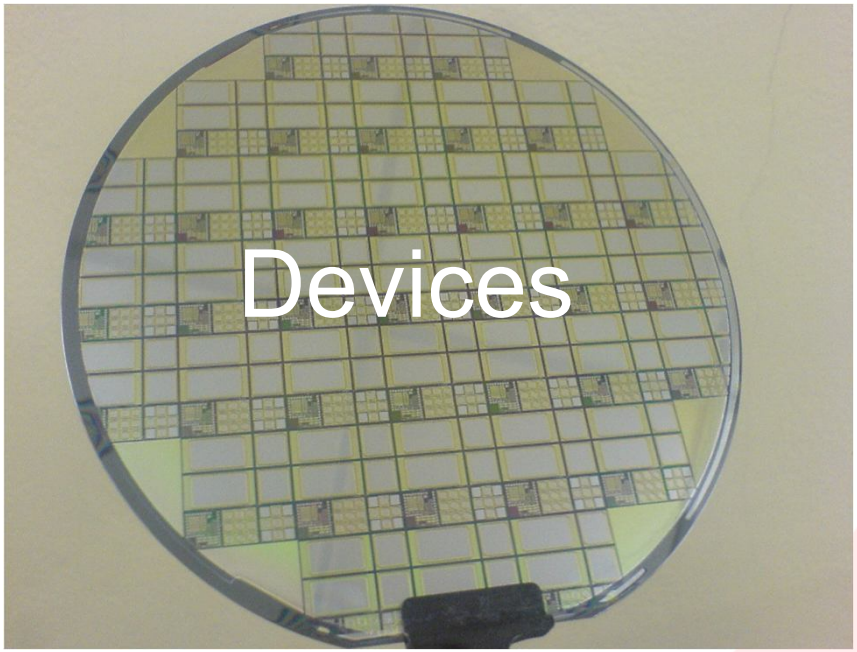
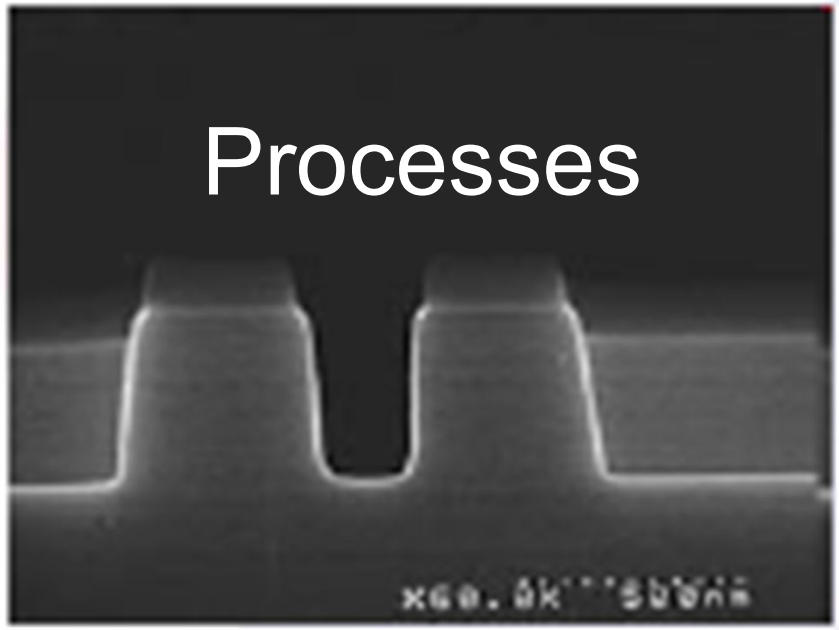
Thai Microelectronics Center





Customer benefit:

OEM

ODM

OBM

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Our participates in the ITS upgrade

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- Incoming wafers QA: 4 point ,SEM, SRP measurement
- Silicon Micro-channel cooling : ongoing new design
- Thinning and laser dicing : coordinating with STARS Microelectronics

Outline

- TMEC's Overview
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- **Incoming wafer QA: status & results**
- Summary

Incoming wafer QA: status & results

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QA activities with TMEC on sample basis:

- 4 point measurement : High resistivity sample
- SEM cross-section inspection: epi layer & wafer thickness
- SRP measurement of resistivity profile in the epi layer

4 point measurement

Sample preparation : HF dip + DI rinse + N_2 dry

Samples :

- TMEC STD wafer : CZ N-type [111] ; 1510±22 Ohm
- High resistivity reference wafer : 5 type

TMEC STD : CZ N-type [111] 1510±22 Ohm

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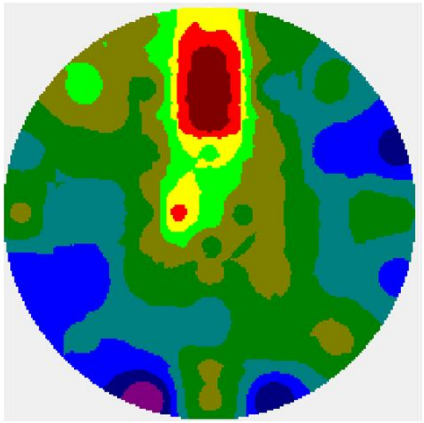
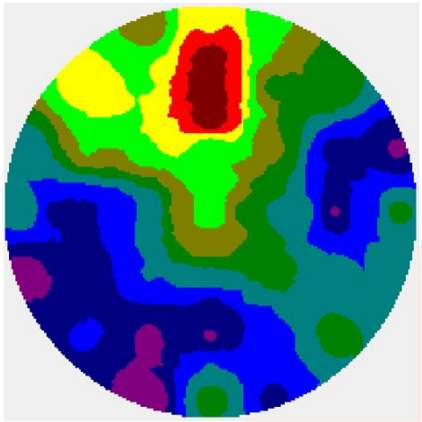
Substrate				Calibrated values (Mean)		
Wafer Mfg.	Orientation	Diameter [mm]	Type	Thickness [um]	Rs [Ohm]	Rho [Ohm.cm]
Topsil	<111>	76.1	N	510±3	1510±22	77±1.2

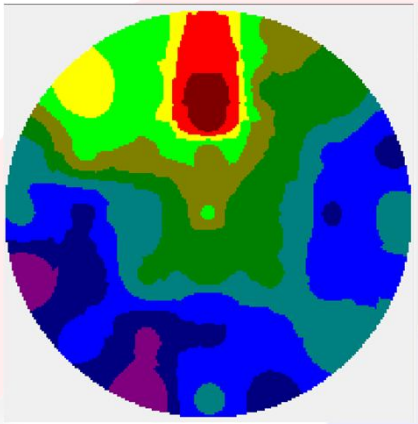
Measured values



Pre HF dip



0 min(after HF dip)



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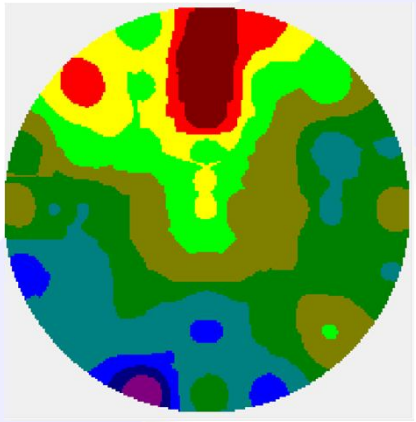

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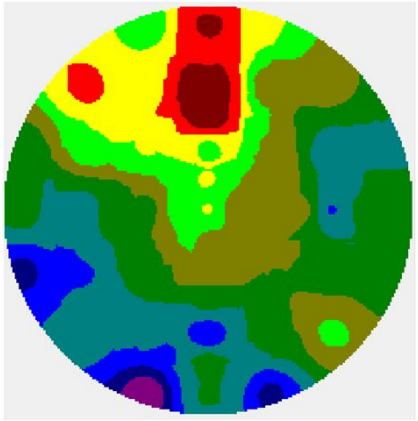

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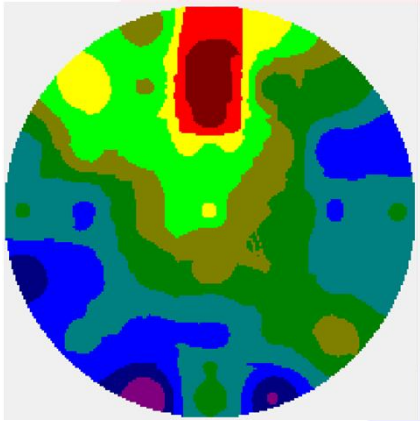

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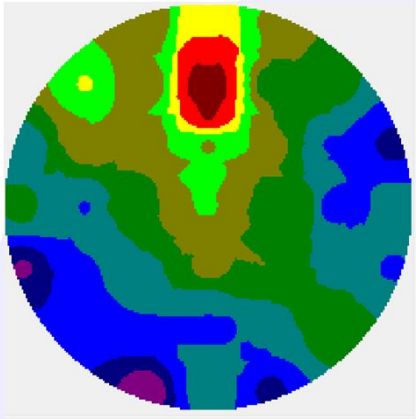

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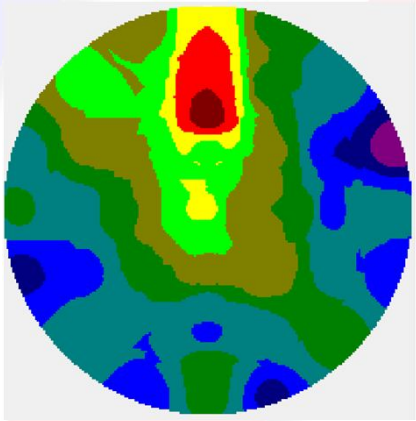

80 min

TMEC STD : CZ N-type [111] 1510±22 Ohm

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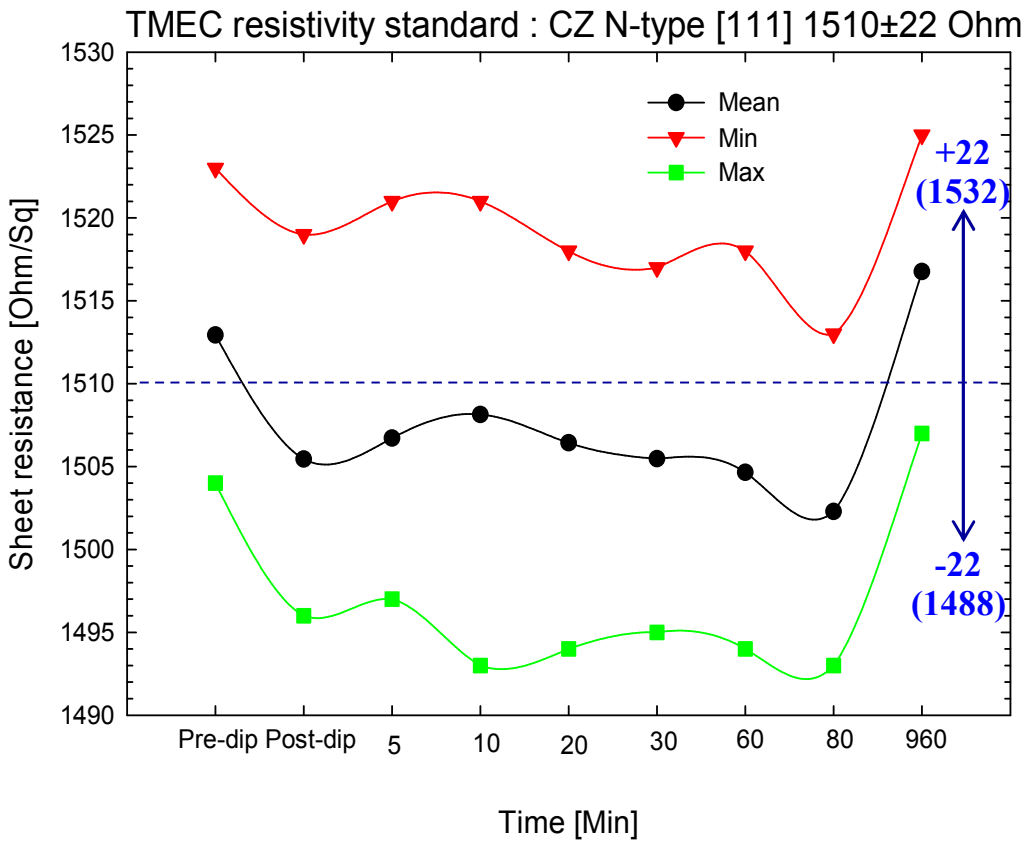
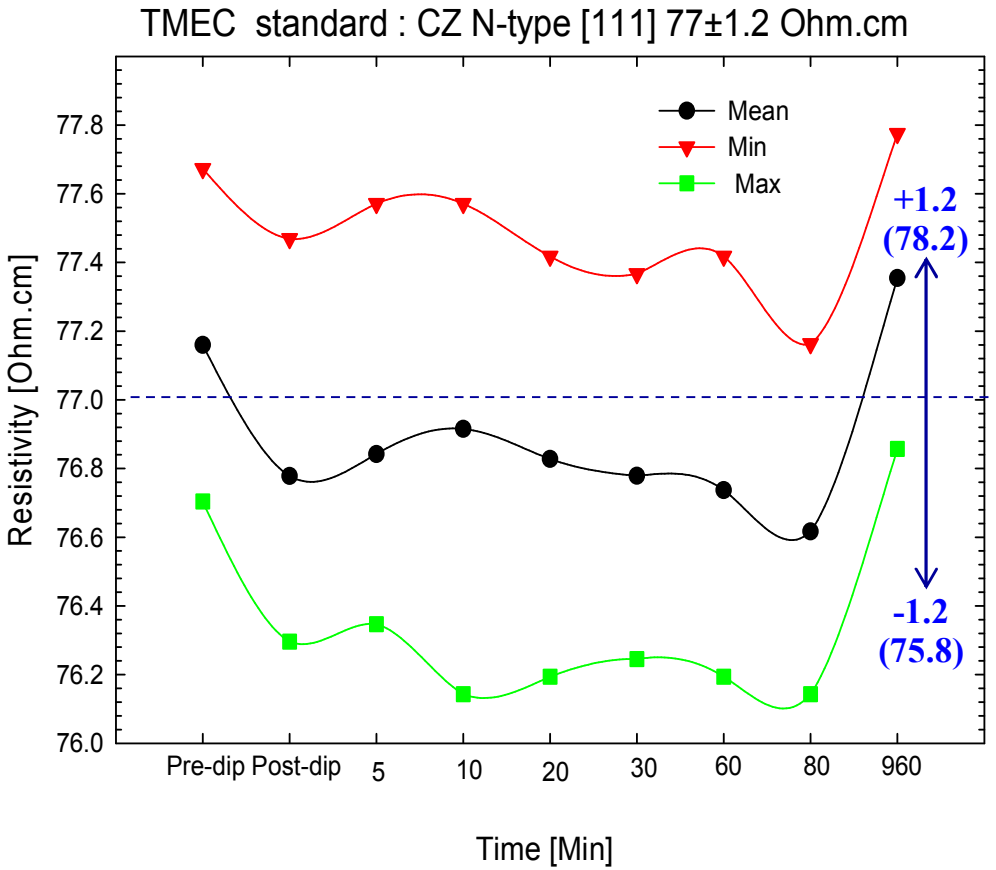
Substrate				Calibrated values (Mean)		
Wafer Mfg.	Orientation	Diameter [mm]	Type	Thickness [um]	Rs [Ohm]	Rho [Ohm.cm]
Topsil	<111>	76.1	N	510±3	1510±22	77±1.2

Measured values



Sheet resistance(R_s)



Resistivity(ρ)

FZ p-type [100], 4,500 -4,700 Ohm.cm

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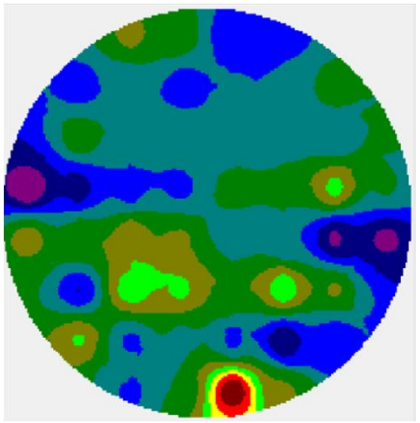
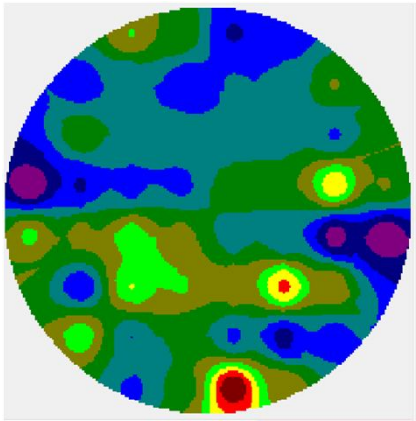
Measured values		Time [Min]								
		0	5	15	20	30	35	60	80	960
Sheet resistance [Ohm/Sq]	Mean	102,360	100,889	100,494	102,792	106,790	111,563	121,513	137,000	272,000
	Min	139,000	131,000	135,000	133,000	141,000	144,000	151,000	172,000	326,000
	Max	79,700	80,500	79,700	81,500	85,500	87,100	98,300	109,000	218,000

Measured values



0 min(after HF dip)



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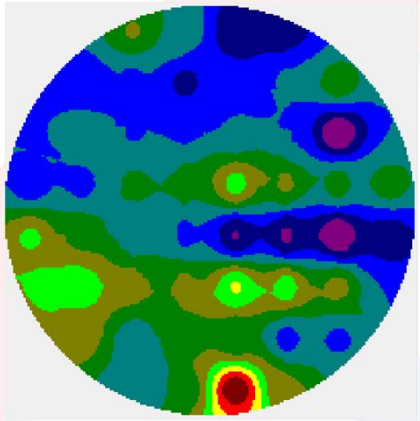

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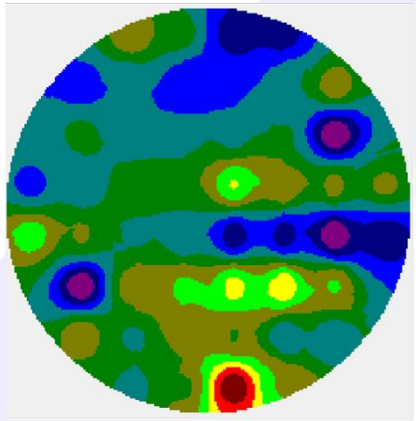

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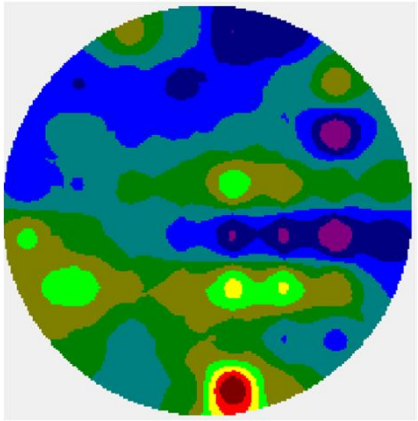

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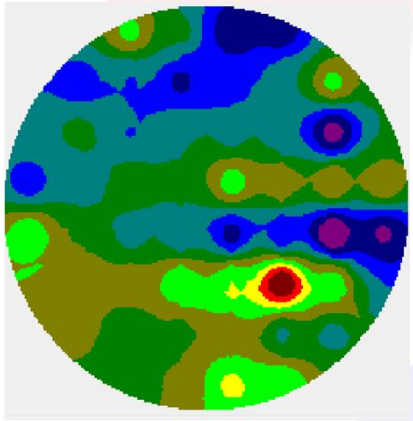

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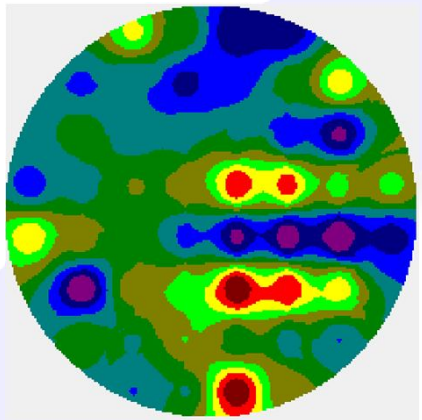

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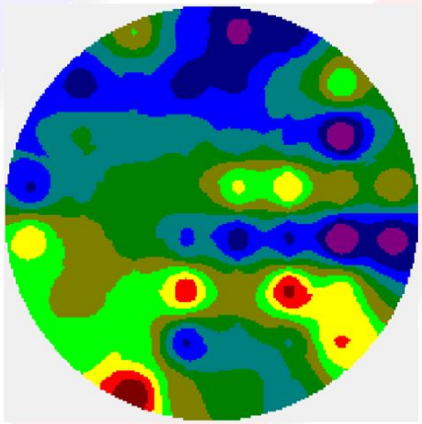
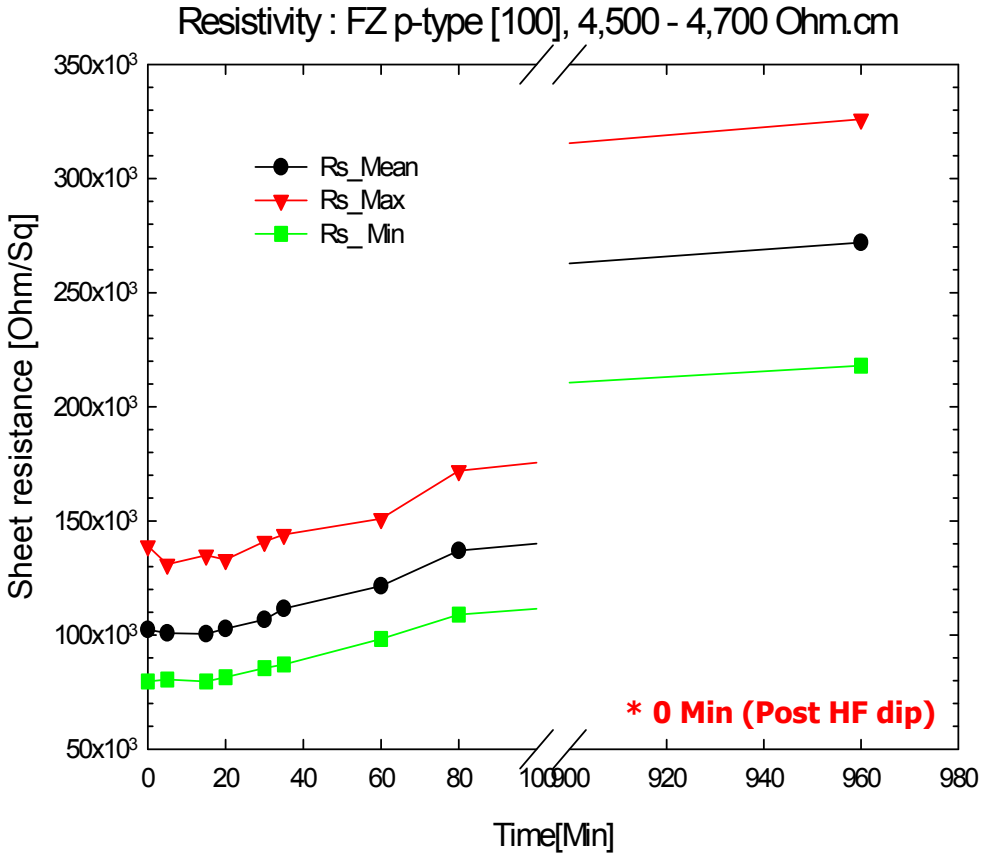


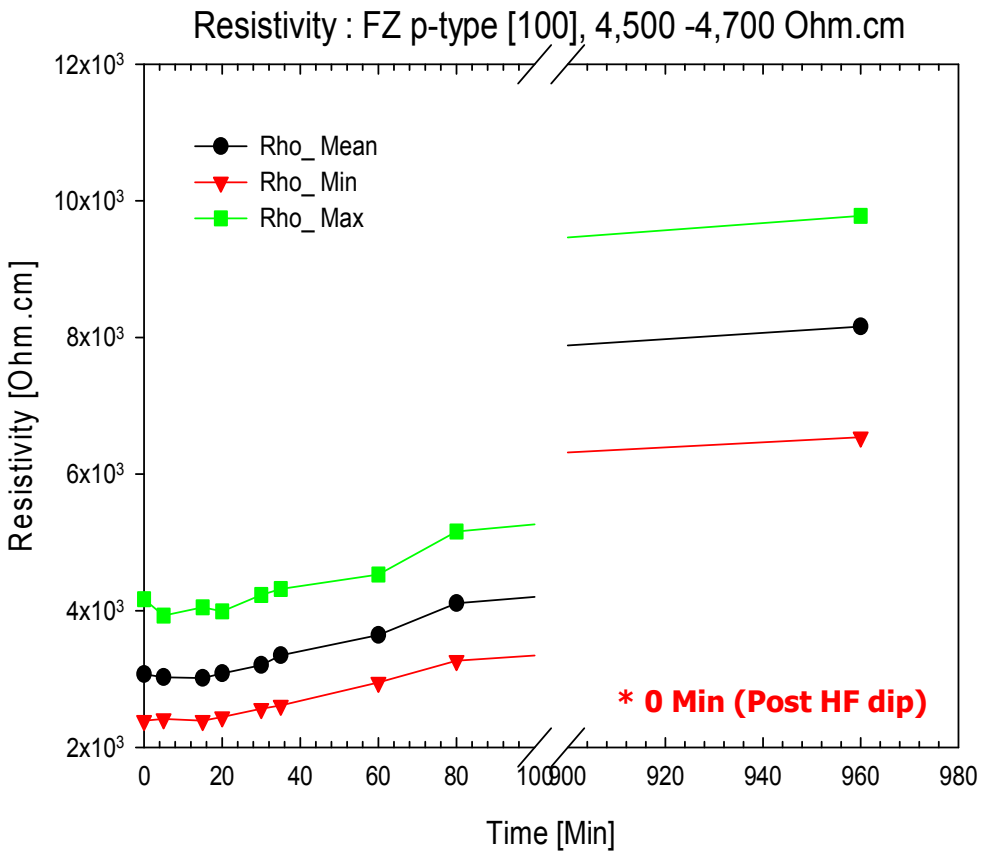
80 min

FZ p-type [100], 4,500 -4,700 Ohm.cm

Measured values		Time [Min]								
		After dip	5	15	20	30	35	60	80	960
Sheet resistance [Ohm/Sq]	Mean	102,360	100,889	100,494	102,792	106,790	111,563	121,513	137,000	272,000
	Min	139,000	131,000	135,000	133,000	141,000	144,000	151,000	172,000	326,000
	Max	79,700	80,500	79,700	81,500	85,500	87,100	98,300	109,000	218,000

Measured values





Sheet resistance(R_s)

Resistivity(ρ)

High resistivity reference wafer : 5 type

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Bulk resistivity measurement results

Wafer Spec.	Type	FZ (N-type)			FZ (N-type)			FZ (P-type)			FZ (P-type)			FZ (P-type)	
	Orientation	[100]			[111]			[100]			[100]			[111]	
	Resistivity [Ohm.cm]	5,000-10,000			3,000-5,000			4,500-4,700			5,000-8,500			8,000-10,000	
	Thickness [um]	380			525			300			350			380	
	Size	4"			4"			2 "			pices			pices	
Sheet Resistance (Rs) calculated(Cal) [Ohm/Sq]	Maximum	131,578.95			57,142.86			150,000.00			142,857.14			210,526.32	
	Minimum	263,157.89			95,238.10			156,666.67			242,857.14			263,157.89	
Rs measured [Ohm/Sq]	Meas. Condition	49 Point			49 Point			29 Point			49 Point			49 Point	
		#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2	#3	#1	#2
	Minimum	46,630	44,830	45,590	55,470	55,050	57,560	96,110	95,580	96,880	271,500	282,900	289,800	128,700	130,900
	Mean	49,250	49,470	50,270	72,600	73,820	74,870	98,620	99,670	100,600	300,600	313,900	319,400	155,700	144,700
	Maximum	55,340	55,030	54,890	85,790	87,670	91,340	102,300	103,300	104,300	330,100	341,900	354,100	340,500	165,200
	% STD	4.138	4.299	4.093	9.49	8.602	7.985	1.58	2.06	1.923	5.426	5.017	5.219	28.53	5.683
	Sort Sigma	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Bulk resistivity(Rho) Cal. from Rs [Ohm.cm]	Minimum	1,771.94	1,703.54	1,732.42	2,912.18	2,890.13	3,021.90	2,883.30	2,867.40	2,906.40	9,502.50	9,901.50	10,143.00	4,890.60	4,974.20
	Mean	1,871.50	1,879.86	1,910.26	3,811.50	3,875.55	3,930.68	2,958.60	2,990.10	3,018.00	10,521.00	10,986.50	11,179.00	5,916.60	5,498.60
	Maximum	2,102.92	2,091.14	2,085.82	4,503.98	4,602.68	4,795.35	3,069.00	3,099.00	3,129.00	11,553.50	11,966.50	12,393.50	12,939.00	6,277.60

XSEM & SRP Measurement

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Samples :

- 8” epi wafer : 20 & 40 um epi thickness
- ITS1 Run : W4, W5, W14, W8, W9, W20, W15, IPHC 1&2

XSEM & SRP Result : 8” epi wafer

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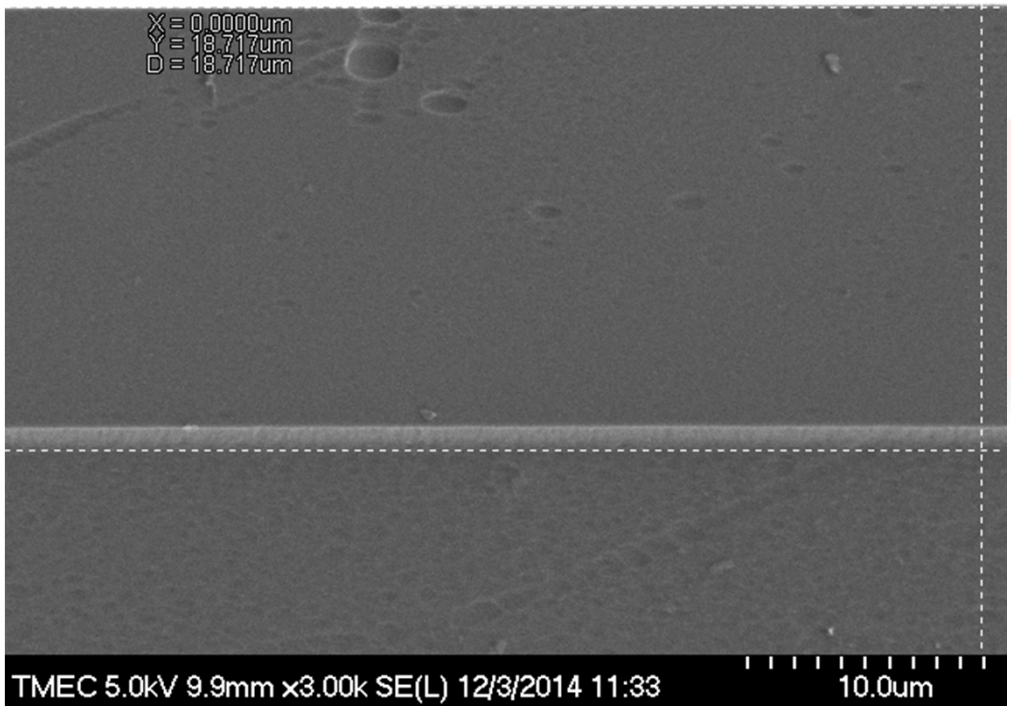
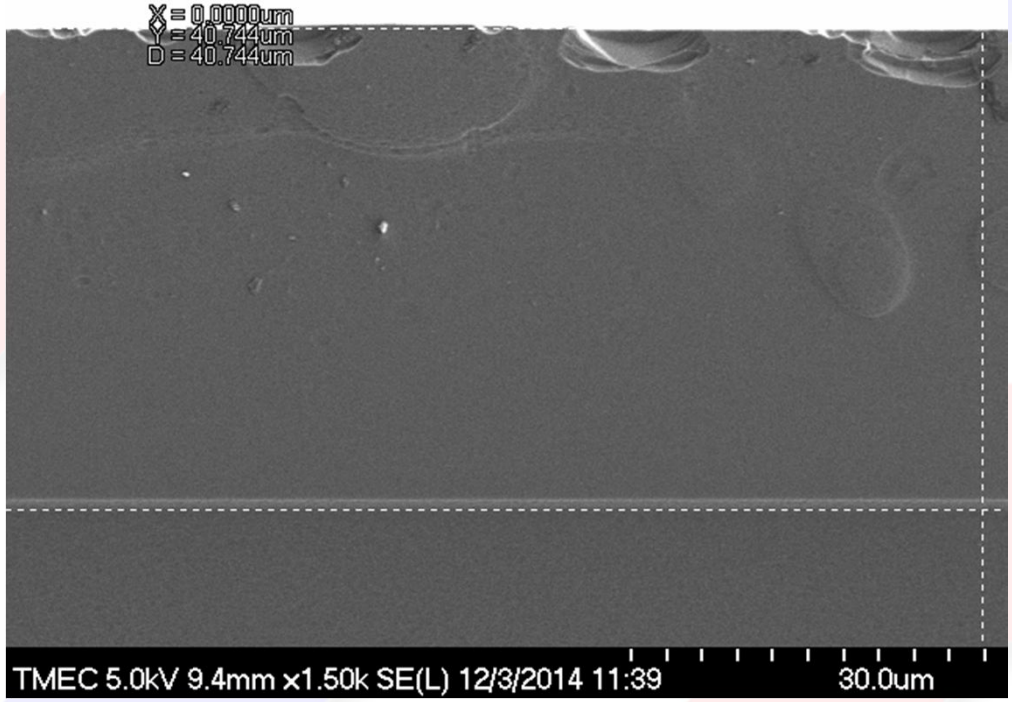
XSEM : thickness

20 um epi layer , average epi resistivity 6.284 kohm.cm



Epi layer thickness : 18.71 um

40 um epi layer , average epi resistivity 7.479 kohm.cm



Epi layer thickness : 40.74 um

XSEM & SRP Result : 8” epi wafer

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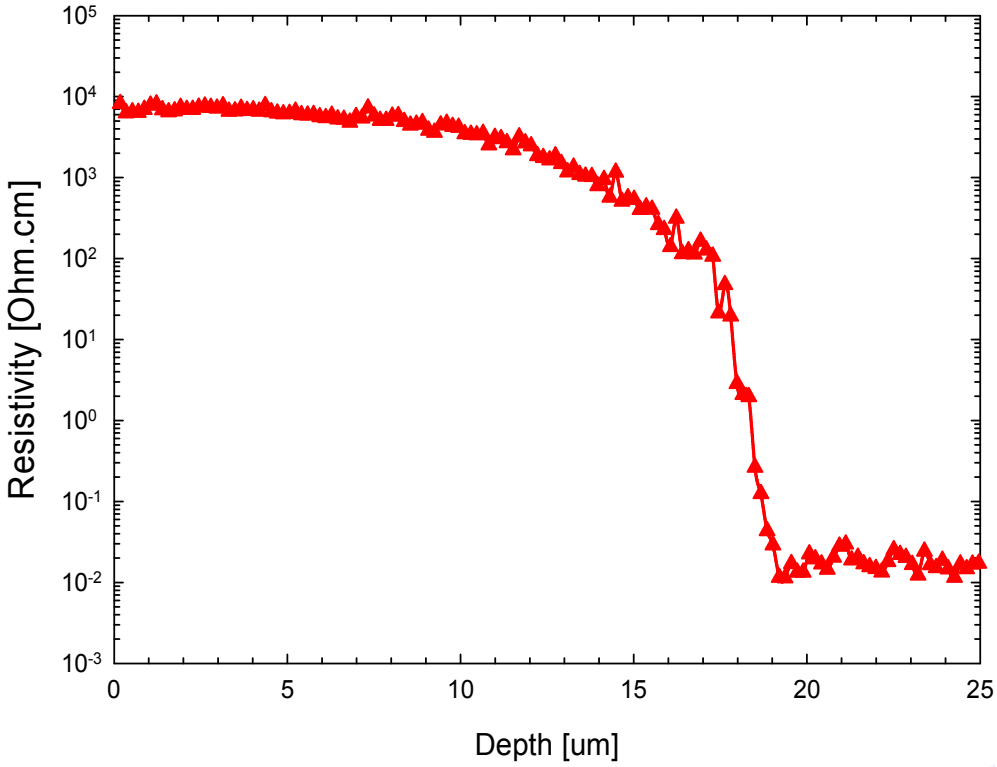
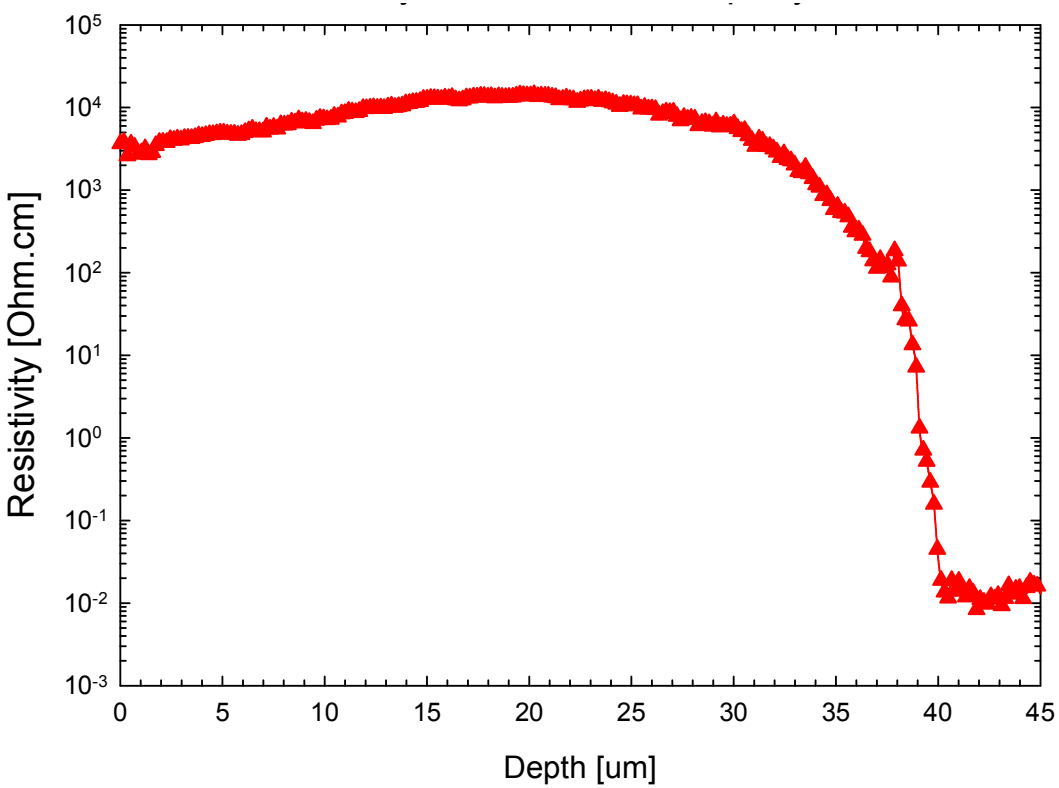
SRP : depth profiler

20 um epi layer , average epi resistivity 6.284 kohm.cm



Epi layer thickness ≈ 19 um

40 um epi layer , average epi resistivity 7.479 kohm.cm



Epi layer thickness ≈ 40 um

XSEM & SRP Result : 8” epi wafer

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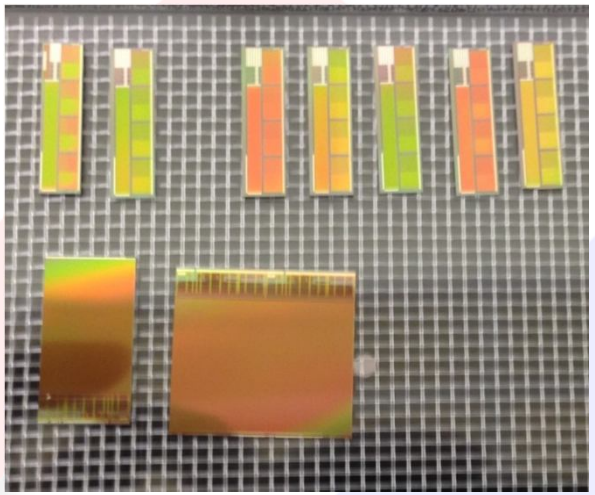
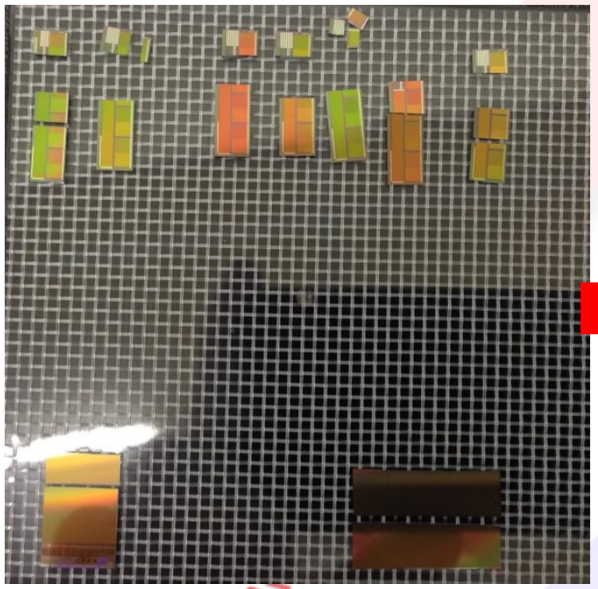
Summary of XSEM & SRP Measurement result

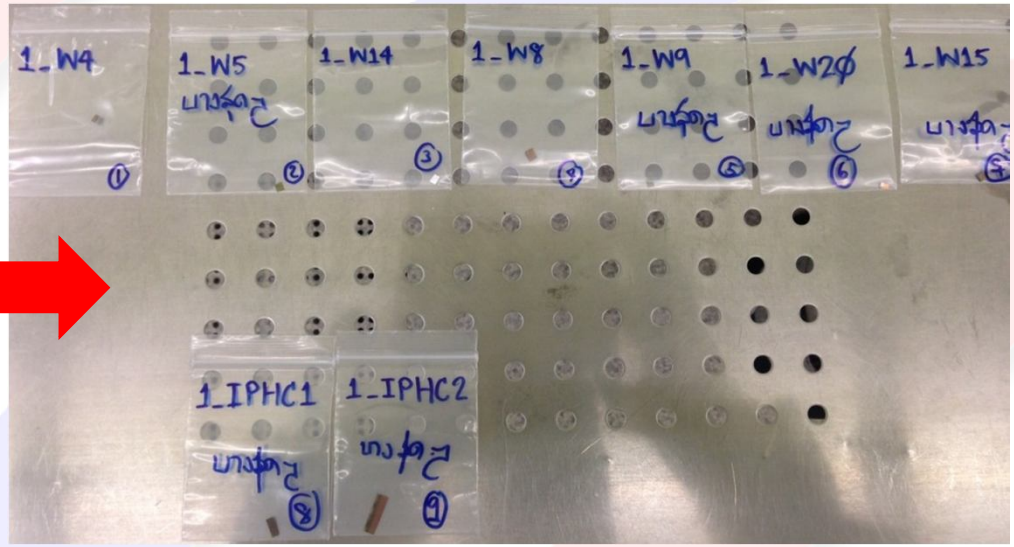
No.	Manufacturer s' data	Measured		
		XSEM	SRP	
		Epi thickness (um)	Resistivity (kΩ· cm)	Epi thickness (um)
1	20 um epi layer , average epi resistivity 6.284 kohm.cm	18.71	> 6	~ 19
2	40 um epi layer , average epi resistivity 7.479 kohm.cm	40.74	> 3 ~ 10	~ 40

XSEM & SRP Result

ALICE ITS1 Dies







XSEM & SRP Result : ITS1 Run

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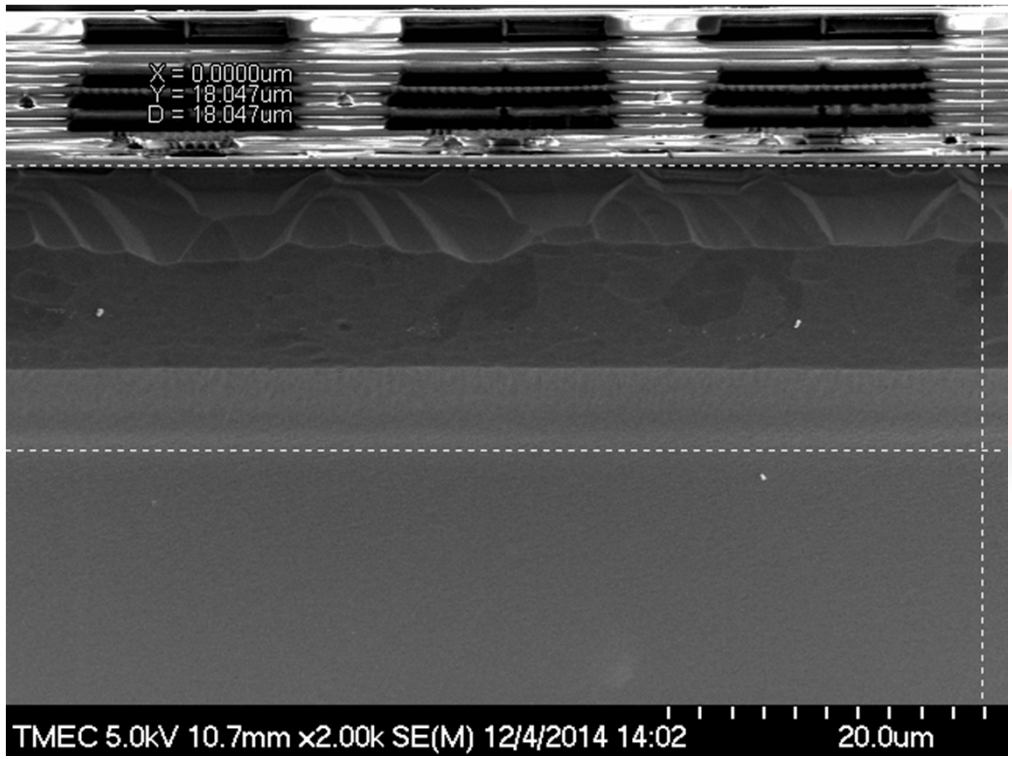
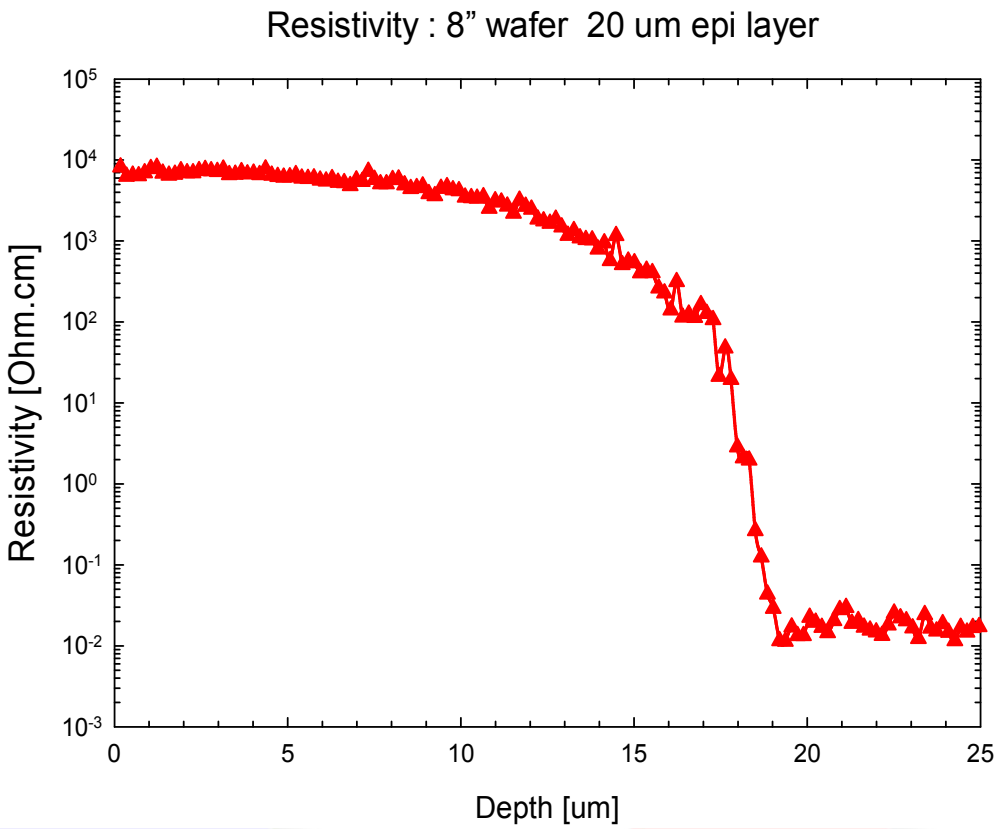
No.1 W4: 18 um epi layer, >1kOhmcm, 450 um thick

XSEM : thickness



Epi layer thickness : 18.04 um

SRP : depth profile



Epi layer thickness ≈ 19 um

XSEM & SRP Result : ITS1 Run

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Summary of XSEM & SRP measurement result

Dies No.	Manufacturer s' data	Measured		
		XSEM	SRP	
		Epi thickness (um)	Resistivity (kΩ· cm)	Epi thickness (um)
1	W4: 18 um epi layer, >1kOhmcm, 450 um thick	18.04	>1	~ 19
2	W5: 18 um epi layer, >1kOhmcm, 50 um thick	17.96	>1	~ 17
3	W14: 20 um epi layer, >1kOhmcm, 450 um thick	18.87	>1	~ 17
4	W8: 30 um epi layer, >1kOhmcm, 450 um thick	29.46	>1	~ 28
5	W9: 30 um epi layer, >1kOhmcm, 50 um thick	31.34		Ongoing
6	W20: 40 um epi layer, >1kOhmcm, 70 um thick	40.47		
7	W15: 20 um epi layer, >1kOhmcm, 50 um thick	20.04		
8	IPHC 1 : 18 um epi layer, >1 kOhmcm	16.86	>1	17
9	IPHC 2: 18 um epi layer, >1 kOhmcm	18.05	>1	17

Summary

- TMEC's Overview
- Our participates in the ITS upgrade
- Incoming wafer QA: status & results
- **Summary**

Summary

We have joined the ITS upgrade :

- Incoming wafers QC for 4 point ,SEM, SRP measurement ,
- Silicon Micro-channel cooling
- Thinning and laser dicing

Summary

- 4 Point measurement : Due to very low substrate doping concentration the probe tips are most probably not forming an Ohmic contact during these measurements and causing erroneous results
- SRP & XSEM : Most of the tests were performed on the chips with an epitaxial layer with a thickness of ~ 18μm and a resistivity of > 1kΩ·cm

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Thank you

http://tmec.nectec.or.th

NECTEC
a member of NSTDA
สวทช
NSTDA

Spare slide

8” epi wafer : 20 & 40 um epi thickness

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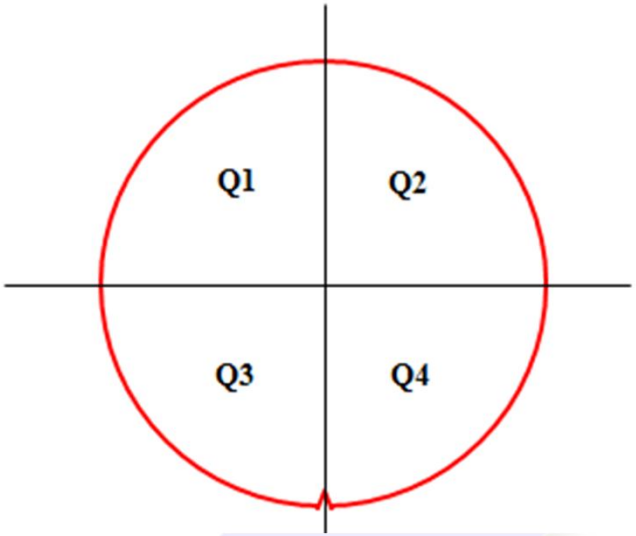
Bulk resistivity measurement

Wafer spec.	Type	8” wafer with 40 um epi thickness				8” wafer with 20 um epi thickness			
	Resistivity [Ohm.cm]	7,479 (Avg.), 9,801(Max.), 5,156(Min)				6,284(Avg.), 7,411(Max.),5,156 (Min.)			
Sheet Resistance (Rs) measured [Ohm/Sq]	Meas. Condition	49 Point				49 Point			
		Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
	Mean	63,479	65,835	60,483	82,033	83,309	75,639	65,261	98,304
	Minimum	54,630	57,420	53,360	75,100	73,690	60,870	59,540	82,240
	Maximum	69,930	78,240	66,590	92,980	101,000	98,880	70,770	119,200
	% STD	5.563	8.211	4.81	4.865	8.905	12.546	4.126	8.944
Bulk resistivity(ρ) Cal. from Rs [Ohm.cm] ($\rho = Rs*t$)	Mean	4,856.14	5,036.38	4,626.95	6,275.52	6,206.52	5,635.11	4,861.94	7,323.65
	Minimum	4,179.20	4,392.63	4,082.04	5,745.15	5,489.91	4,534.82	4,435.73	6,126.88
	Maximum	5,349.65	5,985.36	5,094.14	7,112.97	7,524.50	7,366.56	5,272.37	8,880.40



HIGH-RESISTIVITY SILICON(HRS) MEASUREMENT *

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The challenges of resistivity measurement techniques for HRS :
It is very difficult to accurately and consistently measure the resistivity of HRS wafers using the standard method:

- **Four-Point Probe (4PP) measurement : The instrument indicated that contacts are no longer Ohmic, they show mostly Schottky type behavior and we believe that plays a role in the inaccurate measurement.**

- **Hall Effect Measurement : The current-voltage plots were not Ohmic, the Hall coefficients did not match and the results were not repeatable.**

*Source : Pinakpani Nayak, "Characterization of High-Resistivity Silicon Bulk and Silicon-on-Insulator Wafers", PhD Thesis, ARIZONA STATE UNIVERSITY, p. 170-185, 2012.

HIGH-RESISTIVITY SILICON(HRS) MEASUREMENT *

Table 6.4 Summary of resistivity measured by different methods for a bulk silicon sample with 1000 Ω.cm manufacturer specified resistivity.

Resistivity (Ω.cm) (Manufacturer Value ≈ 1000 Ω.cm)						
Method ⇒	Four-Point Probe	Hall (Silver Paste Contact)	Hall (Gold Contact)	Hall (Indium Contact)	C-V Doping Profile	C-V Extraction
Resistivity	6.5k[a], 5.7k[b], 50k[c]	Undetermined	755	2.69k	133	220
Average Doping	NA	Undetermined	9.1×10^{12}	7.22×10^{12}	10^{14}	NA

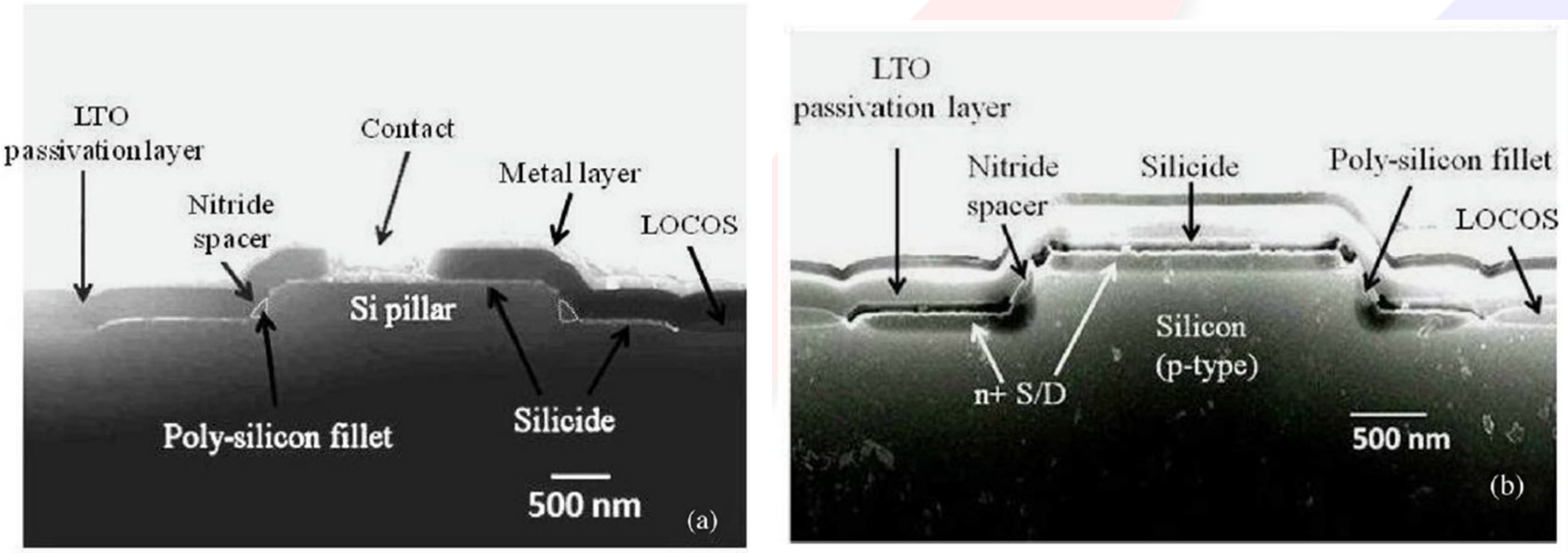
[a] polished surface, [b] unpolished surface, and [c] unpolished surface after annealing

"Due to very low substrate doping concentration the probe tips are most probably not forming an Ohmic contact during these measurements and causing erroneous results. It is believed that the contact resistance and the types of contact, Ohmic or Schottky, play a significant role in the observed measurement anomalies. The strategy is to understand the nature of contacts during standard four-point probe or Hall techniques and find a way to either avoid the contact problem or take into account the contact resistances and separate them from the final measurement to get the actual substrate resistance."

* Source : Pinakpani Nayak, "Characterization of High-Resistivity Silicon Bulk and Silicon-on-Insulator Wafers", PhD Thesis, ARIZONA STATE UNIVERSITY, p. 170-185, 2012.

Stain etching

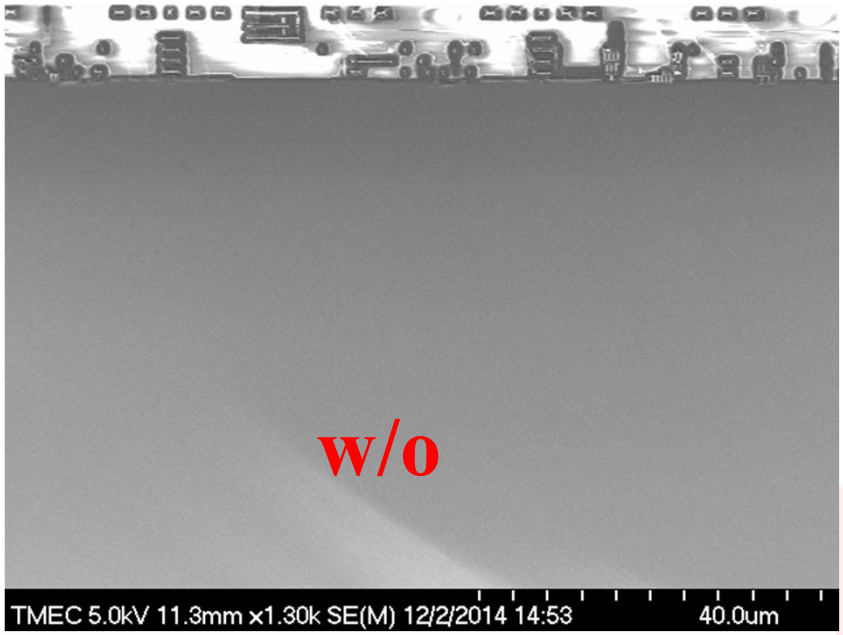
The channel length *L* was obtained from measurements of the pillar heights using cross-sectional scanning electron microscope (SEM) and measurements of the junction depths by stain etching in a HF : HNO3 : CH3COOH, 1:3:8 for 5–10 s

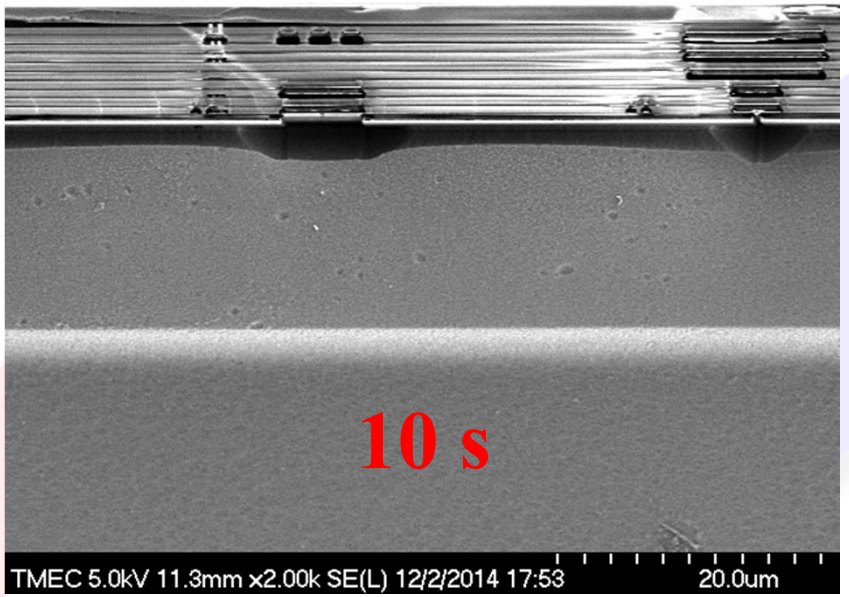


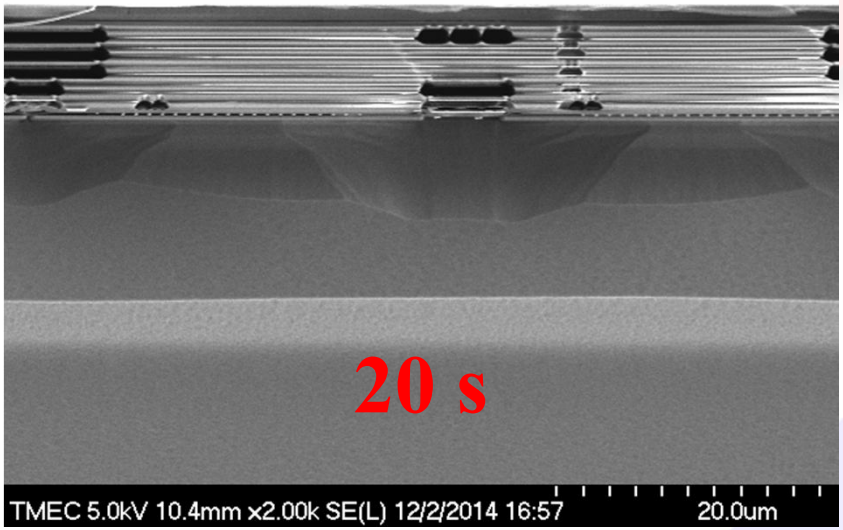
SEM cross section of a 120-nm v-MOSFET after silicide formation (a) without any etch and (b) after stain etching

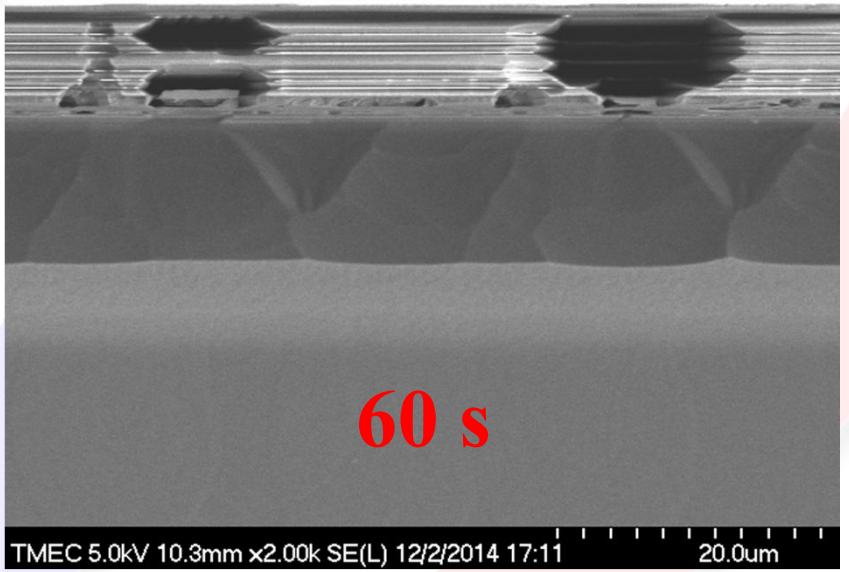
***Source :** M. M. A. Hakim, "Self-Aligned Silicidation of Surround Gate Vertical MOSFETs for Low Cost RF Applications", IEEE TRANSACTIONS ON ELECTRON DEVICES, VOL. 57, NO. 12, DECEMBER 2010.

Stain etching : dip time



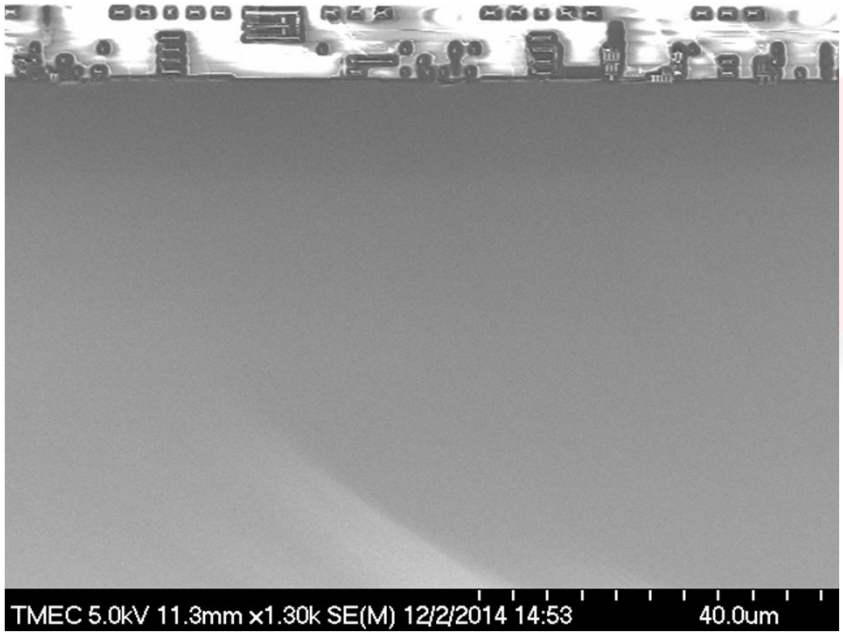




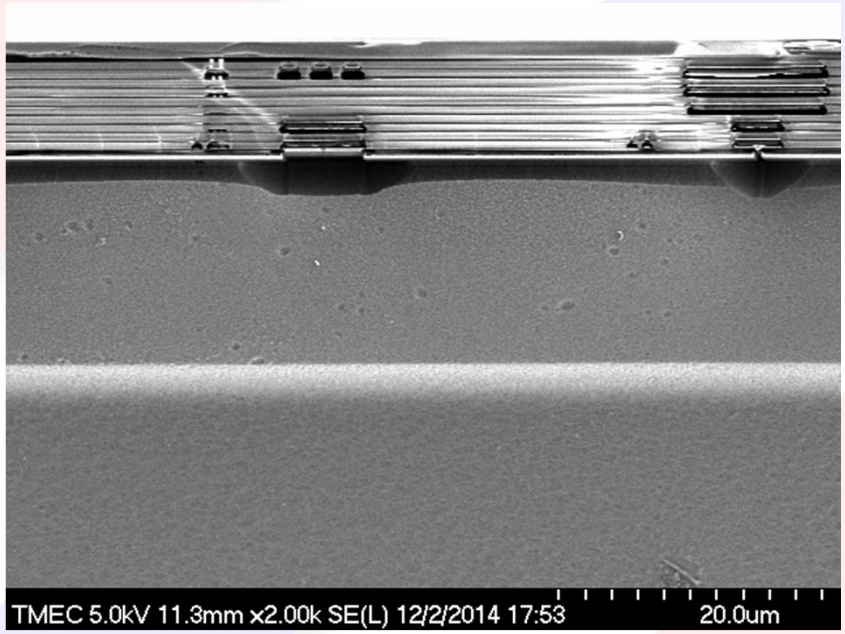


Sample preparation

XSEM : Cross-sectional scanning electron microscope (XSEM) measurements of the epi layer & wafer thickness by stain etching in a HF : HNO_3 : CH_3COOH, 1:3:8 for 10 s



without any etch



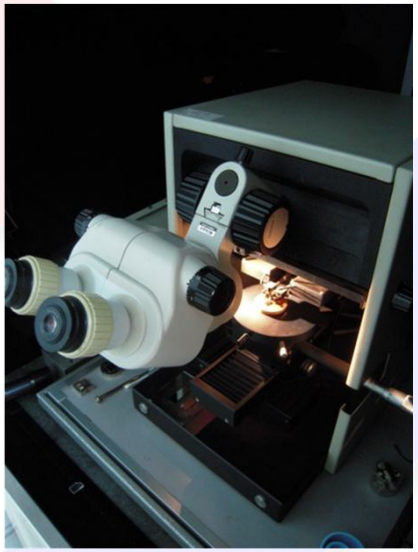
after stain etching 10 s

Sample preparation

SRP :

Bevel-cut sample

Grinding



Spreading-resistance measuring :
SR-210 model