

*Characterizations of Edgeless Si Detectors **

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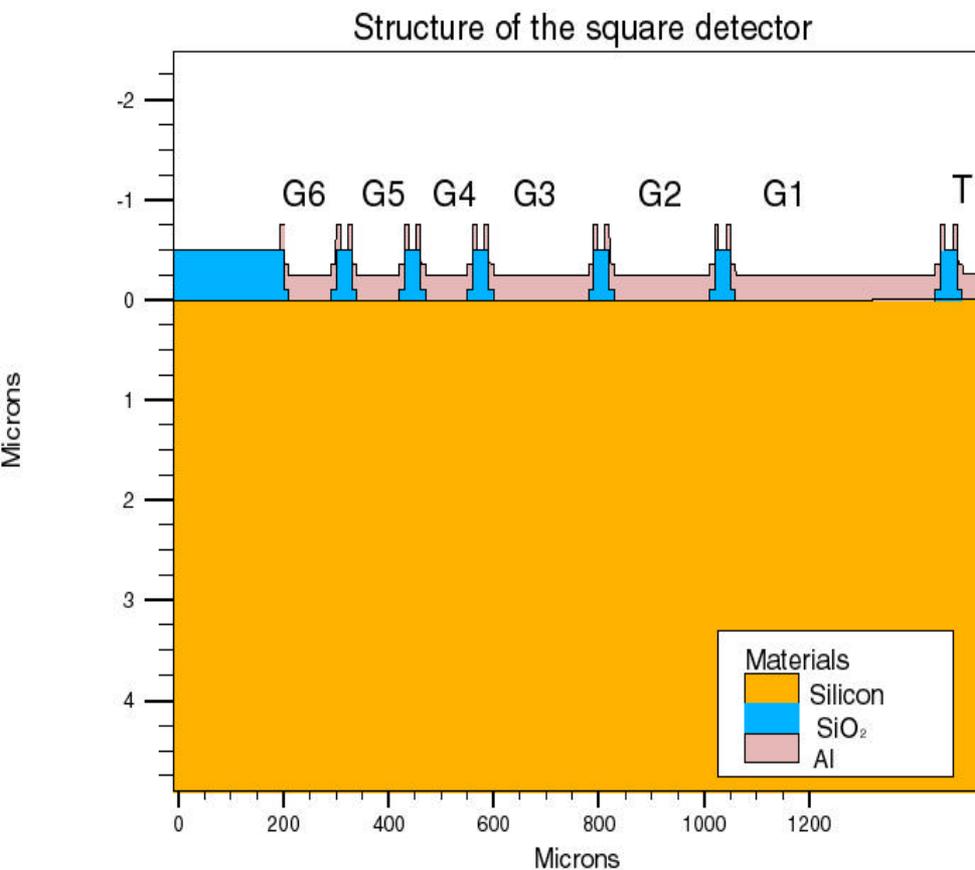
OUTLINE

- Laser cutting study in the past
- Motivation
- Samples used
 - Laser cut (front/back)
 - Scribing (front/back)
- I-V, C-V Characteristics
 - Before cut
 - After Cut
- TCT Measurements
 - RT
 - Low temps
- Low Temp CCE Measurements
- Summary

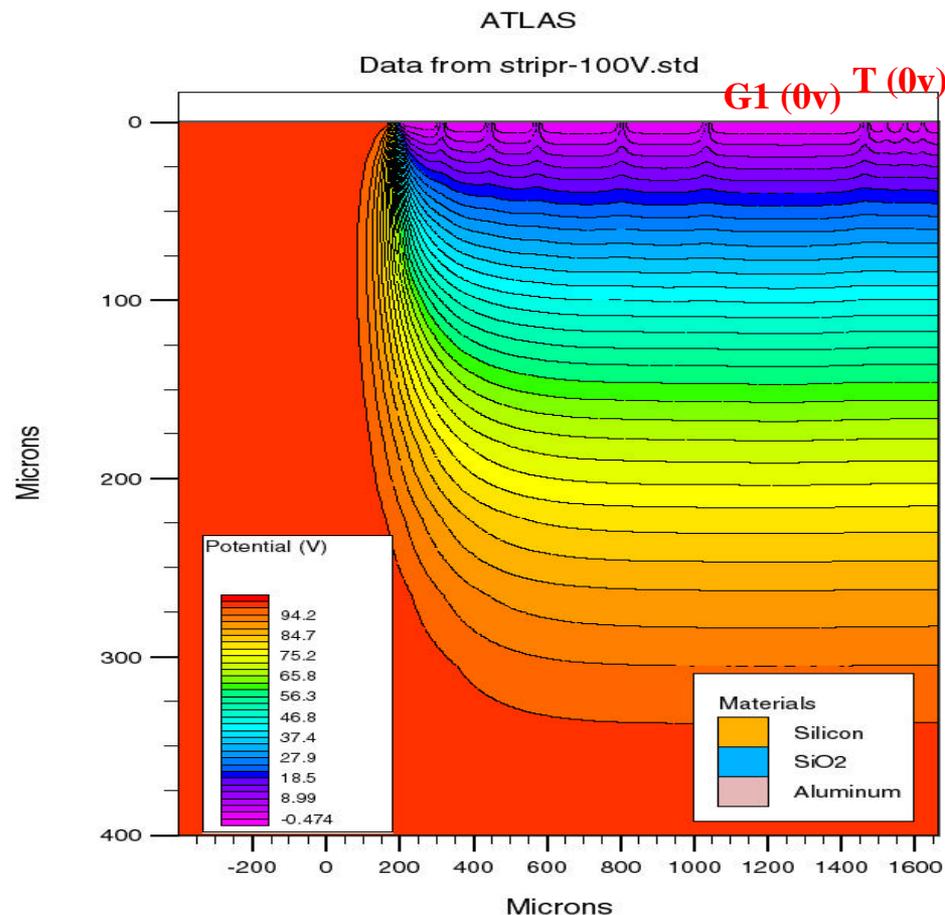
Cutting edge study history

Systematic of the correlation between edge e-field and edge current breakdown had been studied in the past. [Z. Li et al., IEEE TNS Vol. 47, No. 3 \(2000\) p729](#)

Test structure

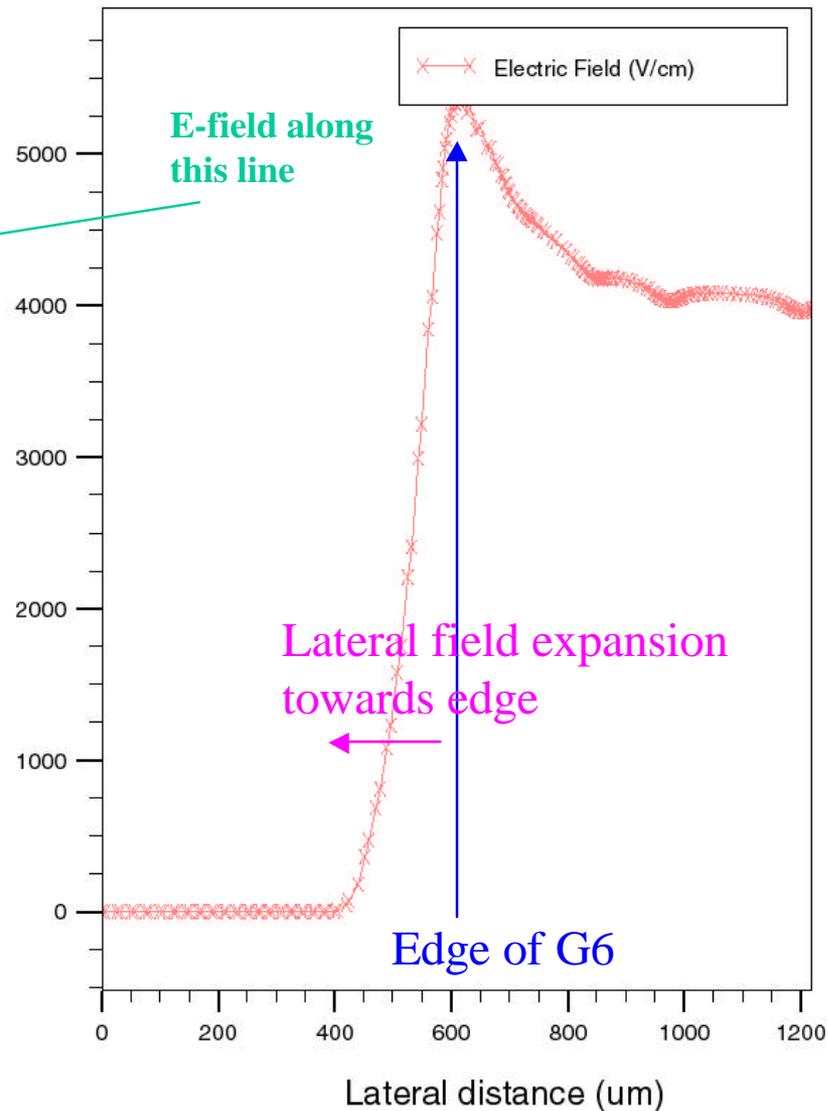
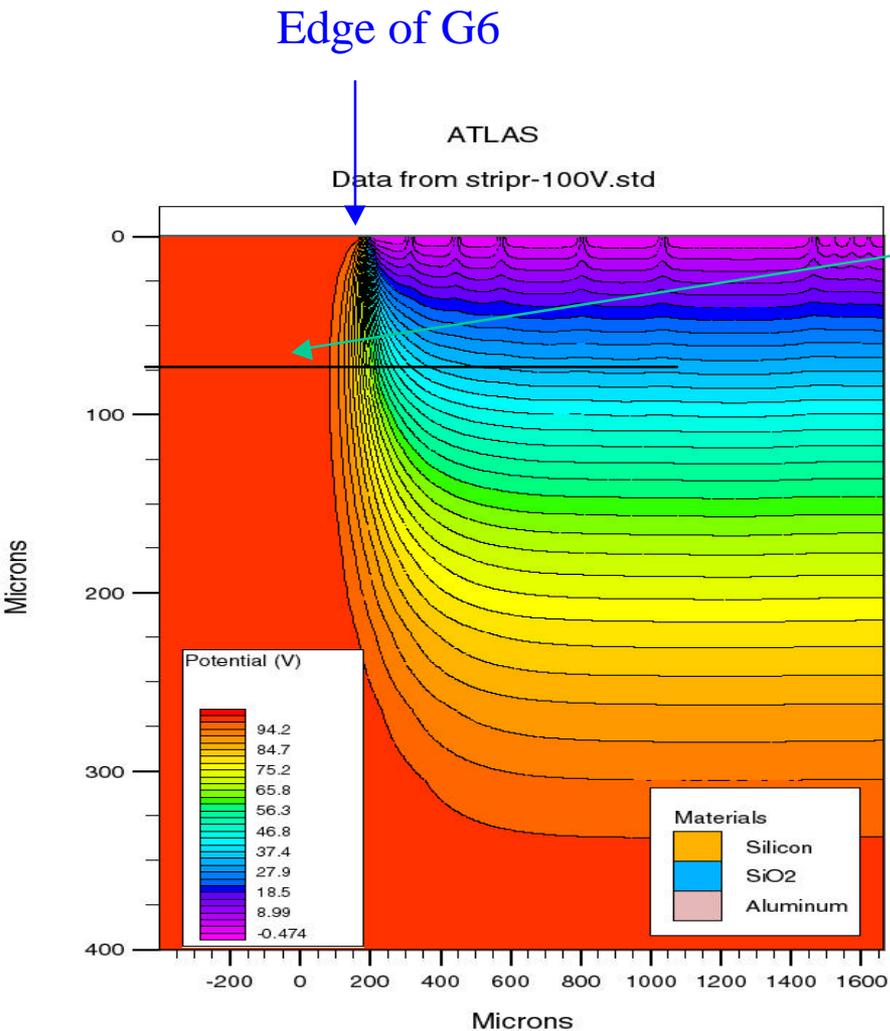


Potential Distribution



E-field profile along $y=75 \mu\text{m}$

V=100V on the backside
GR bias scheme #S6



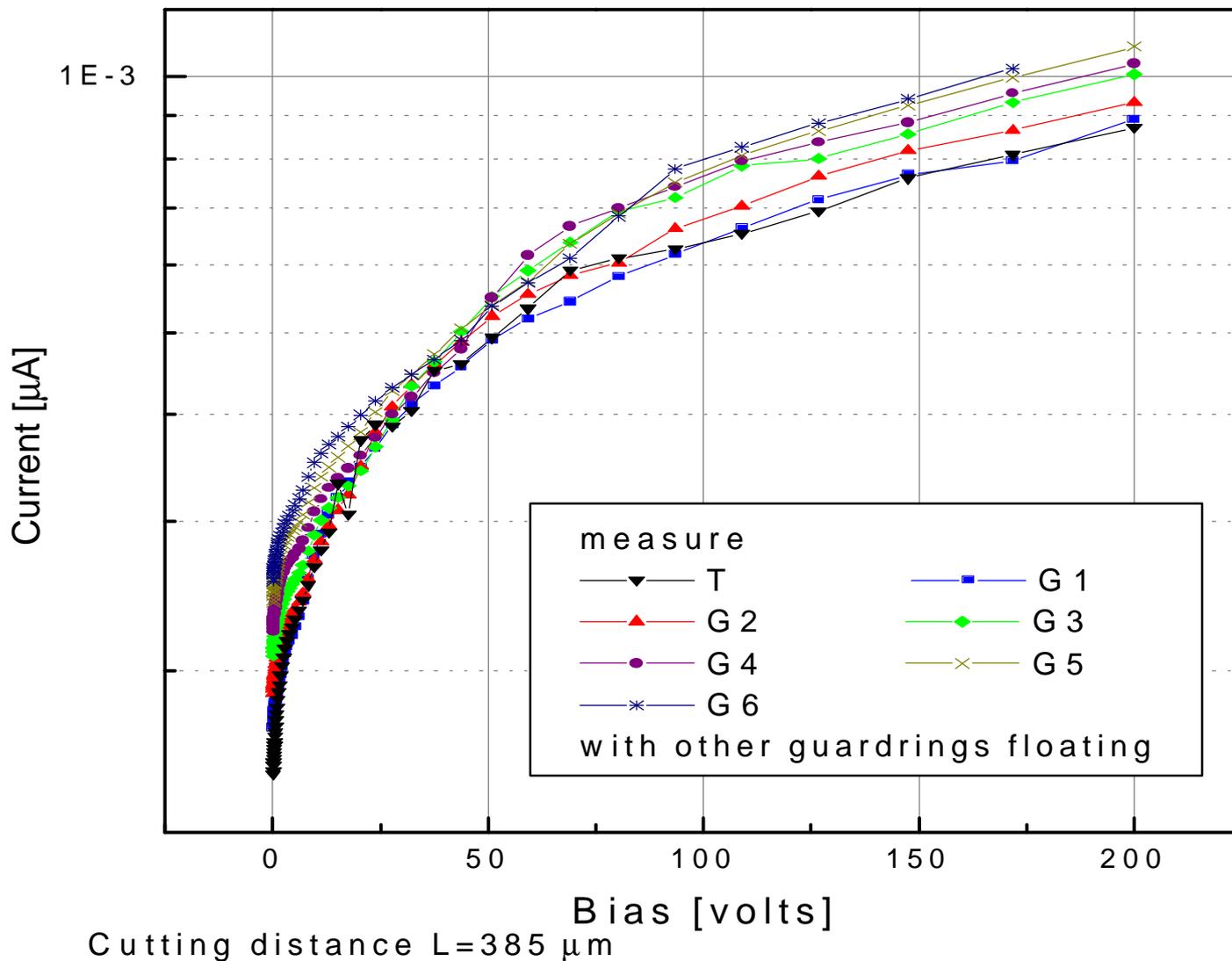
Cutting edge current breakdown (Data)

Measure the test structure and individual guard ring with other guard rings floating

Z. Li et al., IEEE
TNS Vol. 47, No. 3
(2000) p729

Laser cut from
Front side

Cutting distance:
385 μm from G6



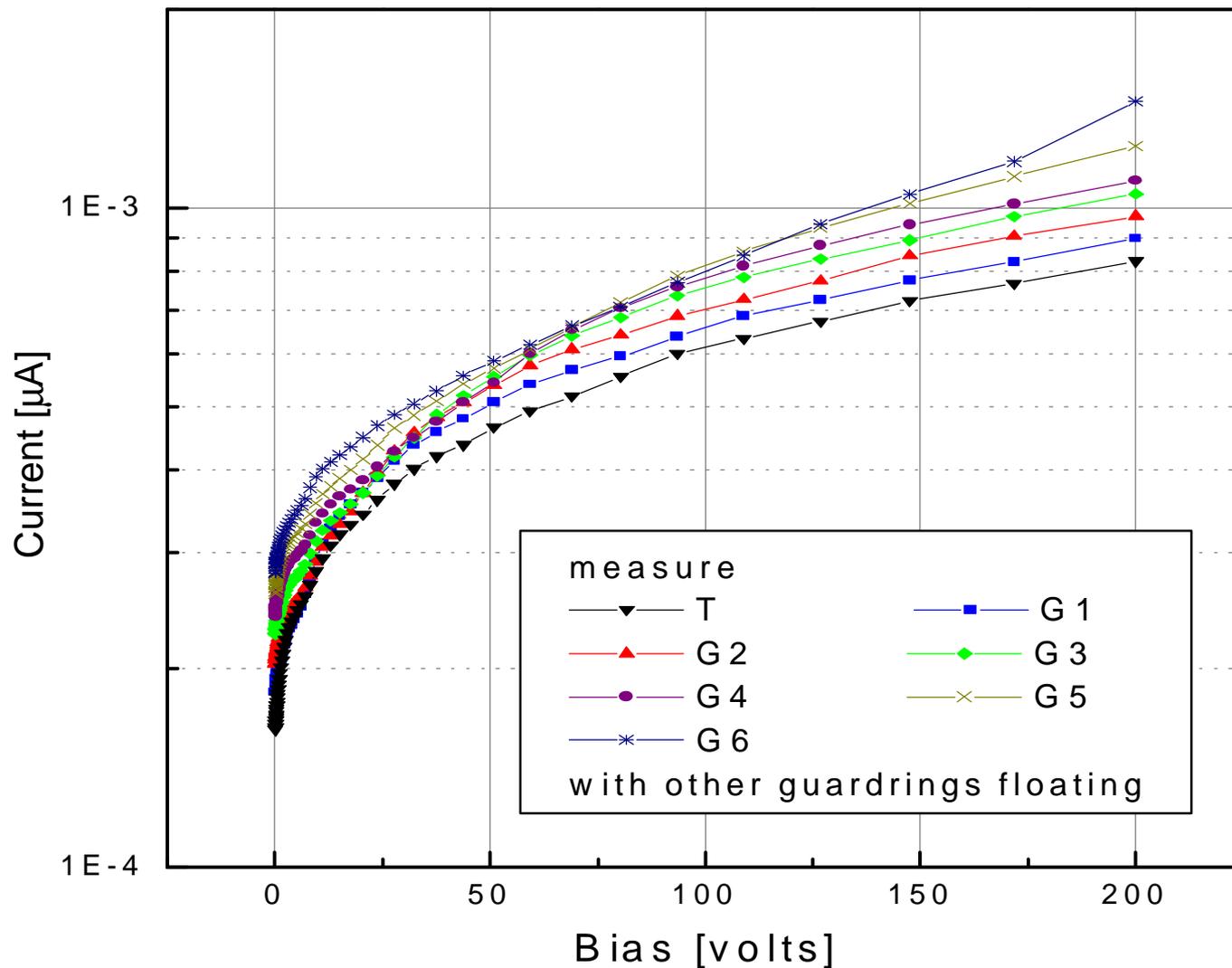
Cutting edge current breakdown (Data)

Measure the test structure and individual guard ring with other guard rings floating

Z. Li et al., IEEE
TNS Vol. 47, No. 3
(2000) p729

Laser cut from
Front side

Cutting distance:
300 μm from G6



Cutting distance $L=300 \mu\text{m}$

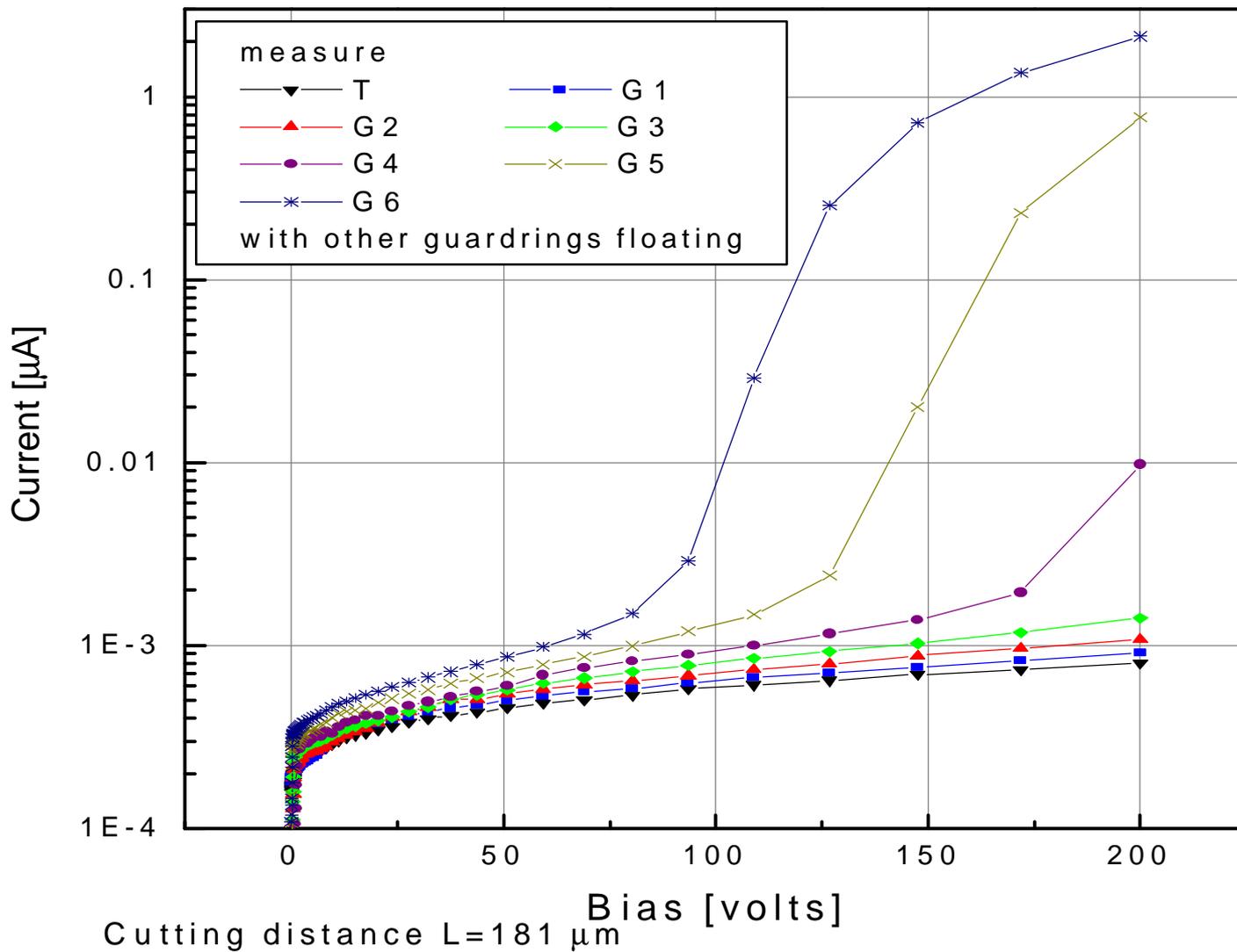
Cutting edge current breakdown (Data)

Measure the test structure and individual guard ring with other guard rings floating

Z. Li et al., IEEE
TNS Vol. 47, No. 3
(2000) p729

Laser cut from
Front side

Cutting distance:
181 μm from G6



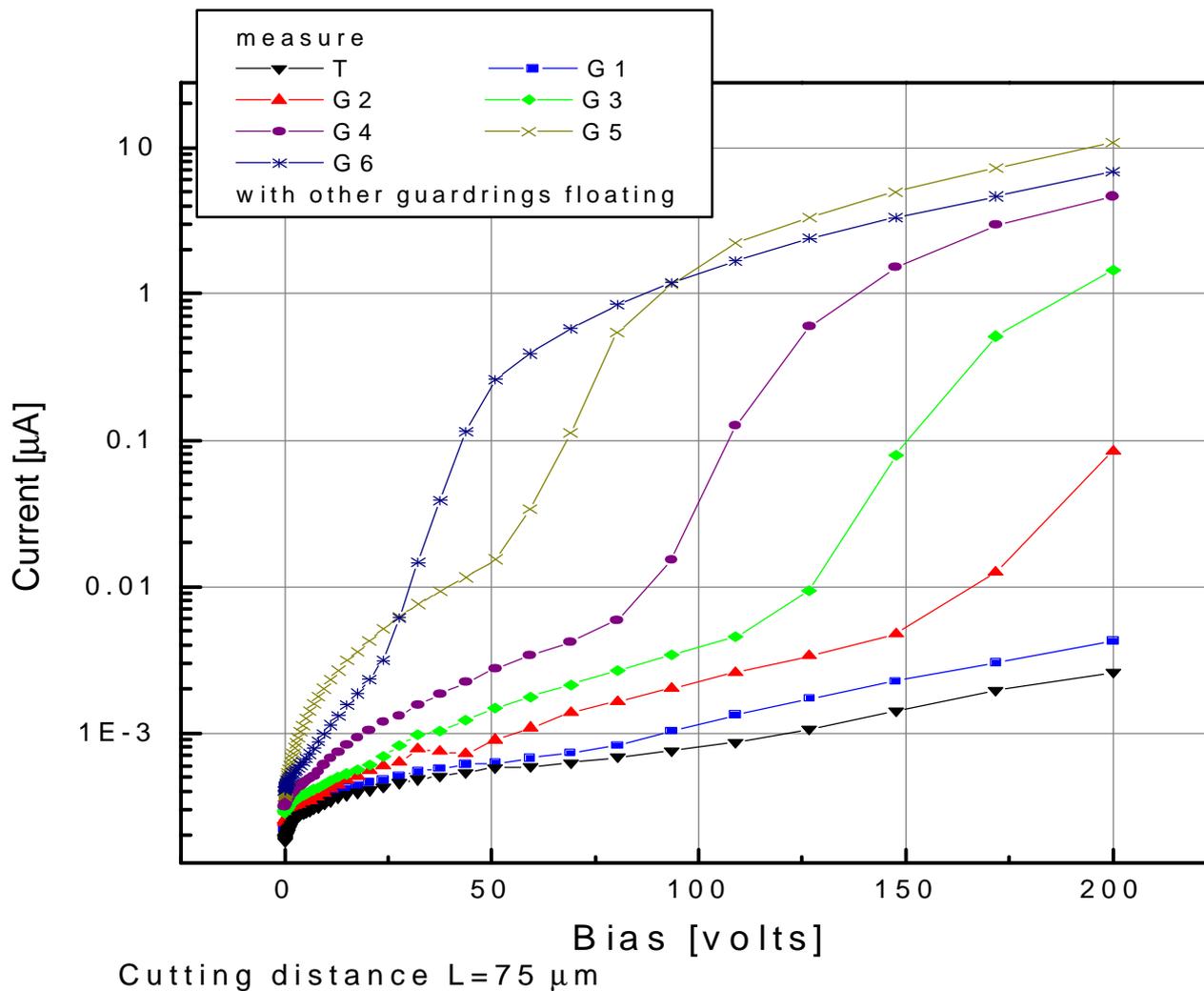
Cutting edge current breakdown (Data)

Measure the test structure and individual guard ring with other guard rings floating

Z. Li et al., IEEE
TNS Vol. 47, No. 3
(2000) p729

Laser cut from
Front side

Cutting distance:
75 μm from G6



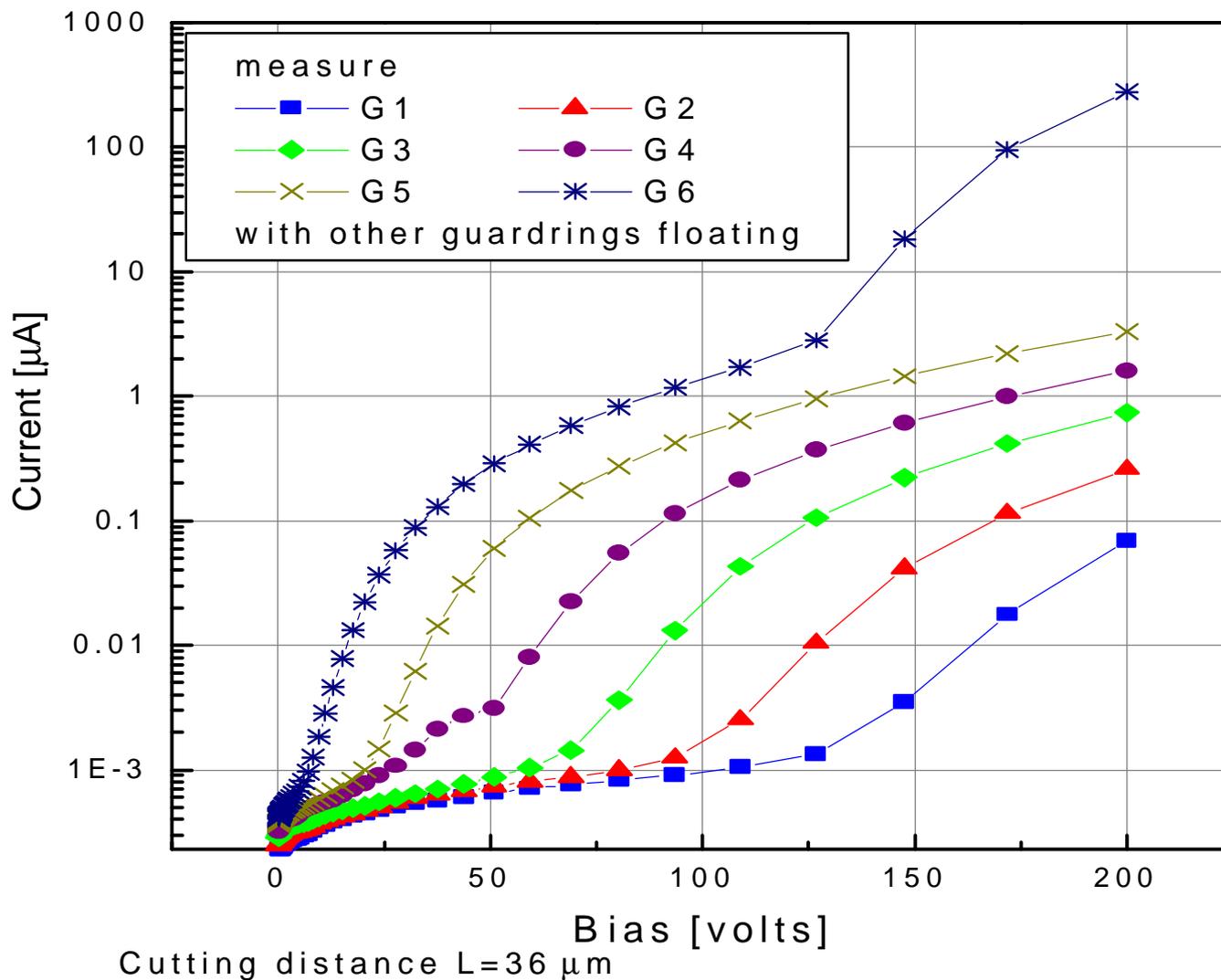
Cutting edge current breakdown (Data)

Measure the test structure and individual guard ring with other guard rings floating

Z. Li et al., IEEE
TNS Vol. 47, No. 3
(2000) p729

Laser cut from
Front side

Cutting distance:
36 μm from G6



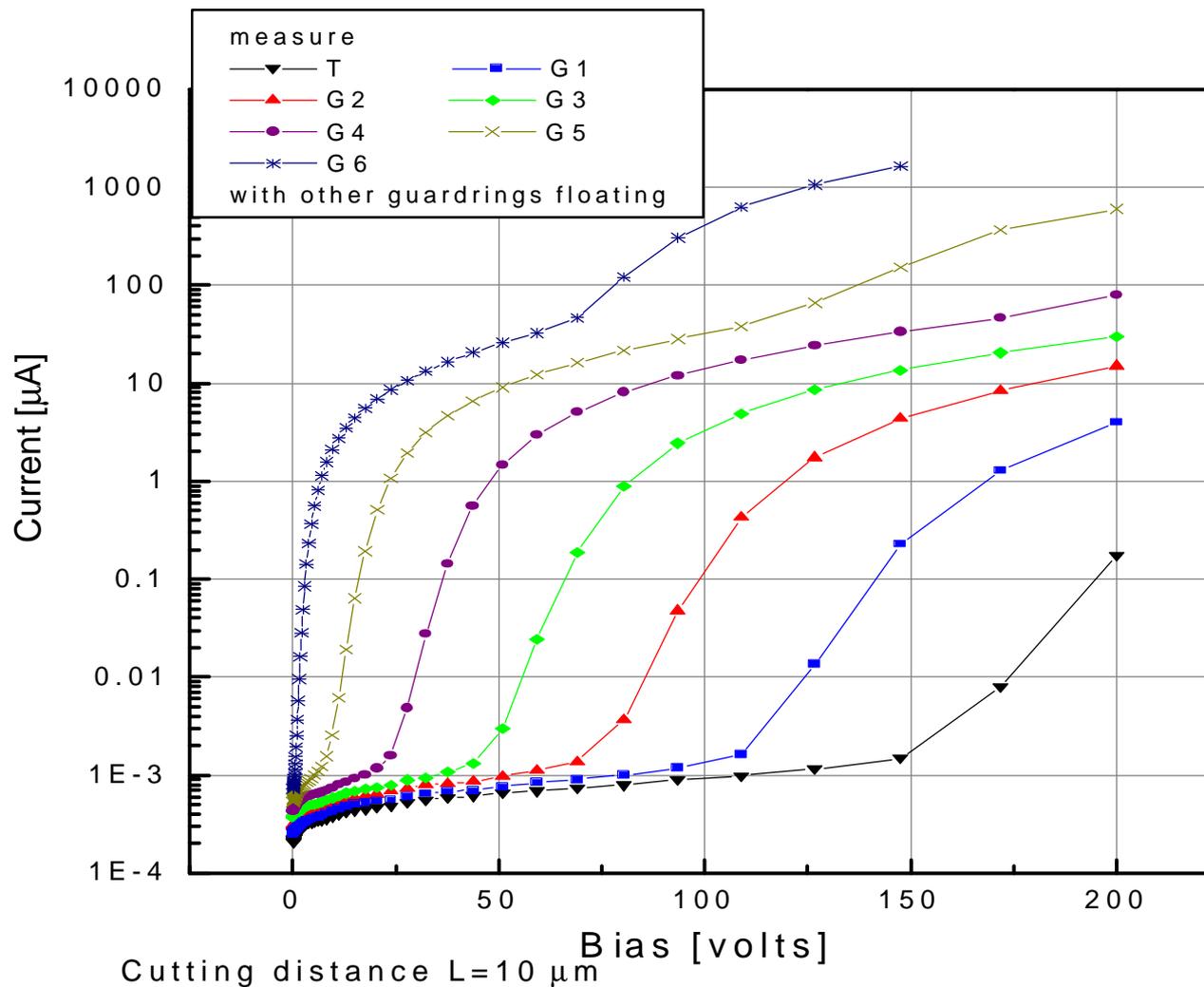
Cutting edge current breakdown (Data)

Measure the test structure and individual guard ring with other guard rings floating

Z. Li et al., IEEE
TNS Vol. 47, No. 3
(2000) p729

Laser cut from
Front side

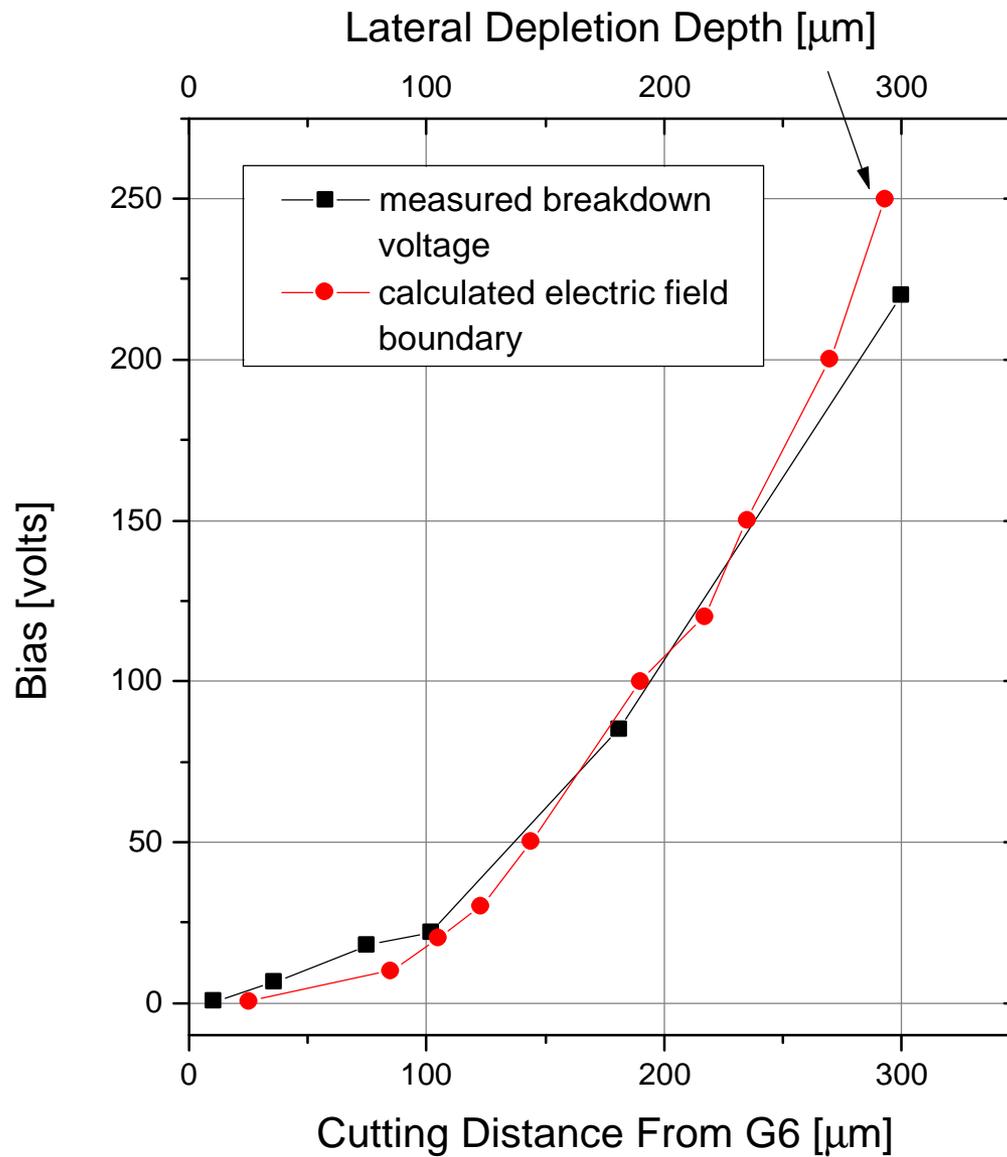
Cutting distance:
10 μm from G6



Correlation between the dependence of simulated lateral depletion depth on bias voltage and cutting edge distance from G6 on the CECB voltage

It is clear that the cutting damage causes breakdown

- 1) Can this damage be kept minimum?
- 2) Can this damage be passivated?



Motivation

- **Detectors with little and no dead edge space area are highly desired in many experiments**
- **This is a project for CERN RD39/TOTEM**
 - **Roman pot detector**
 - **Two halves of the Si detectors come together with the center area a circular hole**
 - **Minimum or no dead space highly desired near the center**
 - **“Edgeless” detector possible?**

Sample list

- **Materials and sample sizes:**

- N-type 4-6 k W-cm, 400 mm thick
- Area before cut 0.25 cm² (0.5x0.5), area after cut 0.228 cm² (0.5x0.455)

1st batch

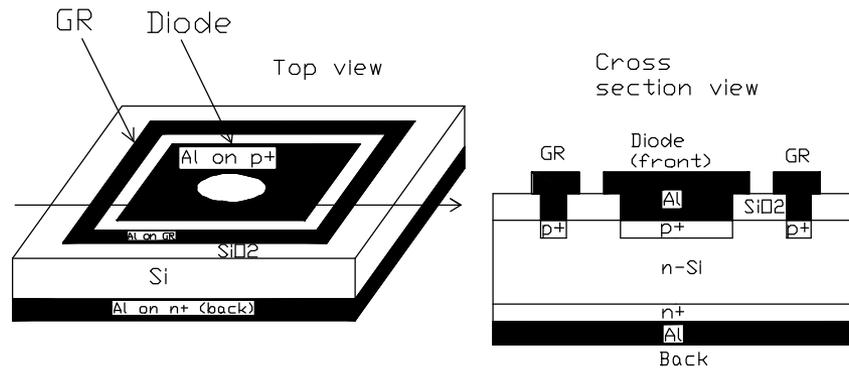
Sample #	Sample type	Dicing method	Dicing side
799-22	p ⁺ /n/n ⁺	Scribing	back
799-23	p ⁺ /n/n ⁺	Laser cut	back
799-26	p ⁺ /n/n ⁺	Laser cut	front

*2nd batch,
edge etched after cut
(HNO₃:HF=3:1)*

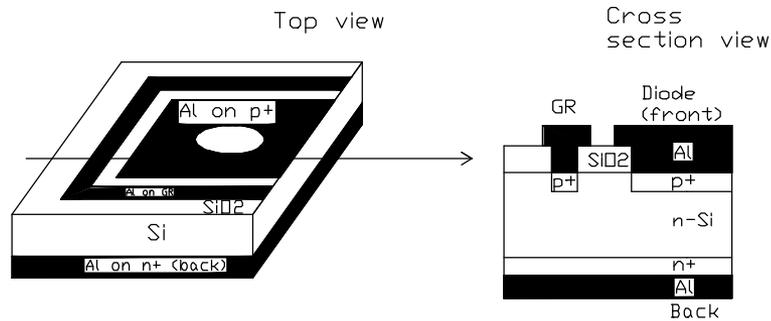
Sample #	Sample type	Dicing method	Dicing side
798-9	p ⁺ /n/n ⁺	Laser cut	front
798-21	p ⁺ /n/n ⁺	Laser cut	back

Illustration of diced diode

Before cutting

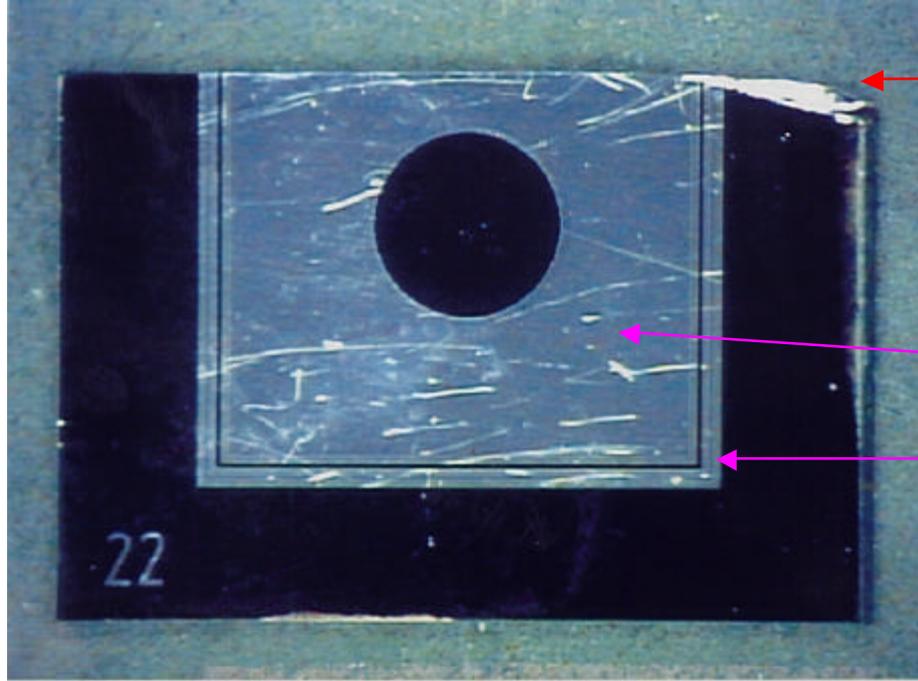


After cutting



*Scribing from
back side*

Front
view



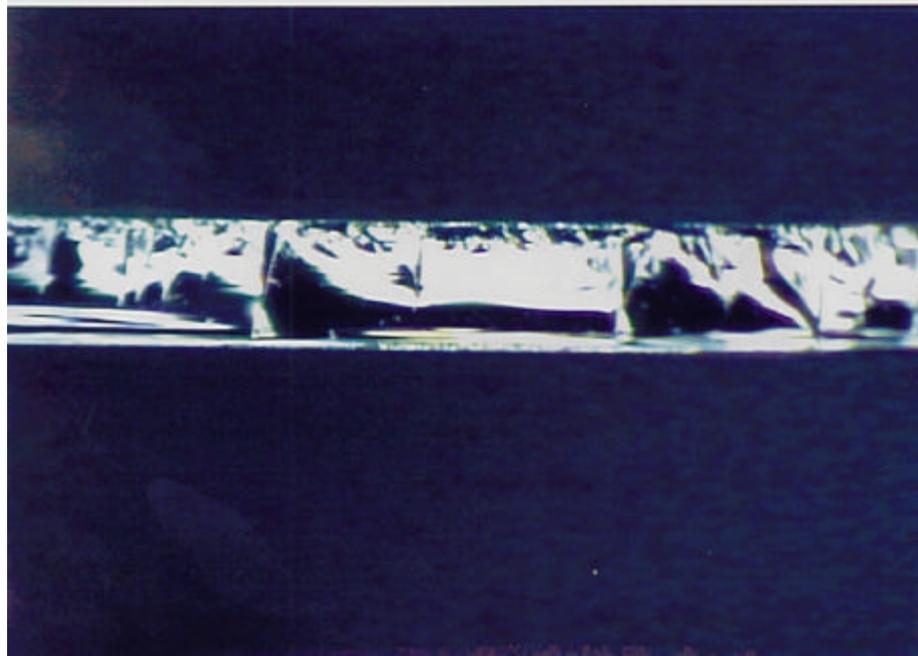
*Cutting
edge*

Diode

GR

BNL WAFFER SVT

Cross
section

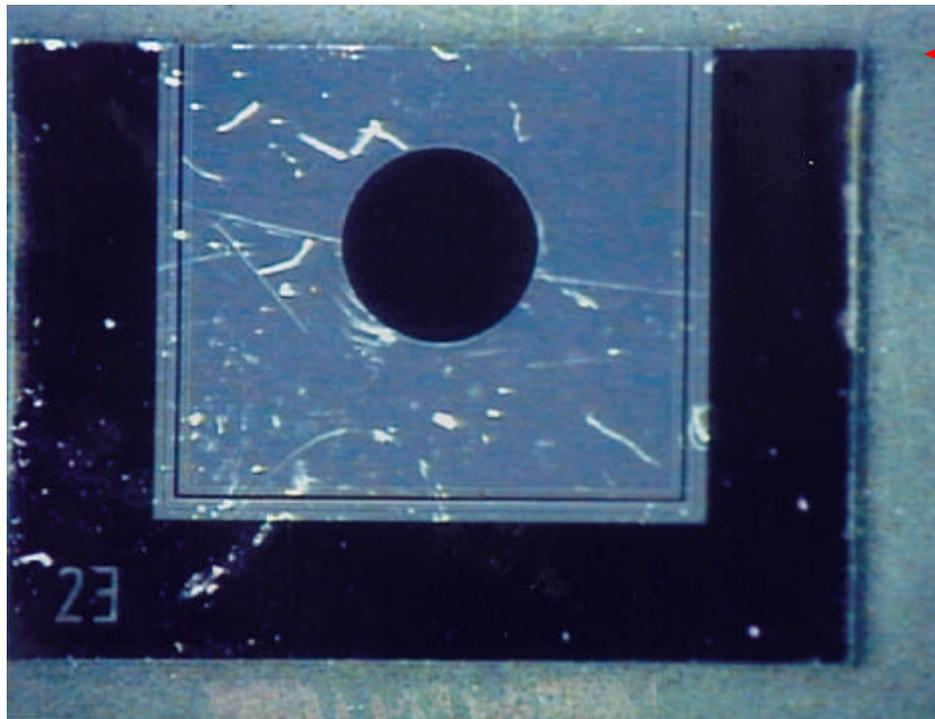


*Back (n⁺)
(scribing
Edge)*

*Front (p⁺)
junction side*

*Laser cut
from
back side*

Front
view



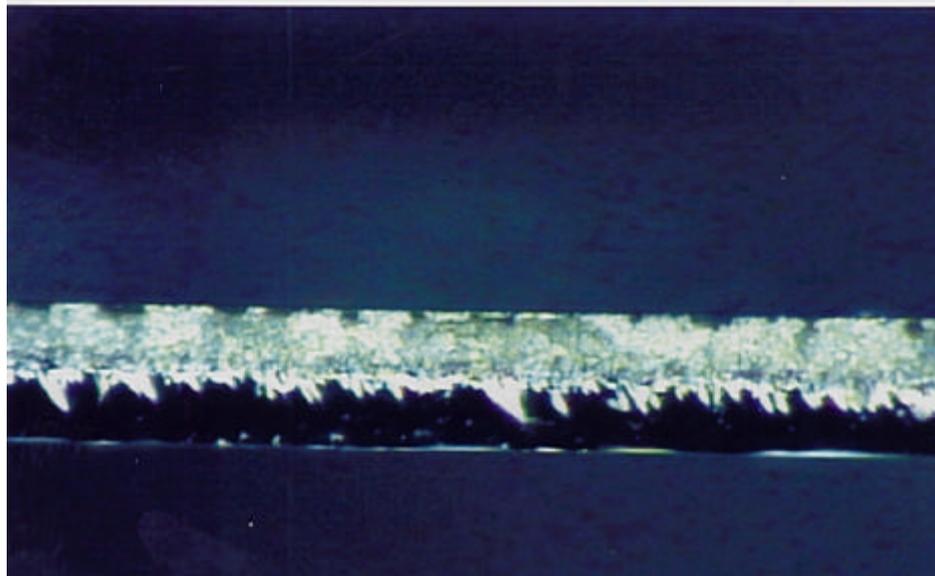
NL WAFFER SVT

*Cutting
edge*



Cross
section

Less damage
on the
junction side



*Back (n^+)
(cutting
Edge)*

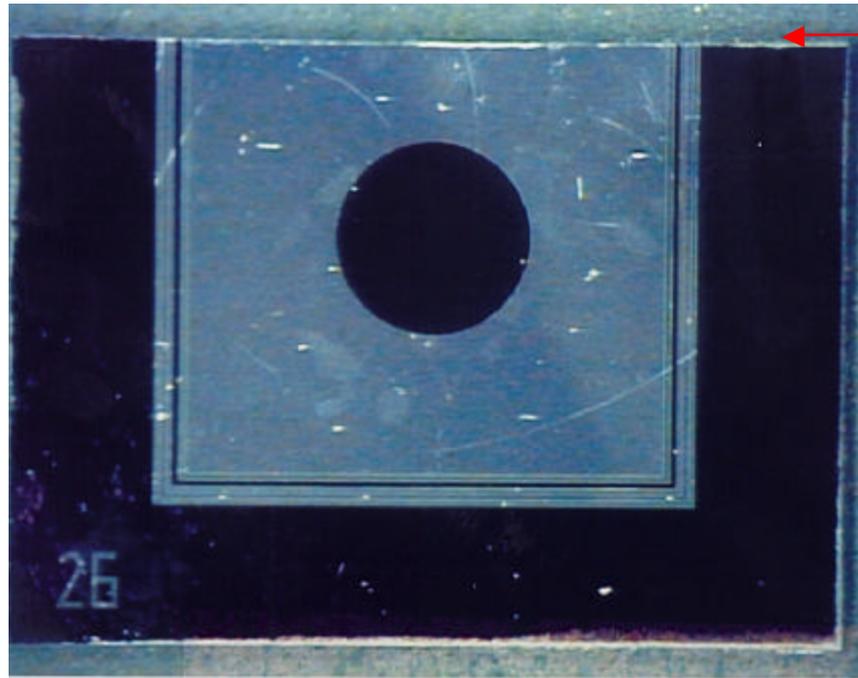


Front (p^+)



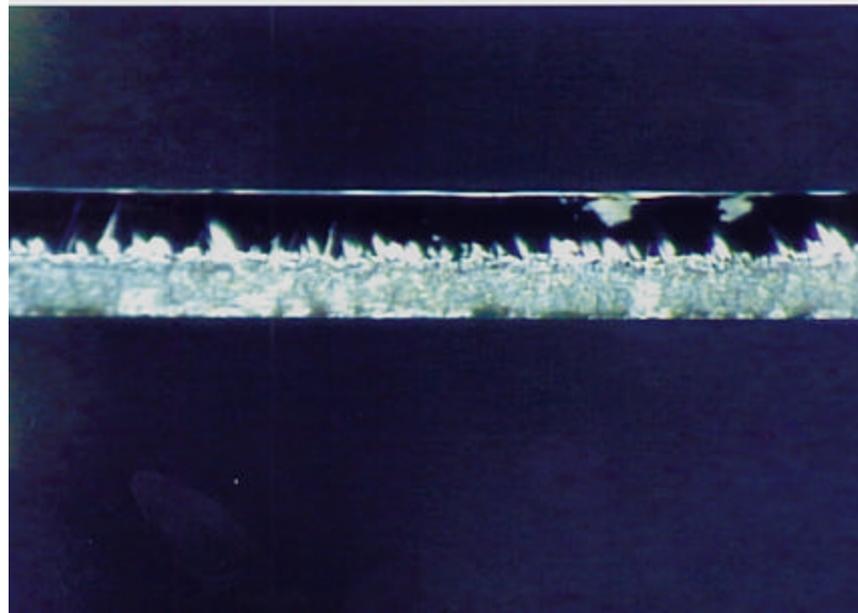
*Laser cut
from
front side*

Front
view



*Cutting
edge*

Cross
section



Back (n⁺)

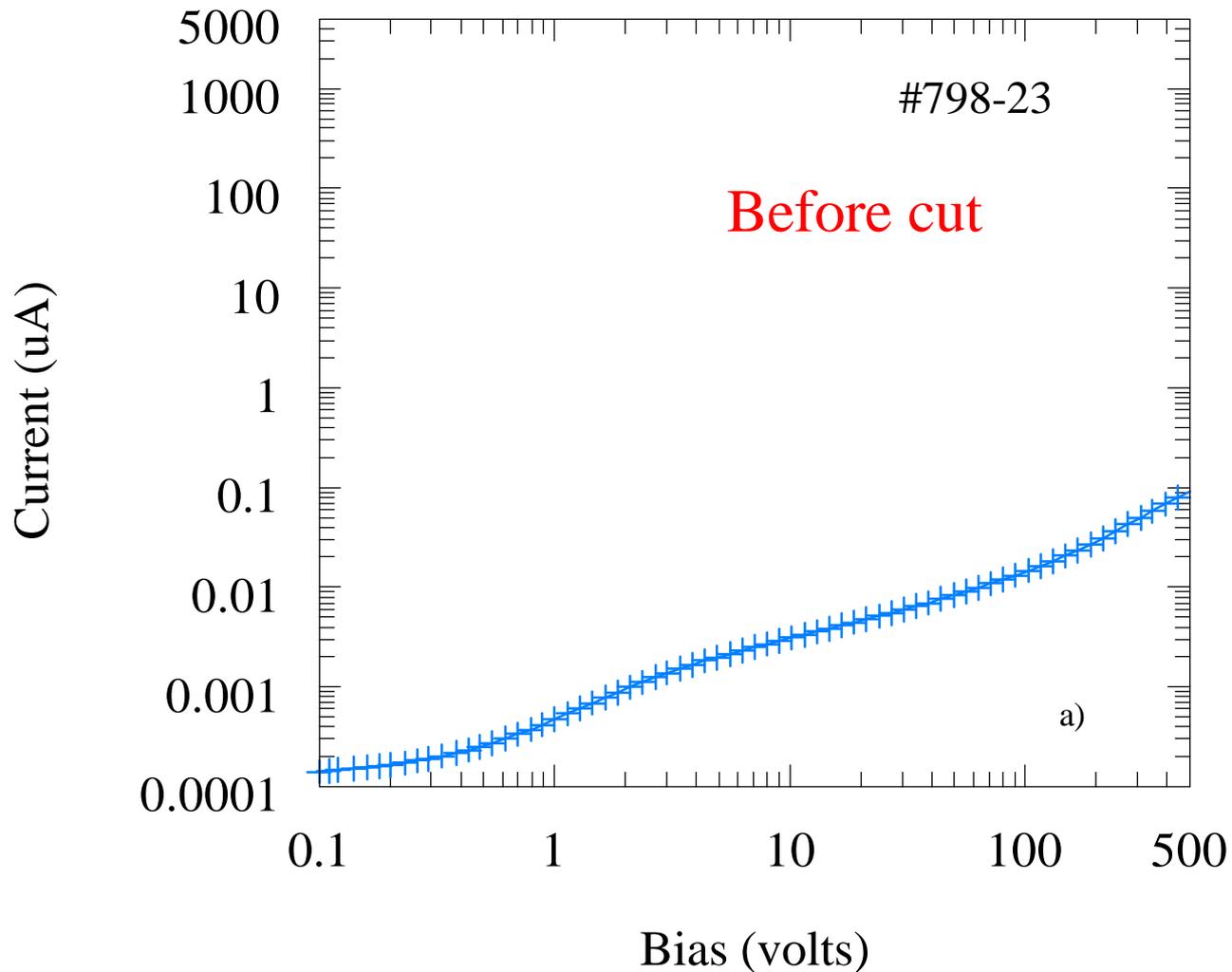
*Front (p⁺)
(Cutting
Edge)*

*More damage
on the junction
side*

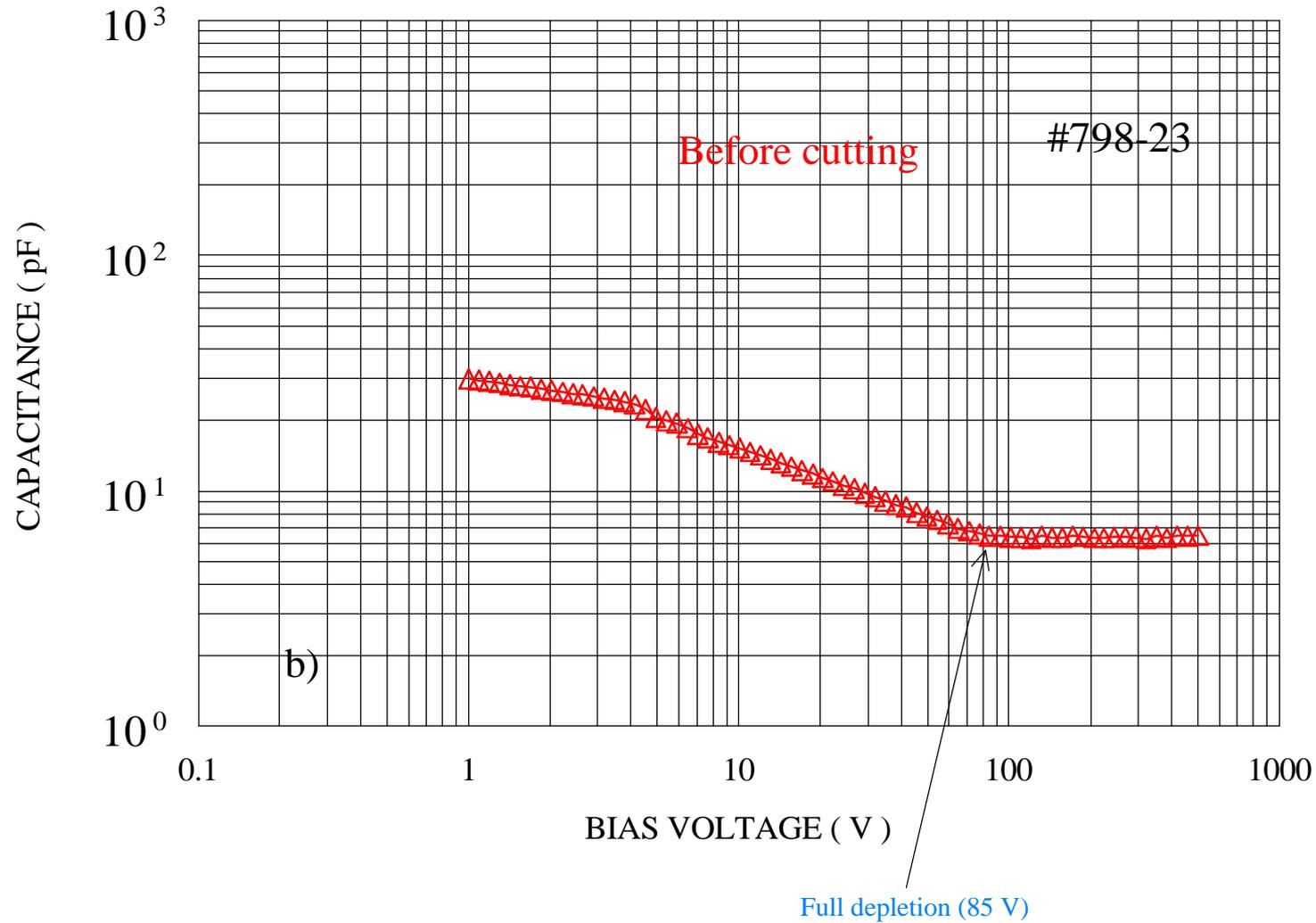
Laser wafer dicing



I-V characteristic before cutting

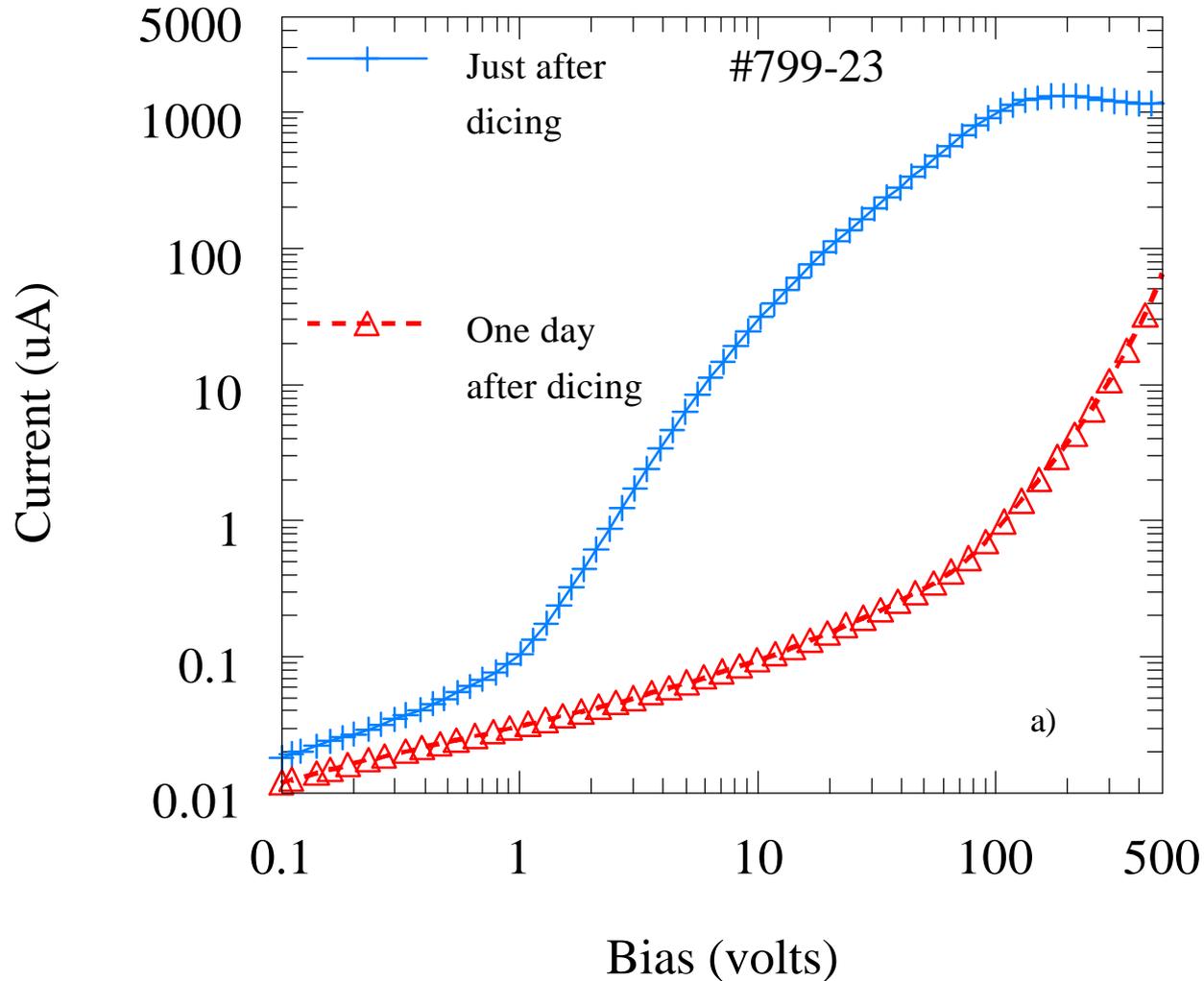


C-V characteristic before cutting



I-V characteristics after cutting

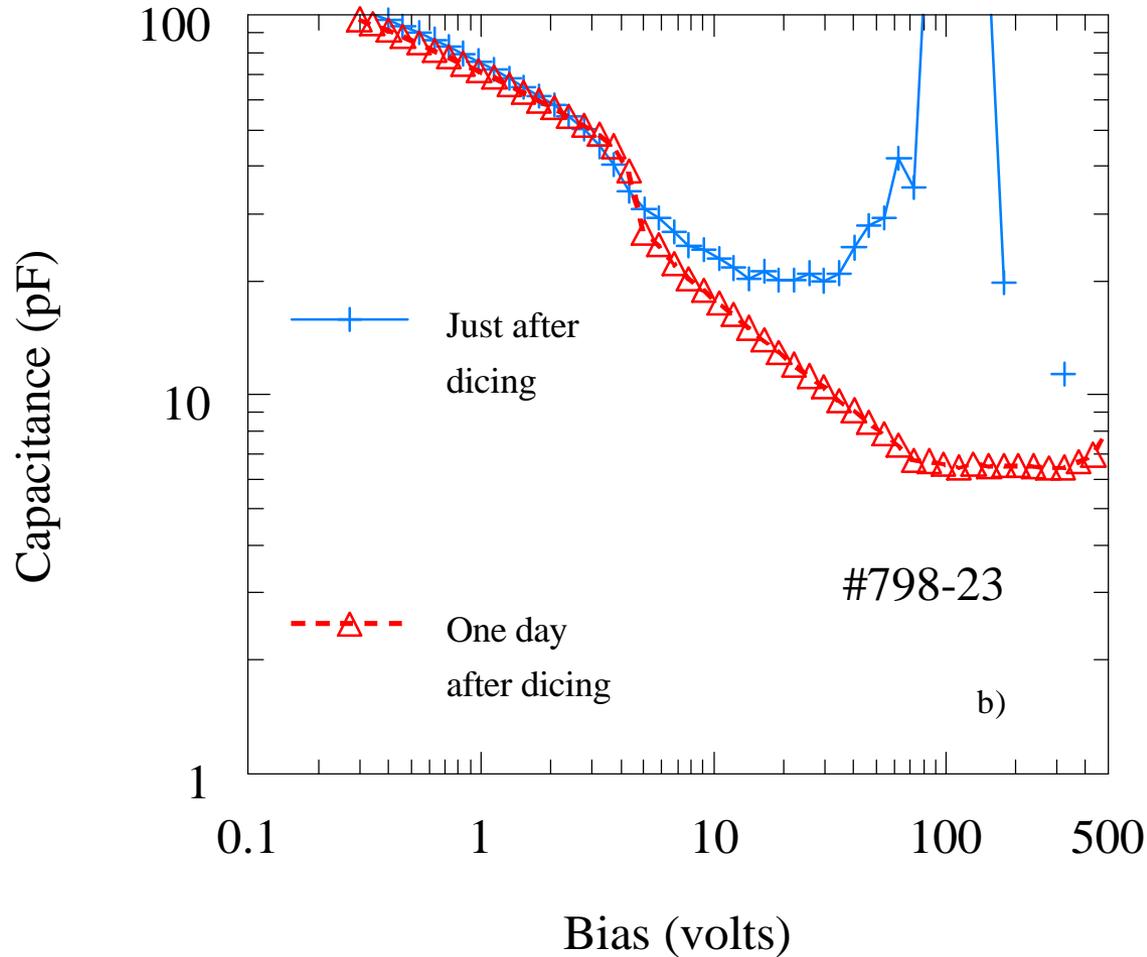
Laser cut from the **back** side



Big current recovery due to surface passivation in RT aging in air

C-V characteristics after cutting

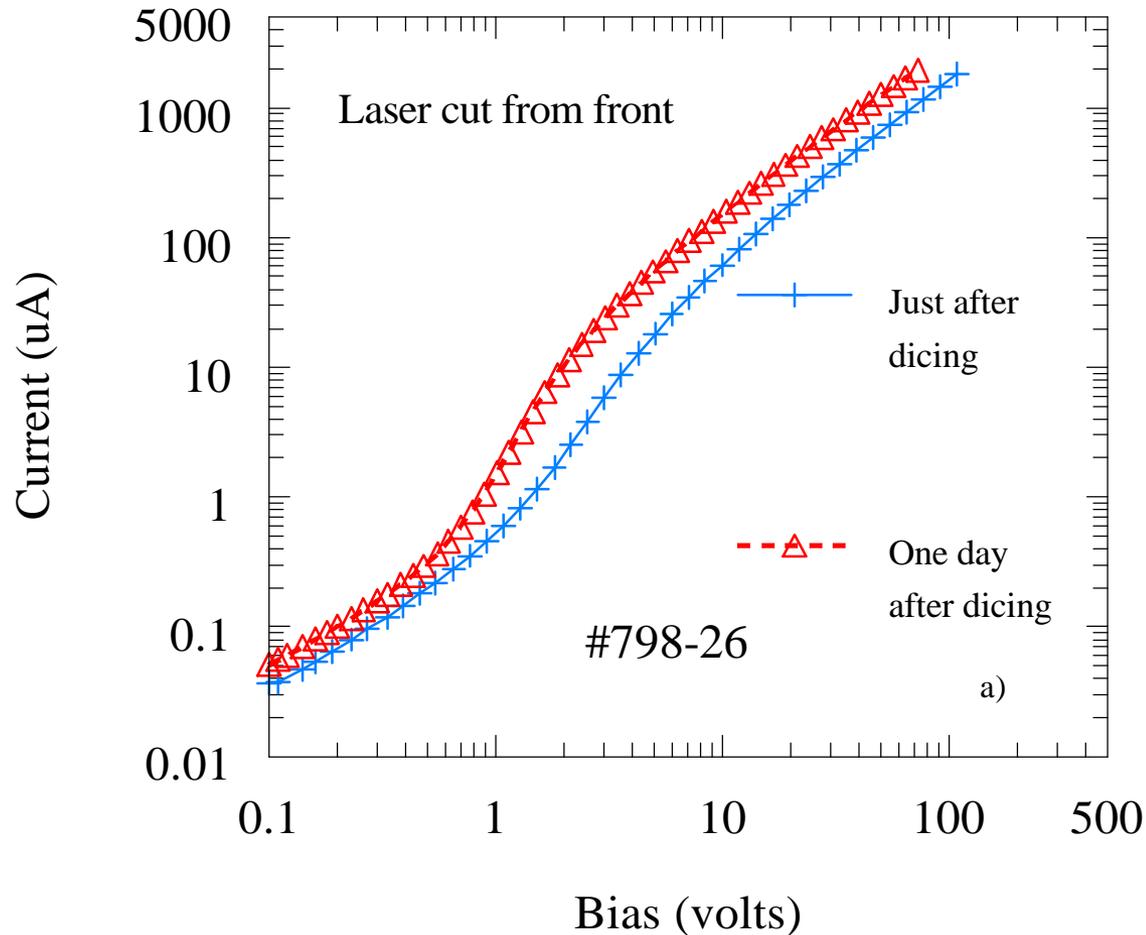
Laser cut from the **back** side



Total C-V recovery

I-V characteristics after cutting

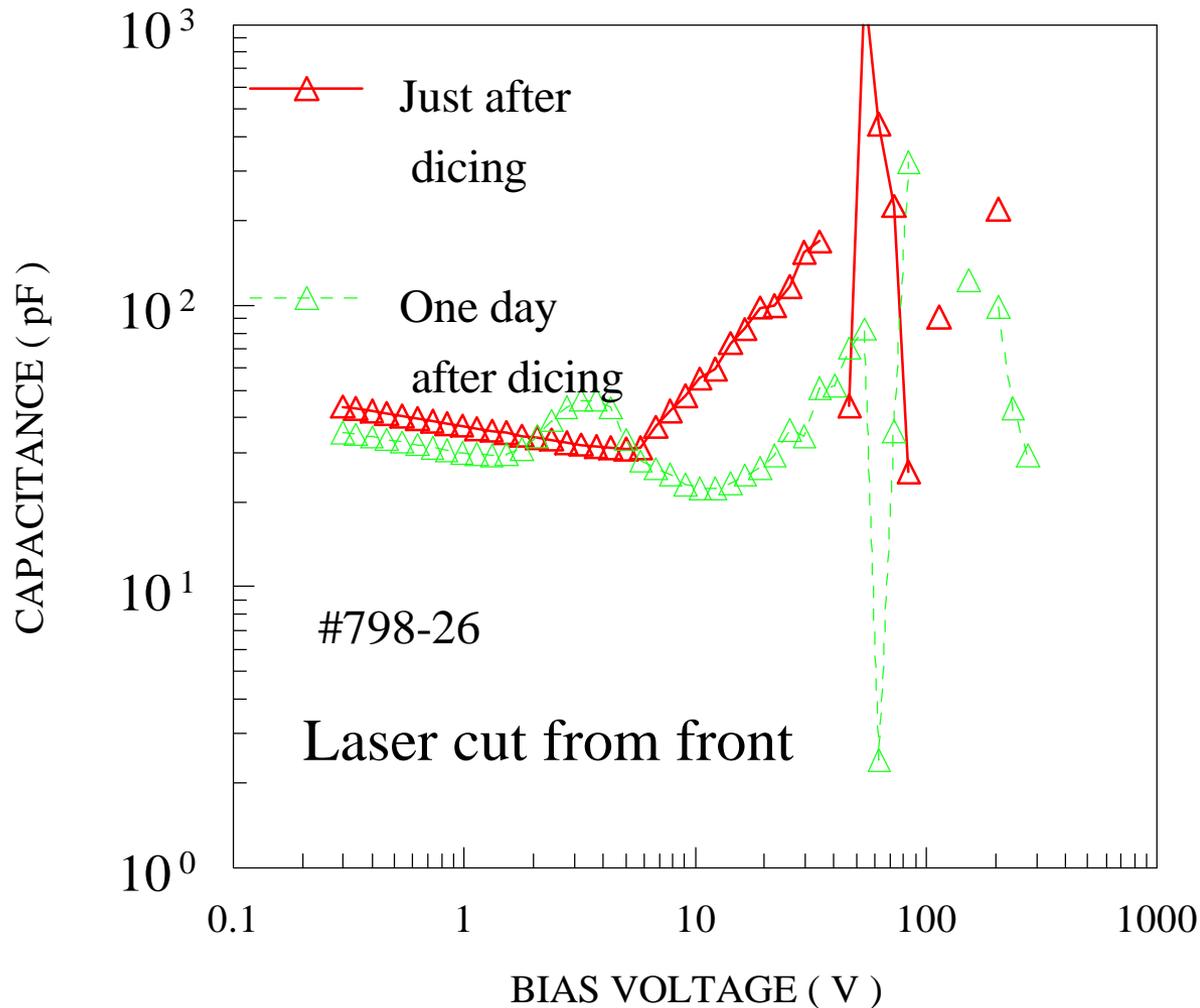
Laser cut from the **front** side



Very little current recovery: no surface passivation in RT aging for the more damaging cutting side (junction side)

C-V characteristics after cutting

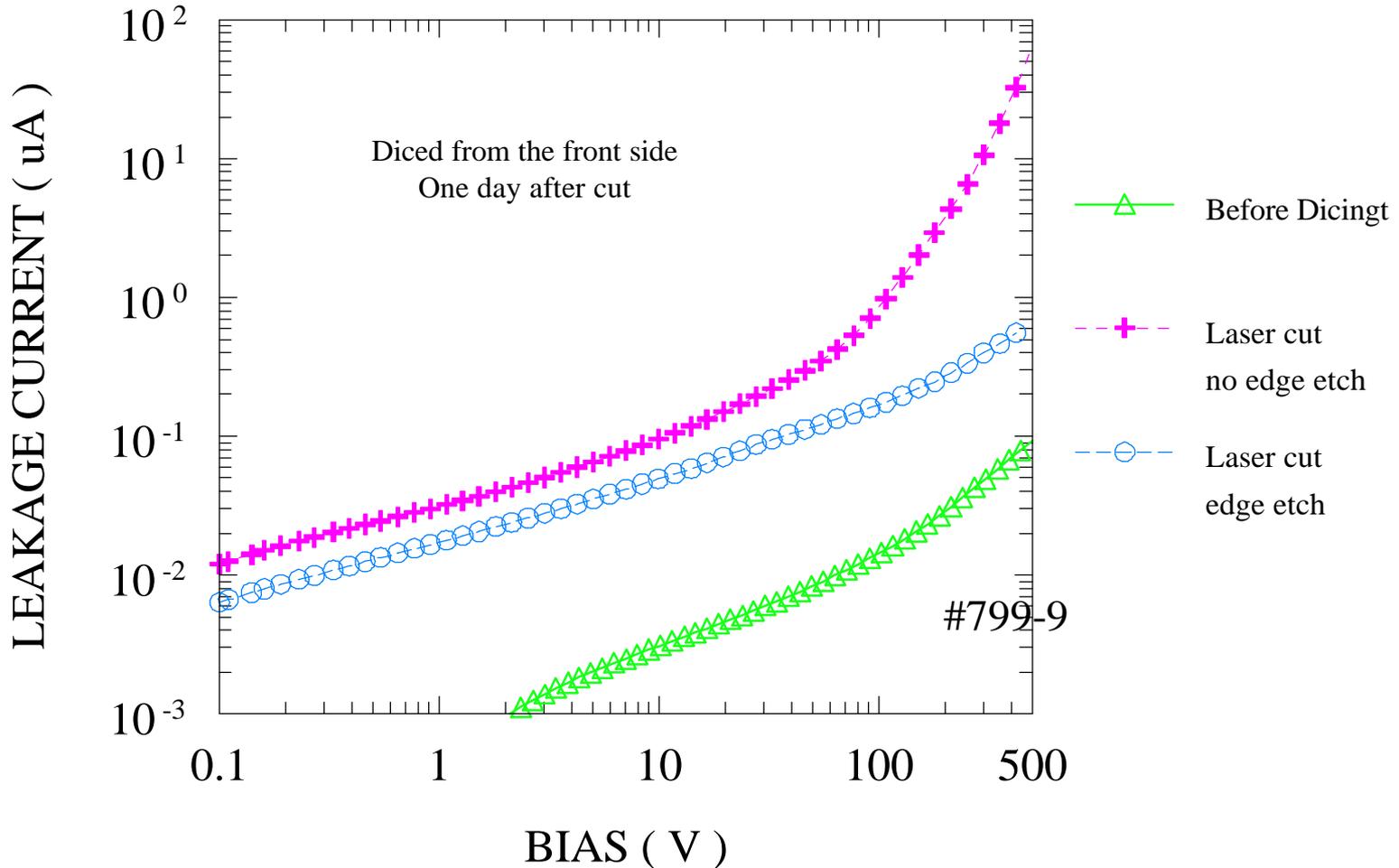
Laser cut from the **front** side



Very little C-V recovery

I-V characteristics after cutting

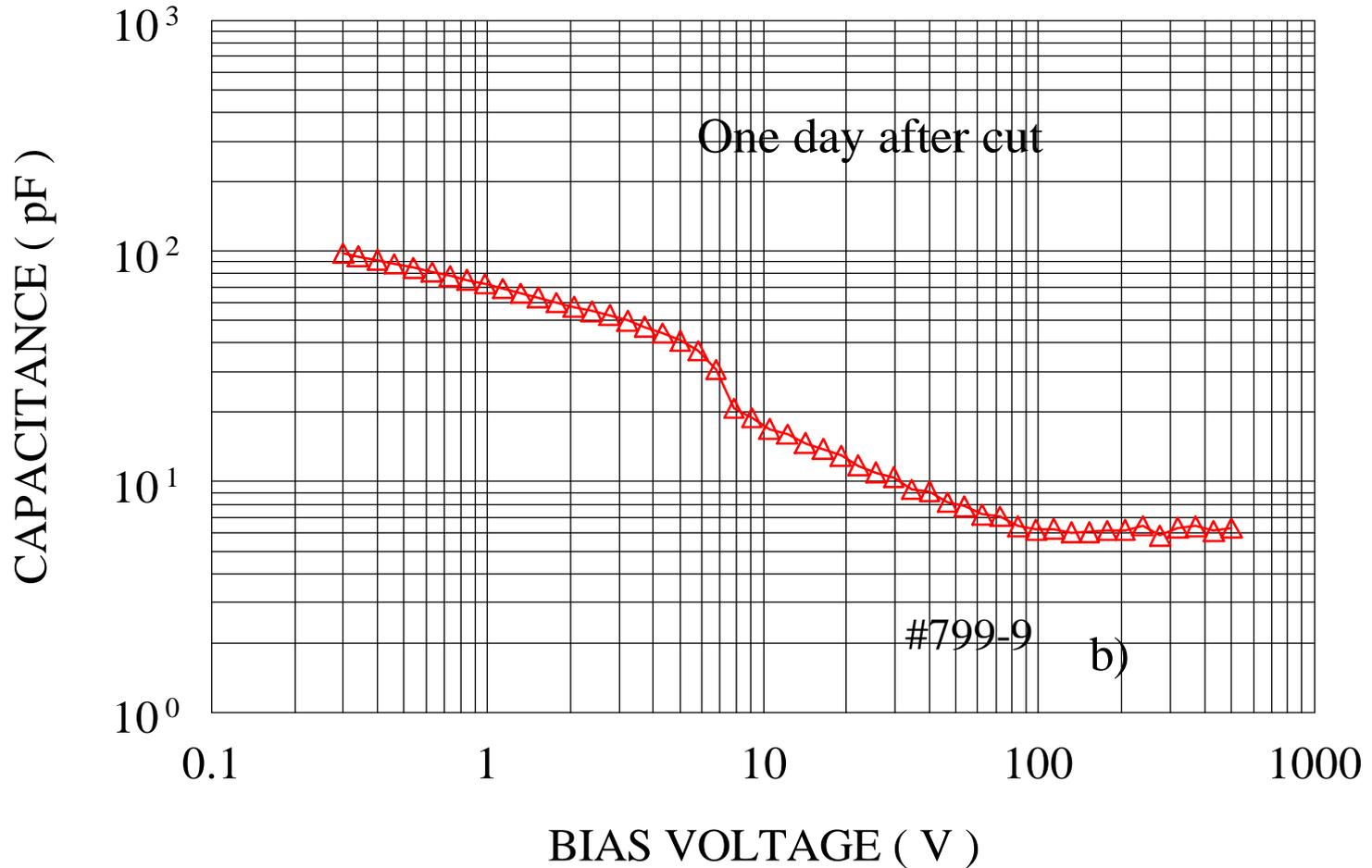
Laser cut from the front side and edge treatment



Even much lower current: chemical removal of the cutting damage

C-V characteristics after cutting

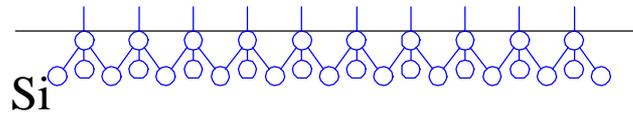
Laser cut from the front side and edge treatment



Normal C-V behavior

Model for Damage Passivation

Dangling bonds

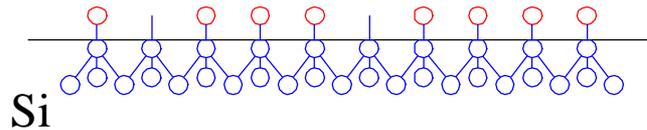


Clean break-off
edge

RT aging



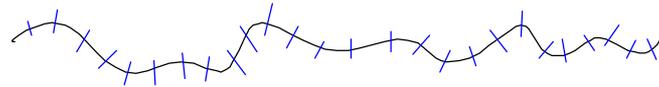
○ oxygen



Surface states
passivated

Model for Damage Passivation

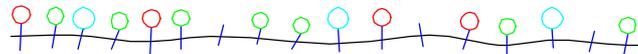
Much higher
Dangling bond concentration



Laser cut surface
rough surface

Chemical
etching

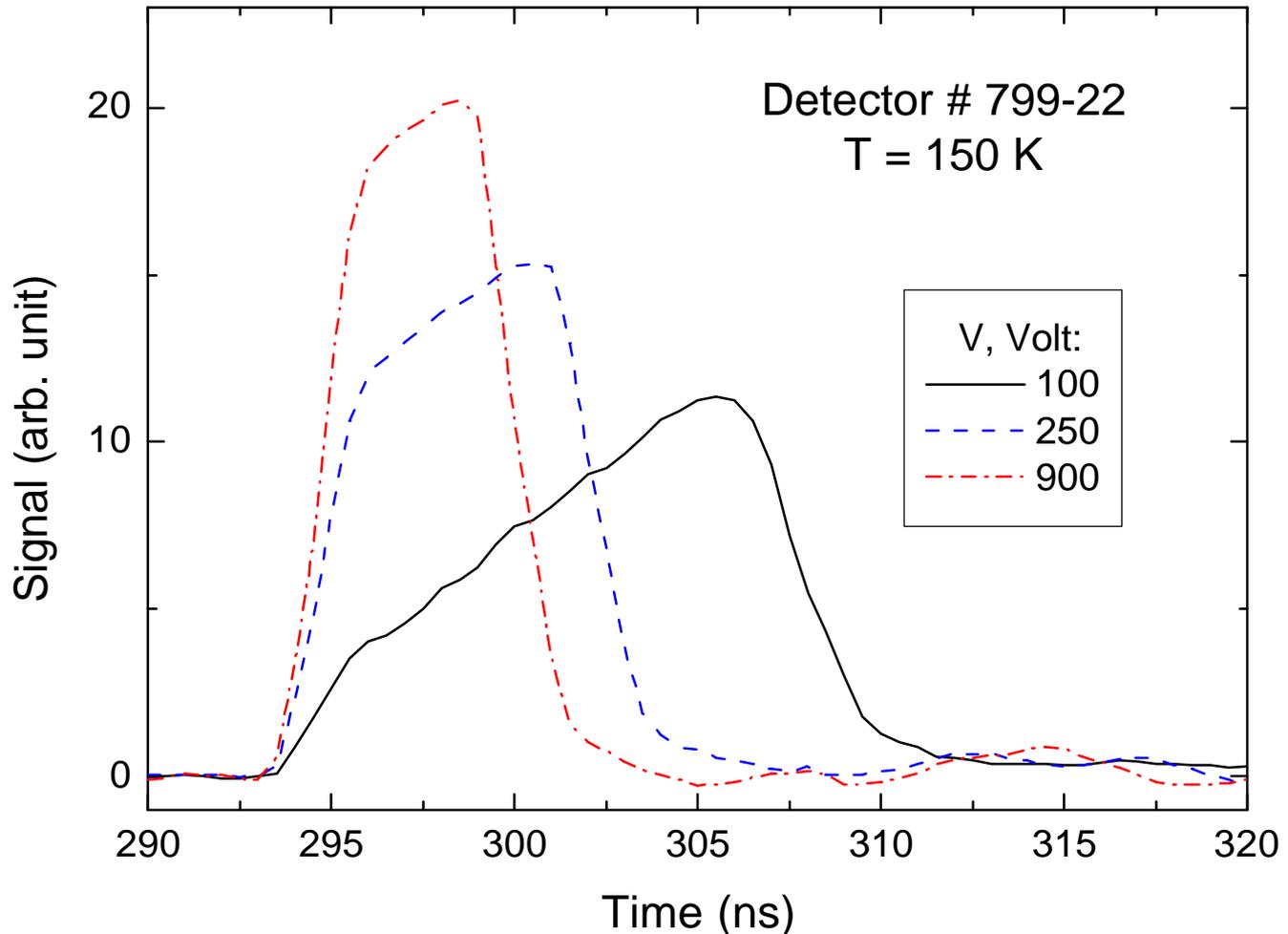
○ oxygen
○ OH
○ H



Smother surface
Surface states
passivated

TCT characteristics after cutting

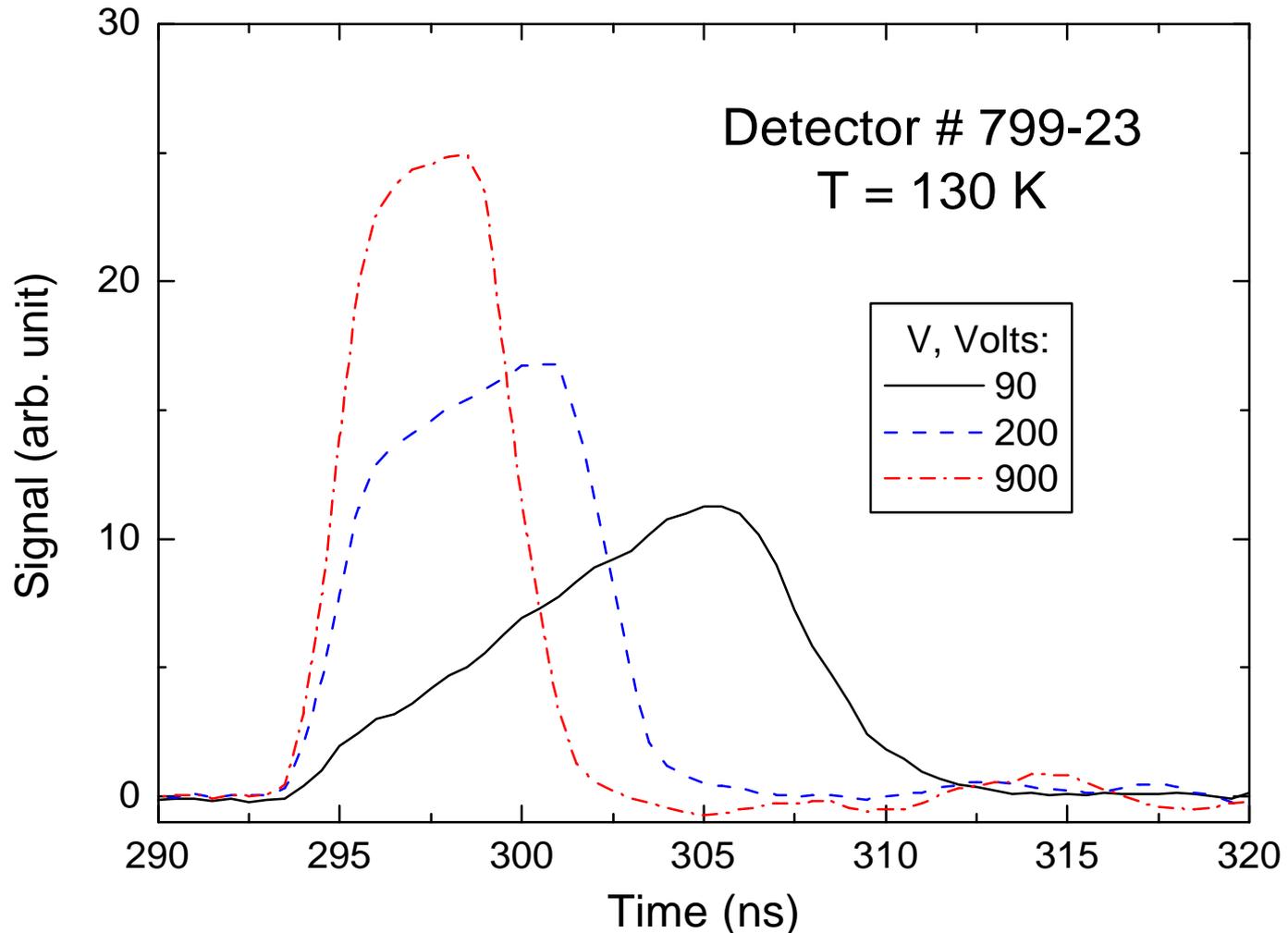
Scribed from the **back** side



Hole current shapes: red laser illumination on the back side

TCT characteristics after cutting

Laser cut from the **back** side

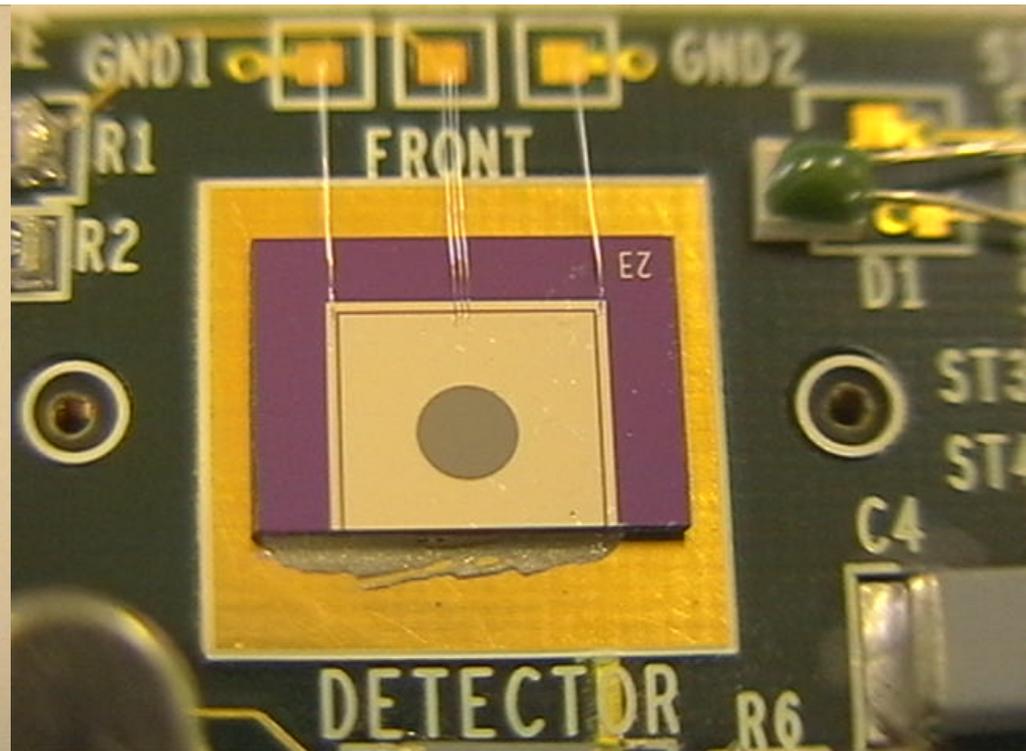
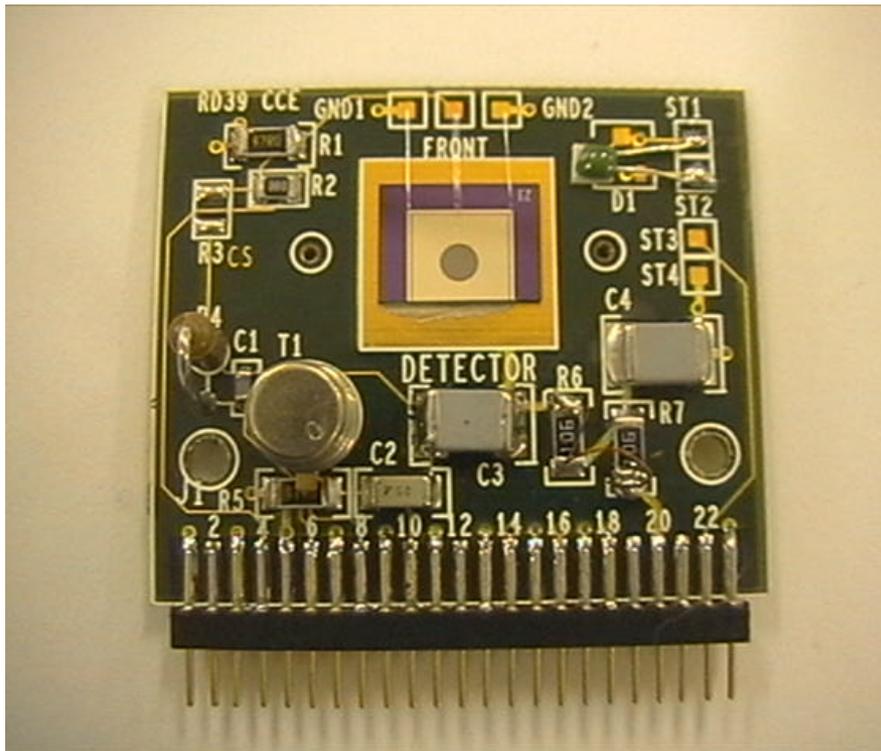


Hole current shapes: red laser illumination on the back side

Low temp CCE measurements

CCE measurements has been done at LIP, Portugal
With a 0.1 mCi ^{90}Sr beta source (MIP source)

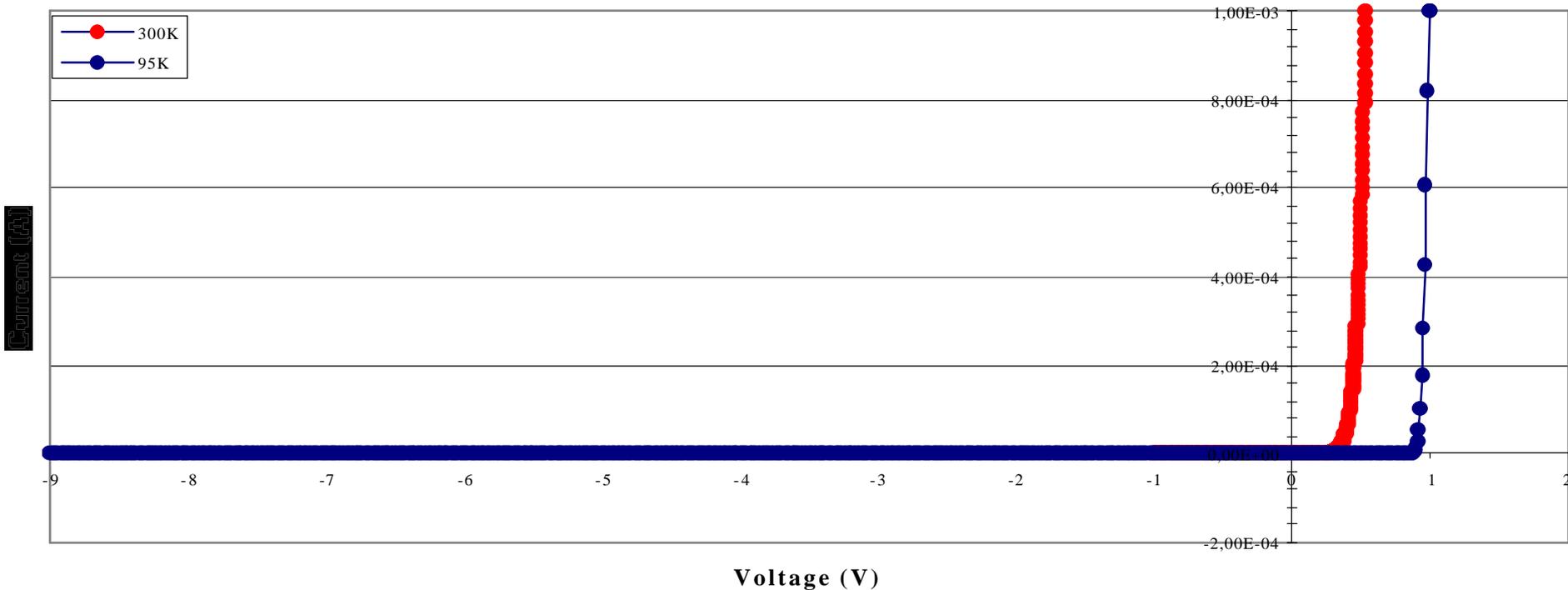
Laser cut from the **back** side



Low temp CCE measurements

Laser cut from the **back** side

I-V Detector 799-23

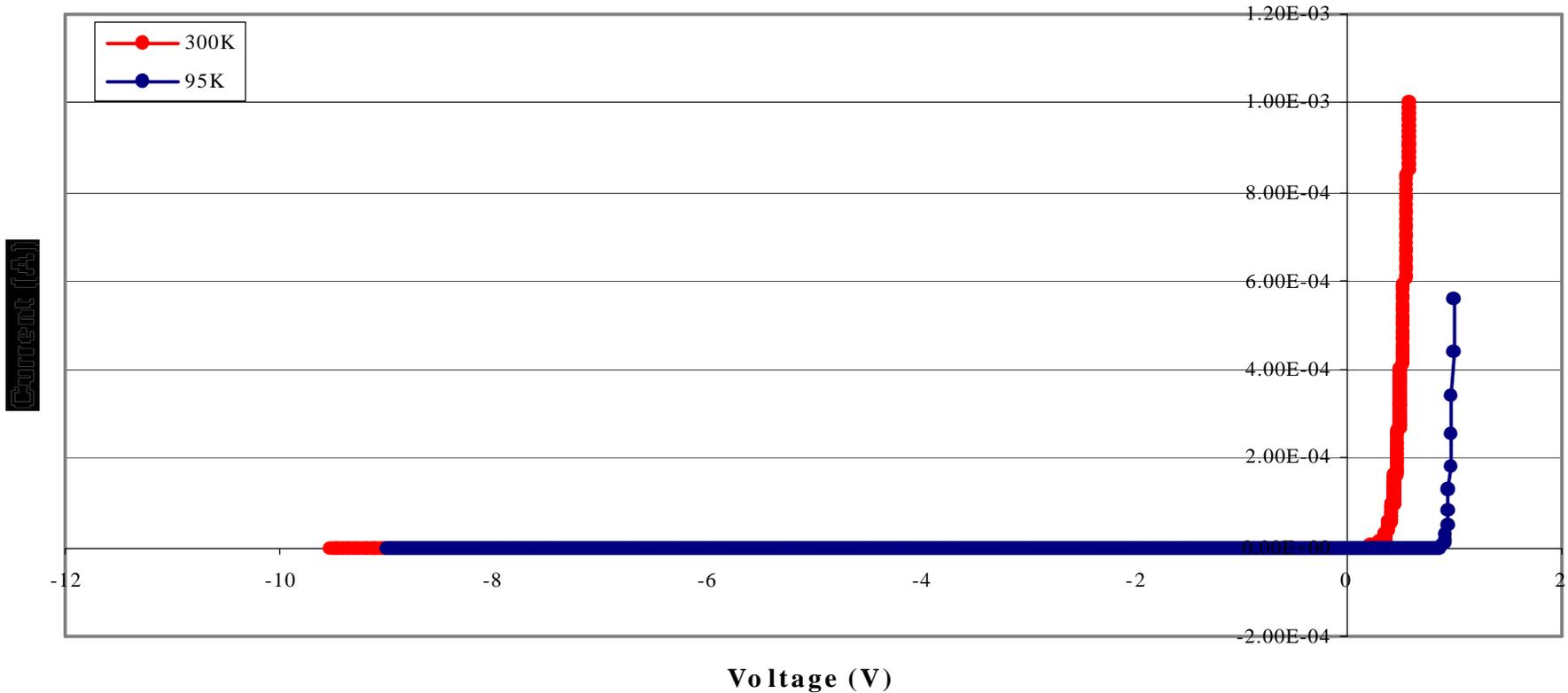


This detector reaches 100% CCE at 270 K and 50V reverse bias !!!
(preliminary)

Low temp CCE measurements

Scribed from the **back** side

I-V Detector 799-22

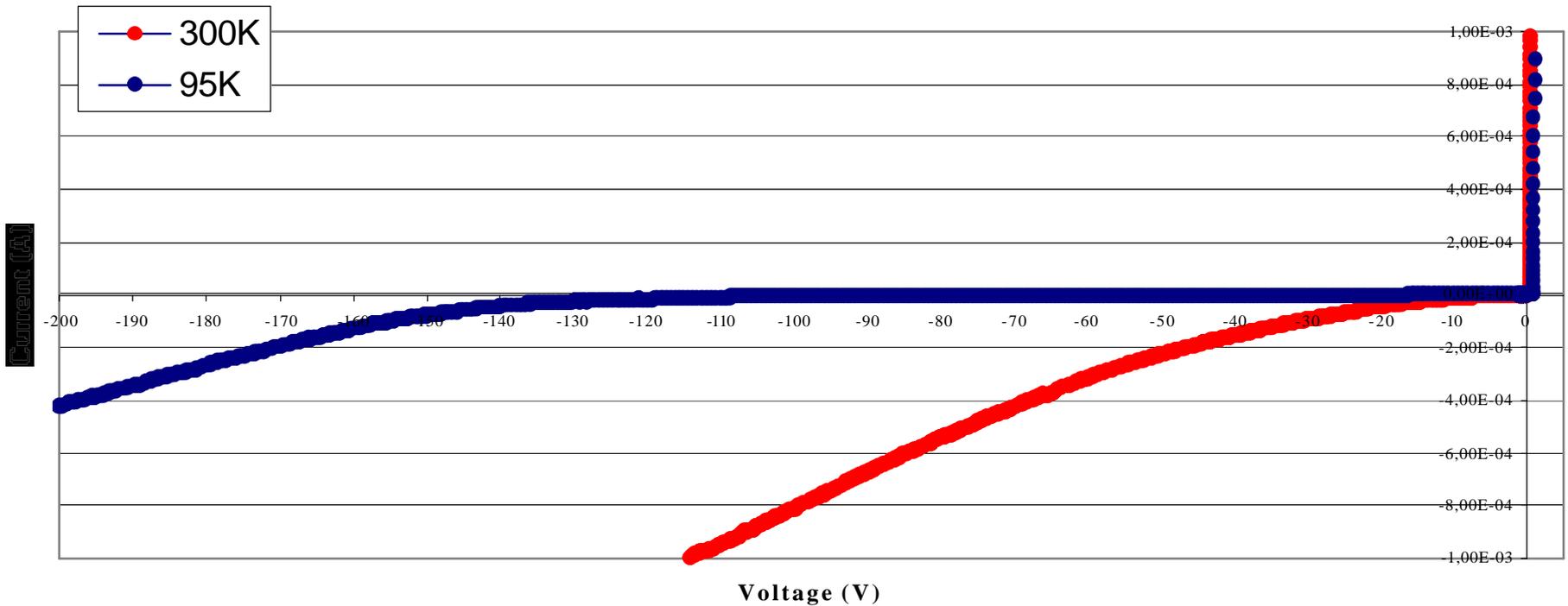


This detector reaches 100% CCE at 270 K and 100V reverse bias !!!
(preliminary)

Low temp CCE measurements

Laser cut from the front side

I - V De t e c t o r 7 9 9 - 2 6



(preliminary)

This detector reaches only 28.5% CCE at 110 K and 100V reverse bias
!!! (due to high leakage current, voltage drop on bias resistor (20 MΩ))

Summary

- Laser cut or scribing of $p^+/n/n^+$ Si detectors all the way into the p^+ implant (edgeless detector) are possible if cut from the back side
- Low leakage and no breakdown of current up to 500 volts possible if the cutting edge is RT aged.
- Chemical edge treatment can also removed most of cutting damage
- The remaining leakage current is dominated by edge/surface current
- The charge collection properties are not affected by the dicing with the techniques and/or treatments described in this work