Current measurements on 3D silicon sensors

Step1. Before and after UBM and dicing

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TALENT ESR13, WP5, CERN

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- IV curve before and after dicing. Guard ring technique
- IV curve after dicing. By GUARD RING technique and by PIXEL technique
- IV curve reproducibility
- IV curve at different temperatures

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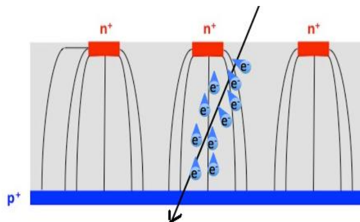
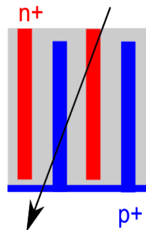
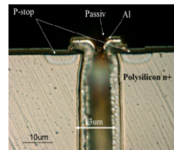
3D Silicon sensors. Features

- It is a new sensor technology. It covers 25% Insertable-B Layer

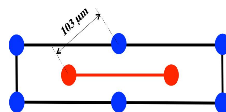




3D-DDTC
3D-Double-sided-Double-Type-Columns



a)Radiation hardness $5x10^{15} n_{eq}/cm^2$
b)Lower deplection voltage $< 15V$
c)Faster charge collection
d) More expensive and difficult fabrication (by etching)



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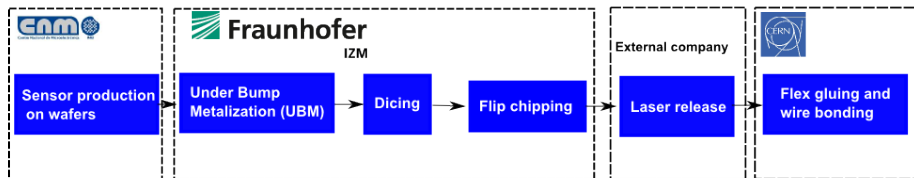
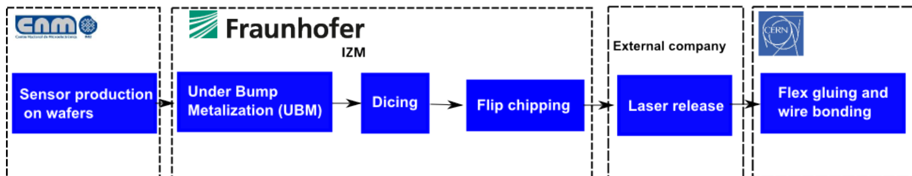
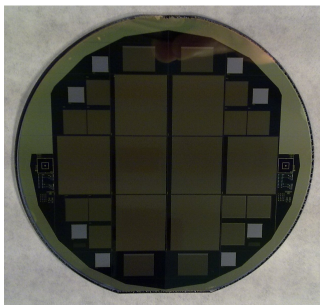
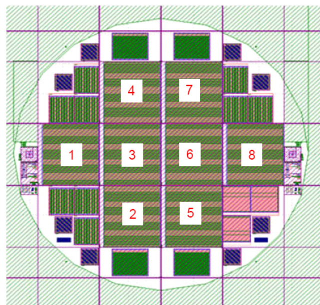
3D Silicon sensors. Fabrication process



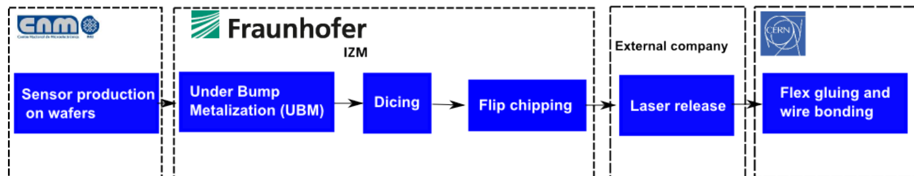
3D Silicon sensors. Fabrication process

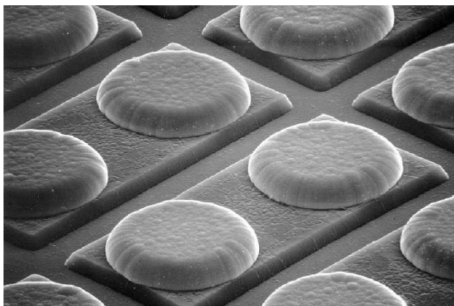




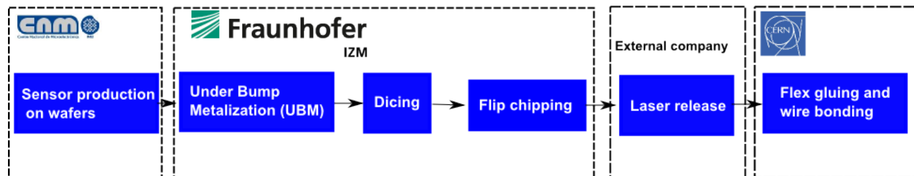


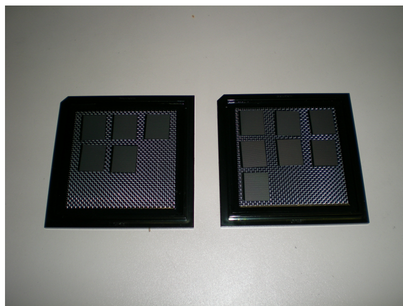
3D Silicon sensors. Fabrication process





3D Silicon sensors. Fabrication process





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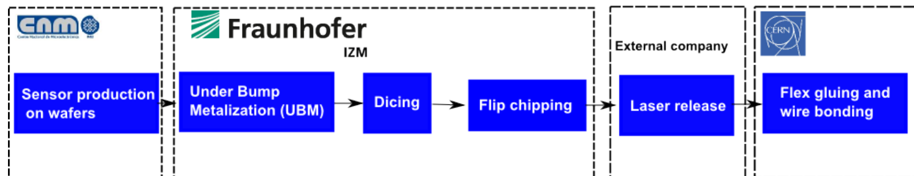
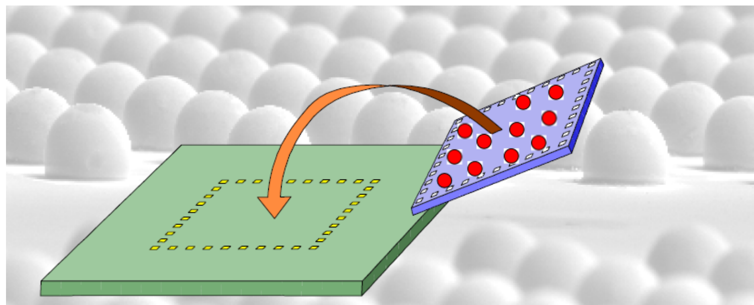
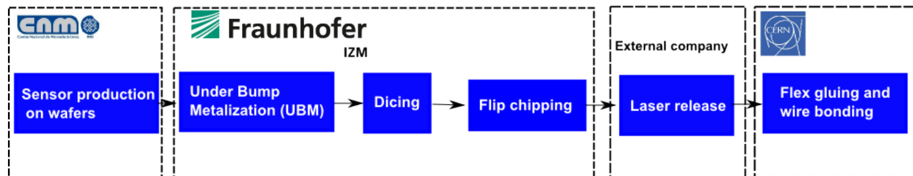
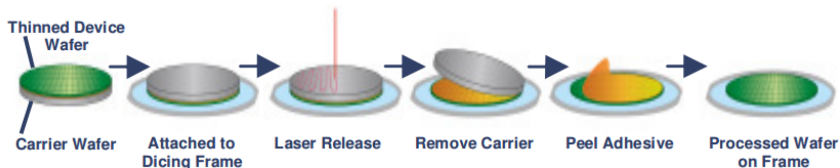


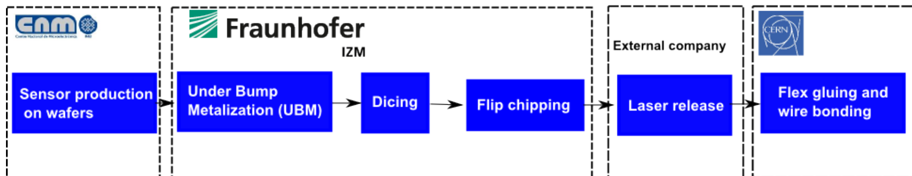


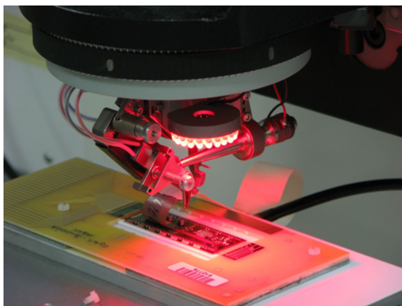
3D Silicon sensors. Fabrication process





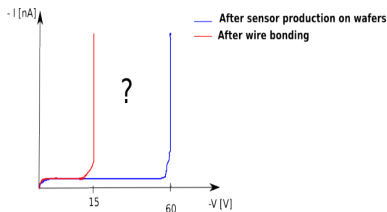
3D Silicon sensors. Fabrication process

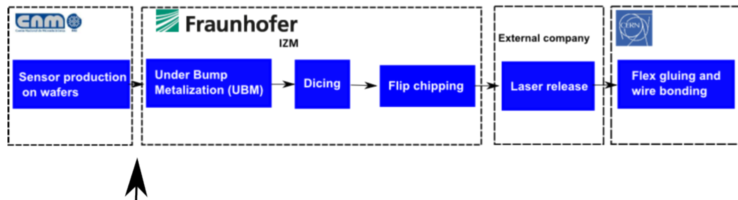




IV curve during the module fabrication process

A dramatic decreasing of the Breakdown Voltage was found in some CNM 3D sensors between the sensor production on wafers and after wire bonding





To find out the critic step of the module fabrication process

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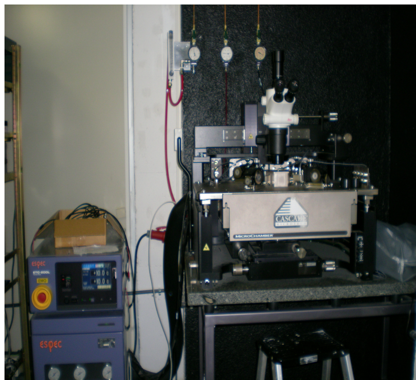
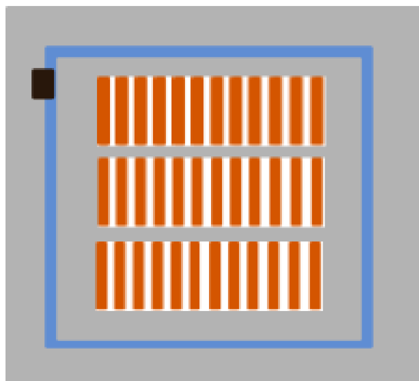
Step1: IV curve before and after UBM and dicing

- The measurements were performed in CNM laboratory. Probe station



Step1: IV curve before and after UBM and dicing

- The measurements were performed in CNM laboratory. Probe station
- Techniques of measure: Guard ring technique- Pixel technique

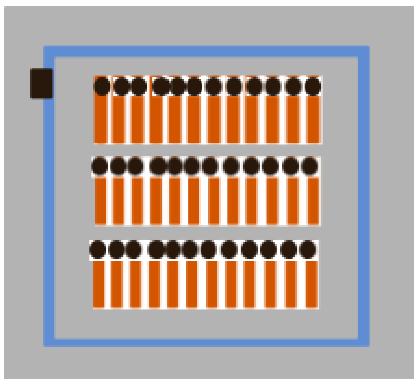


GUARD RING TECHNIQUE

It can be used before and after UBM and dicing. You get I_{Guard}

Step1: IV curve before and after UBM and dicing

- The measurements were performed in CNM laboratory. Probe station
- Techniques of measure: Guard ring technique- Pixel technique



PIXEL TECHNIQUE

It can be used just after UBM. You get $I_{Guard} + I_{Pixel}$

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IV curve before and after dicing. Guard ring technique

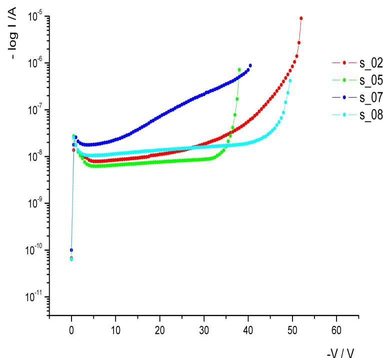


Figure : Wafer 5936-05.Before dicing

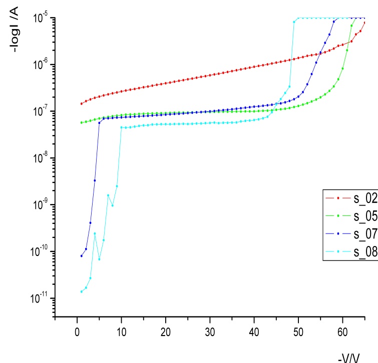


Figure : Wafer 5936-05. After dicing

1. **A light increase of the leakage current.**

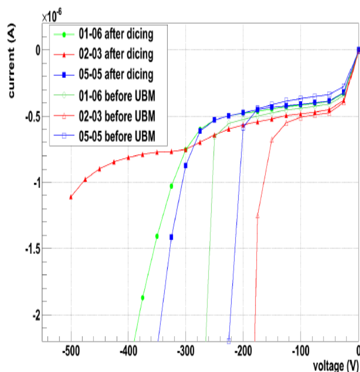
IV curve BEFORE and AFTER dicing. GUARD RING technique

		Edge check		IV test	
Wafer	Sensor	front side	Back side	Before dicing	After dicing
5936-05	02	3 corners cracked	cracks	50 V	45V
5936-05	05	ok	saw tooth chipping	37 V	59V
5936-05	07	ok	ok	39V	51V
5936-05	08	ok	ok	48V	48V
5936-06	01	ok	ok	56V	67V
5936-06	02	ok	ok	56 V	0V
5936-06	03	ok	ok	55 V	65V
5936-06	04	single chipping	saw tooth chipping	55 V	62V
5936-06	05	ok	ok	55 V	63V
5936-06	07	ok	ok	5V	5V
5936-06	08	ok	saw tooth chipping	57 V	67V

1. 7 sensors increase the BV after dicing. 2 sensors decrease the BV (1 broken). 2 sensors maintain the BV.
   UBM and Dicing are not the critic fabrication process.

IV curve before and after dicing.GUARD RING technique

Same results were found on FEI4 Planar sensors. Master thesis Jennifer Jentzsch [1]



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IV curve after dicing.
By GUARD RING technique and by PIXEL technique

		Edge check		IV test after dicing	
Wafer	Sensor	front side	Back side	Guard (January)	Pixel (January)
5936-05	02	3 corners cracked	cracks	45V	32V
5936-05	05	ok	saw tooth chipping	59V	51V
5936-05	07	ok	ok	51V	51V
5936-05	08	ok	ok	48V	46
5936-06	01	ok	ok	67V	52V
5936-06	02	ok	ok	0V	0V
5936-06	03	ok	ok	65V	29V
5936-06	04	single chipping	saw tooth chipping	62V	37V
5936-06	05	ok	ok	63V	0V
5936-06	07	ok	ok	5V	5V
5936-06	08	ok	saw tooth chipping	67V	34V

1. In 7sensors BV is smaller by Pixel technique than by Guard ring tehcnique. **Noisy pixels in its active area** (not possible to see by the Guard technique).
   In 2 sensors BV is similar by both techniques. **Not noisy pixels**

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   - IV curve reproducibility
   - IV curve at different temperatures
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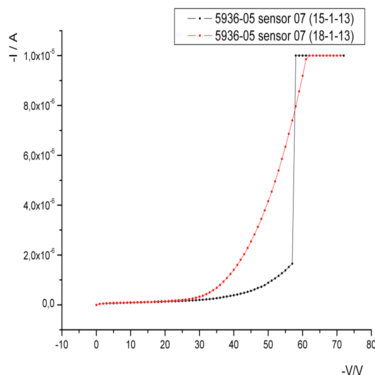
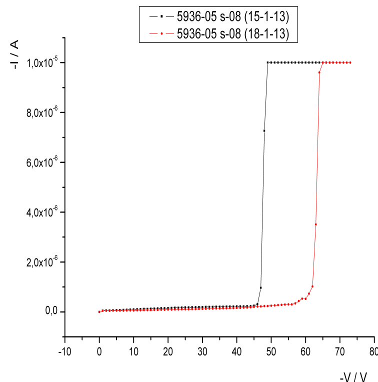
IV curve reproducibility

Parameters controled during the measure: Temperature, humidity





1. Existence of parameters that change the BV and I don't control??

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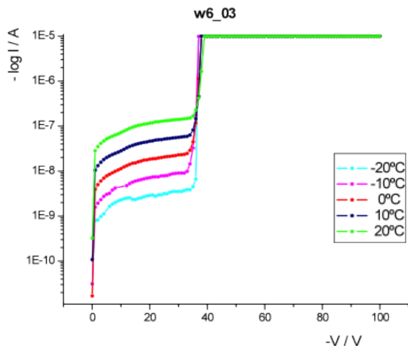
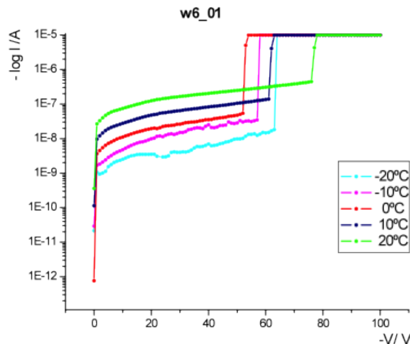
IV at different temperatures





1. In all sensors were oberved an increasement of the leakage current with temperature.
2. Some of them showed a change of the breakdown voltage with temperature as w6−01.

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Conclusions

1. 7sensors increase BV, 2 decrease, 2 maintain during UBM and dicing. **UBM and Dicing are not the critic fabrication process.**
2. A light increase of the leakage current during dicing process. Expected
3. By comparing the BV after dicing between PIXEL technique and GUARD RING technique.
   7 sensors have noisy pixels on the active area.
4. Something strange with reproducibility
5. Expected behavior at different temperatures, except for this BV variations.

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Next steps before go through step 2

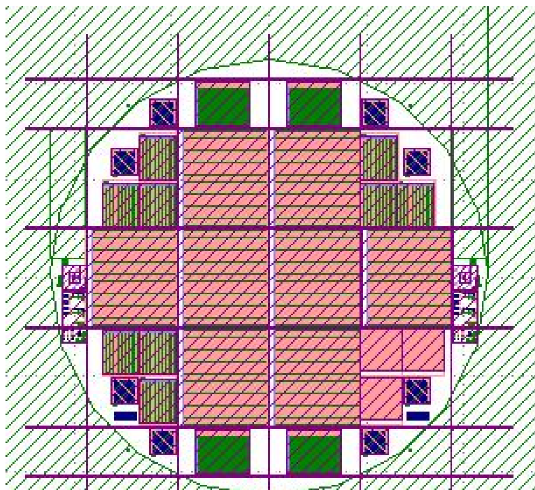
1. Same measurements with 10 new sensors (to reaffirm conclusions)
2. With Voltage fixed. Current-time measurements
3. IV curve at different humidities
4. TCAD simulation

BACKUP

3D Silicon sensors. Features

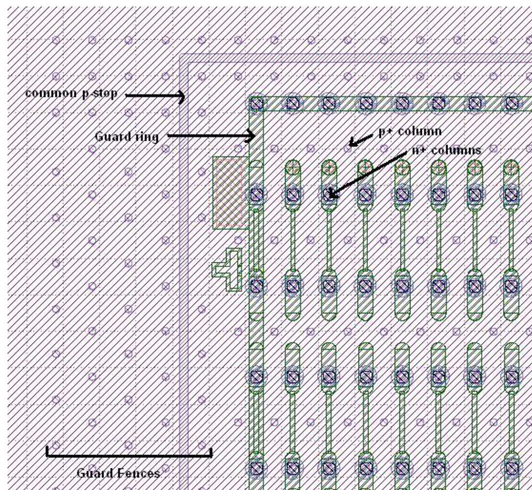
3D Silicon sensors. Features

- CNM Wafer mask



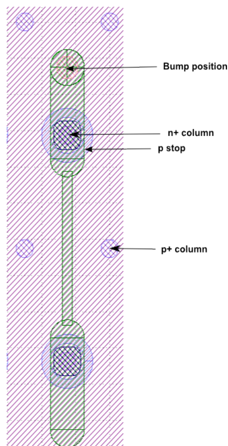
3D Silicon sensors. Features

- CNM Wafer mask
- CNM 3D sensor mask



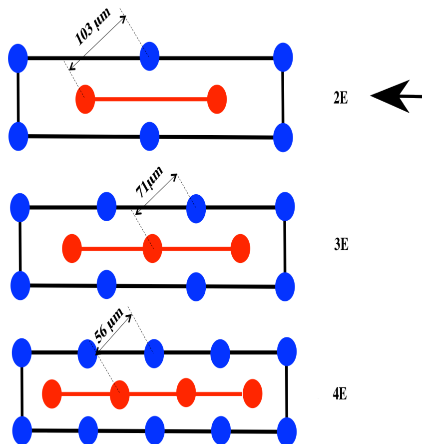
3D Silicon sensors. Features

- CNM Wafer mask
- CNM 3D sensor mask
- Pixel mask



3D Silicon sensors. Features

- There are differents 3D layout configurations



3D Silicon sensors. Features

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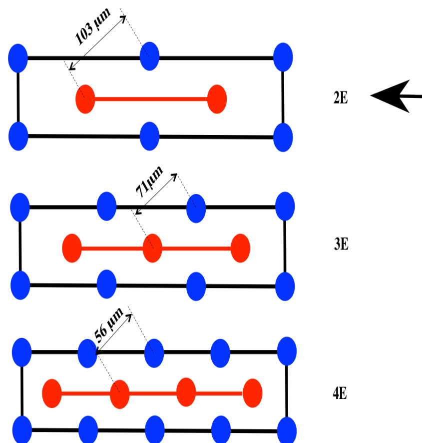


IBL Specifications	
Pixel dimensions	$50\mu m x 250\mu m$
Sensor thickness	$230\mu m$
Deplection V.	$< 15V$
Breakdown V.	$> 25V$
Fluence irradiation	$5x10^{15} n_{eq}/cm^2$

IV curve before and after dicing. Guard ring technique

Wafer 5936-06

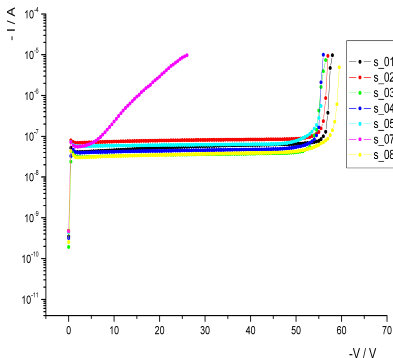


Figure : Wafer 5936-06.Before dicing

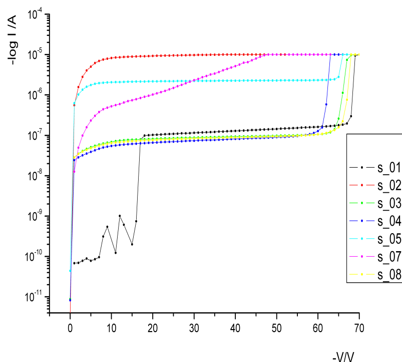


Figure : Wafer 5936-06. After dicing

Pixels technique vs Guard technique Wafer 5936-05

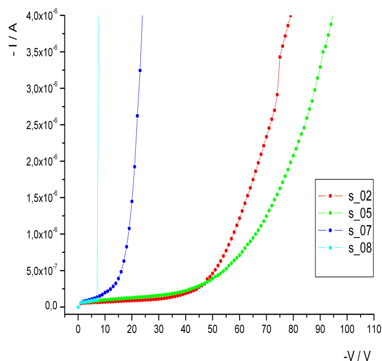


Figure : Wafer 5936-05. IV on pixels

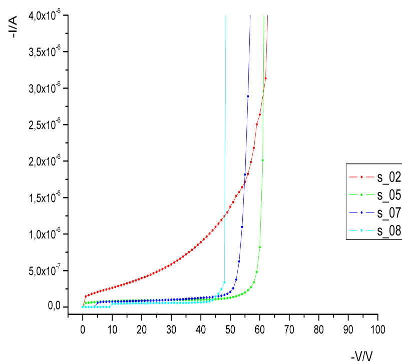
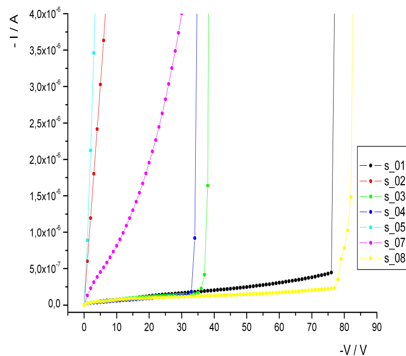


Figure : Wafer 5936-05. IV on Guard

Pixel technique vs Guard technique
Wafer 5936-06



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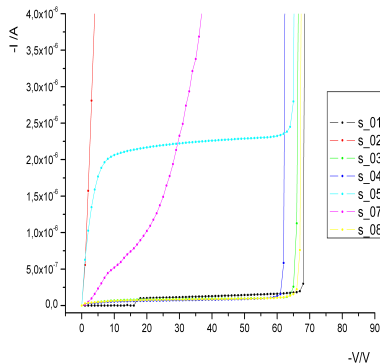

Figure : Wafer 5936-06. IV on Guard

IV curve by Pixel technique and by guard ring technique

		Edge check		IV test after dicing		
Wafer	Sensor	front side	Back side	Pixel (Novemb)	Guard (January)	Pixel (January)
5936-05	02	3 corners cracked	cracks	55V	45V	32V
5936-05	05	ok	saw tooth chipping	72V	59V	51V
5936-05	07	ok	ok	18V	51V	51V
5936-05	08	ok	ok	8V	48V	46
5936-06	01	ok	ok	76V	67V	52V
5936-06	02	ok	ok	0V	0V	0V
5936-06	03	ok	ok	37V	65V	29V
5936-06	04	single chipping	saw tooth chipping	33V	62V	37V
5936-06	05	ok	ok	0V	63V	0V
5936-06	07	ok	ok	5V	5V	5V
5936-06	08	ok	saw tooth chipping	80V	67V	34V

References

1 J. Jentzsch Master,Thesis September 2011. ATLAS FE-I4 Single Chip Assemblies in Laboratory and Testbeam Measurements.

2 Sensor inspection after I-V-measurements Fraunhofer IZM