Fabrication of 3D detectors at The Detector Development Group of The University of Glasgow

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Contents

- Simulation
- Methods to form holes
  - Laser
  - RIE
  - Photoelectrochemical etching

MEDICI 3-D detector model

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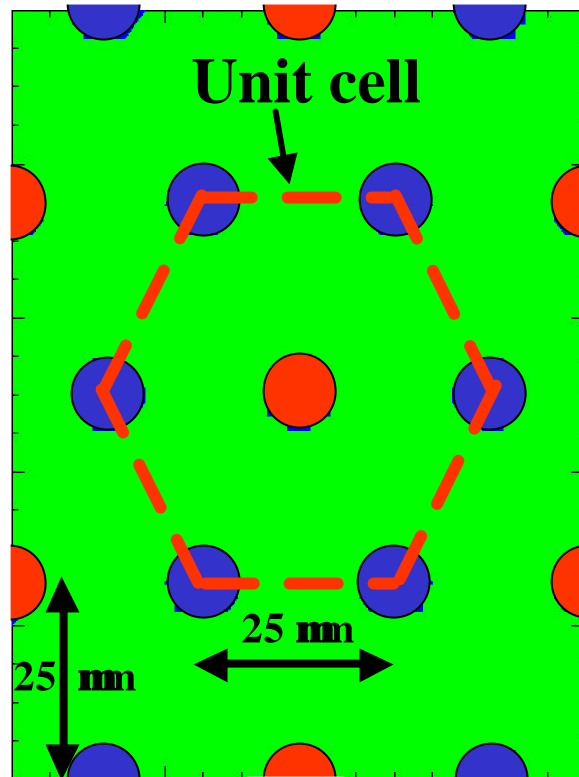

Biased electrode

Grounded electrode

- **n-type GaAs $N_{eff} = 1x10^{14}$ atoms/cm^3**
- **Schottky contacts**
  - barrier height ~ 0.8eV
- **Lifetime of carriers**
  altered to take account of the trapping and de-trapping times
- **Simulation of dry-etch sidewall damage by introduction of a defect concentration around electrodes**

Potential distribution

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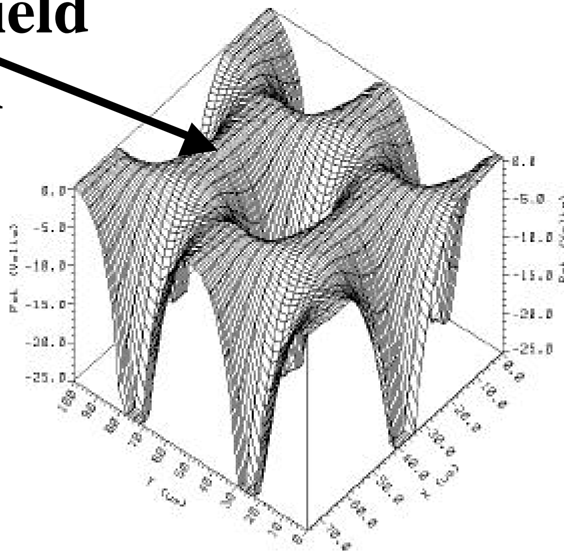
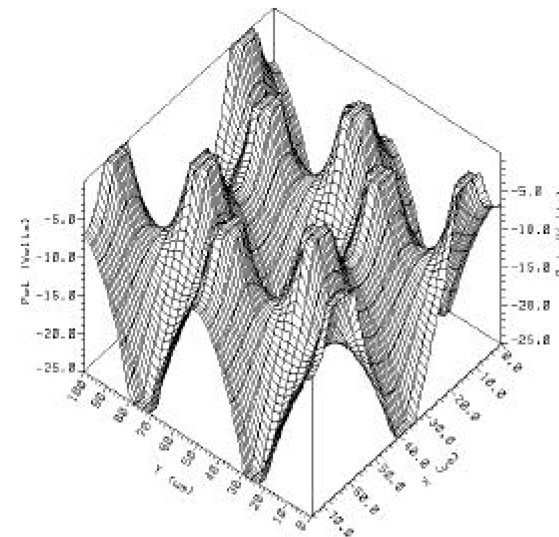
Full depletion at 50 V

Over depletion at 75 V

Low field region

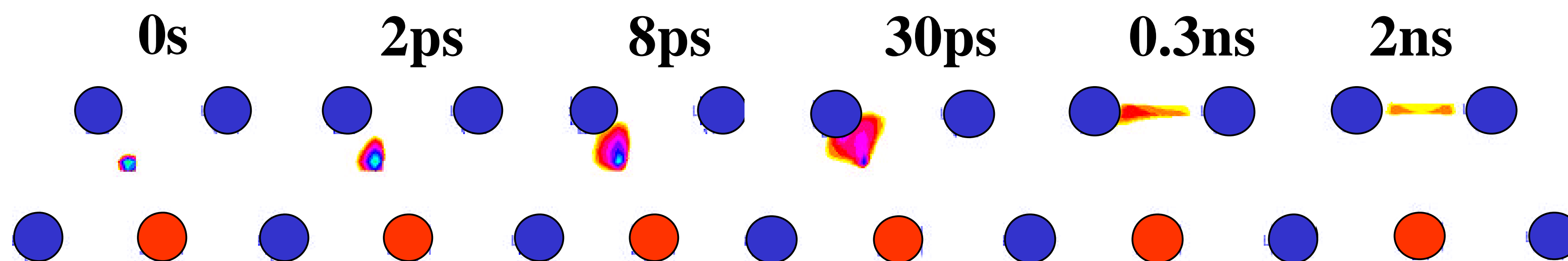




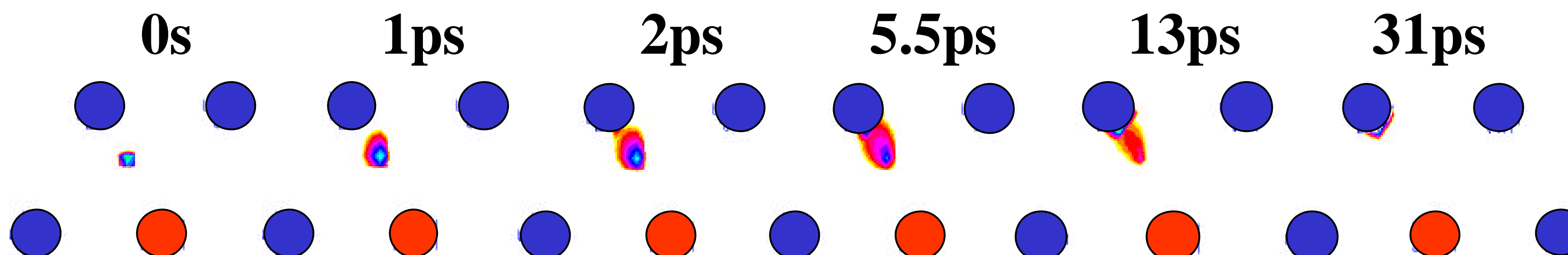
- **Low field region in between pixel boundaries - eliminated by over-depletion**

Movement of carriers

DEPLETED



OVER DEPLETED



Fabrication

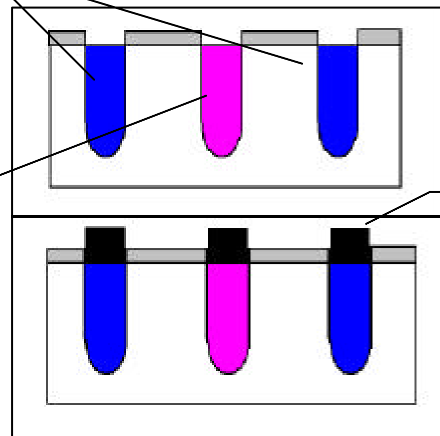
Polishing and cleaning procedure.

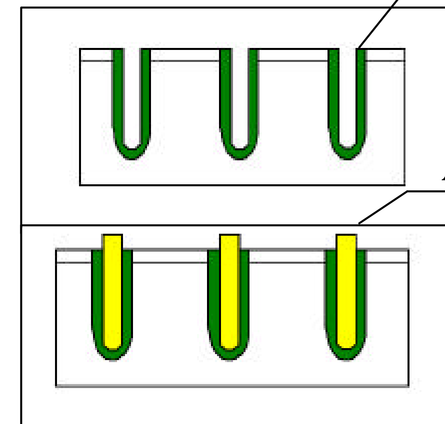
Silicon wafer

SiO_2 deposition,
200nm on both side.

Resist spinning, AZ4562.

- Dry Etching.
- Laser drilling.
- Electrochemical etching.





Oxidise and fill P and N electrodes with Boron or Phosphorus.

Sputtering and electroplating metal to make Schottky contact.

Fabrication options

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	Advantages	Disadvantages	Time
Laser Drilling	• Any material. •No photolithography. •Good depth to diameter ratio (>25:1).	•Slow process for big arrays. •Sidewall damage . •Tapering. •Repeatability.	1hole/*3-5sec*.
Dry etching	•Standard photolithography process.	•Sidewall damage. •Limited depth to diameter ratio (10:1). •Si and GaAs only.	*$1\,\mu m/min$*.
Electrochemical etching	•Good depth to diameter ratio (>20:1). •No sidewall damage.	•Si only (GaAs and SiC?). •Complex photolithography	*$0.6\,\mu m/min$*.

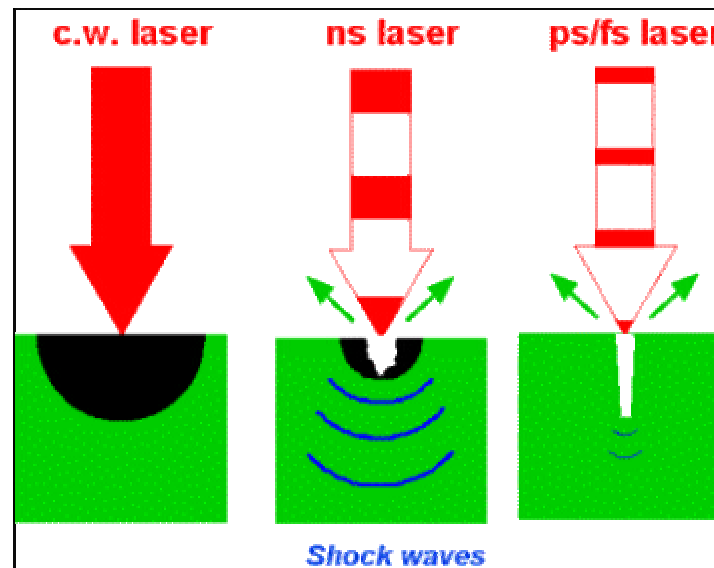
fs Laser

Advantages

- Material independent.
- No heated affected zone (HAZ).
- Low shockwave damage.

Disadvantages

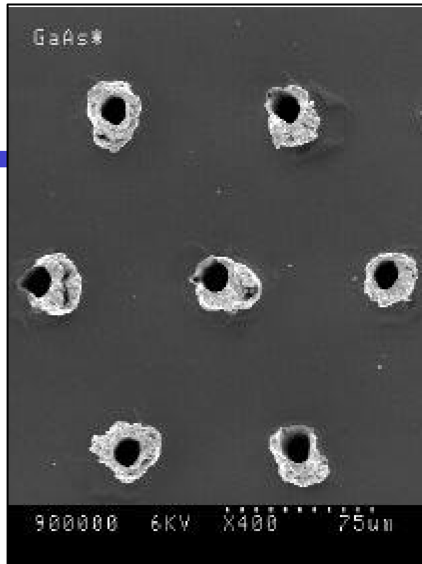
- Tapering.
- Repeatability.
- Surface debris.

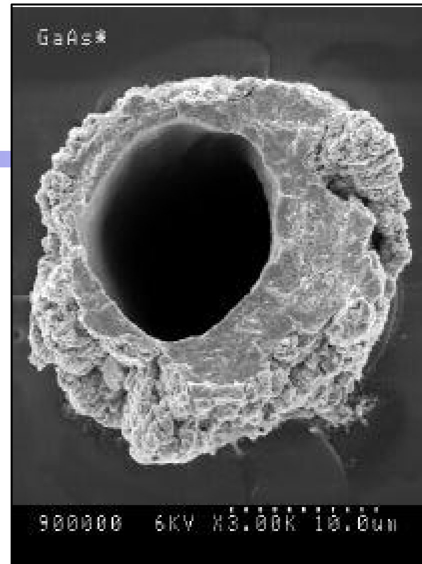


Laser characteristics

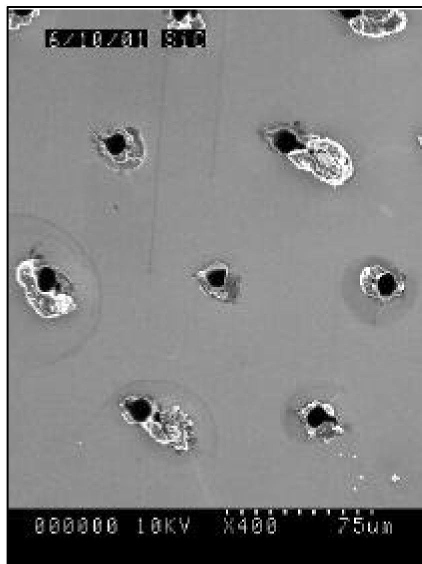
- **Ti:Sapphire laser (TOPS facility)**
- **3 mJ pulse with duration of 40 fs**
- **1 kHz repetition rate**
- **810 nm wavelength**
- **405 nm wavelength (using doubling crystal)**

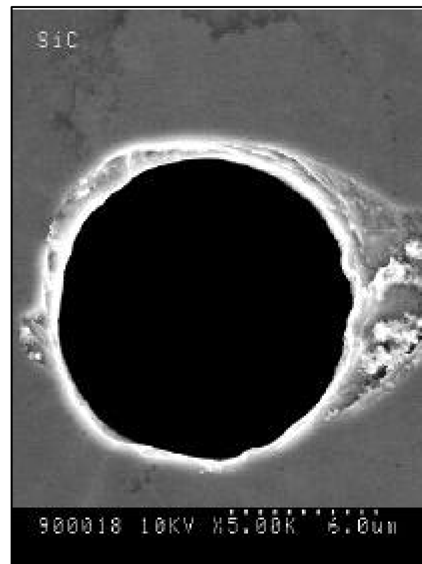
Laser drilling





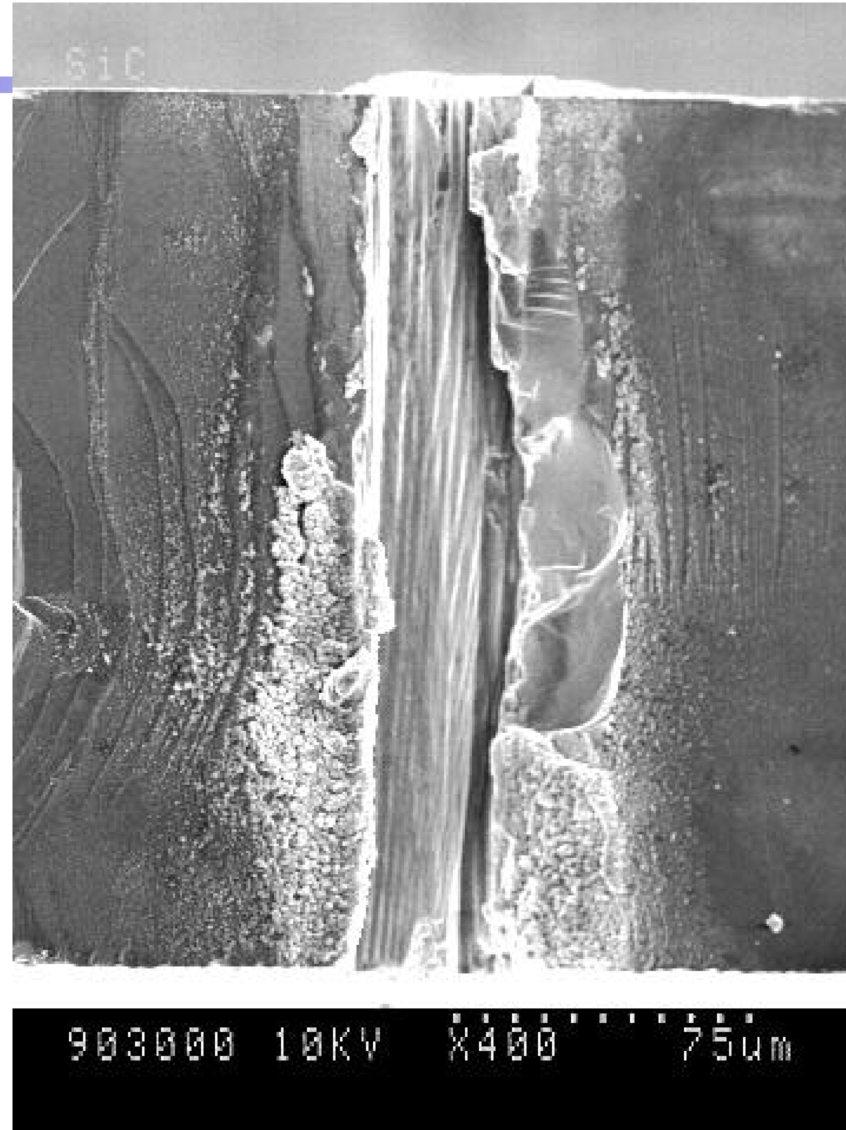
GaAs
- diameter : *10 μm.*
- depth : *300-500 μm.*





SiC
- diameter : *8 μm.*
- depth : *300 μm.*

Results in SiC (cut)



200 μm
sample

Dry etching

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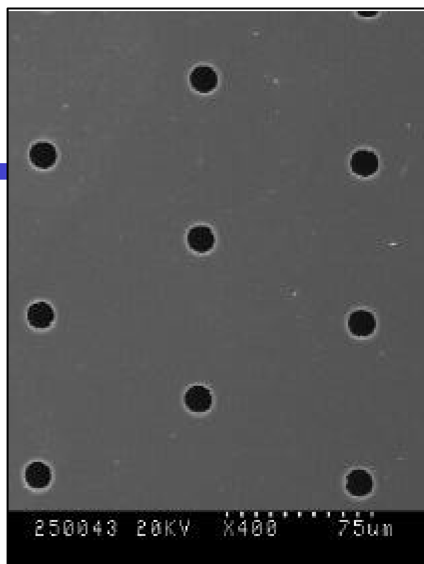
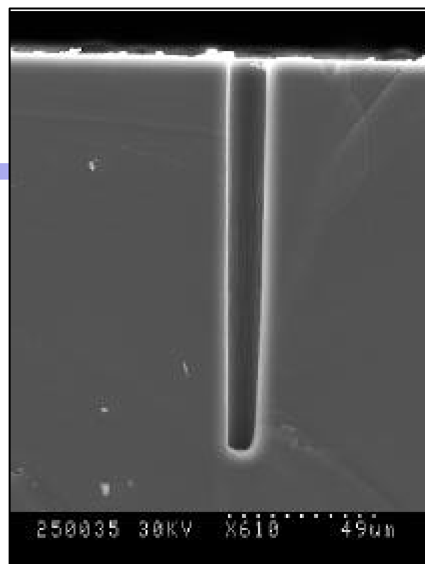
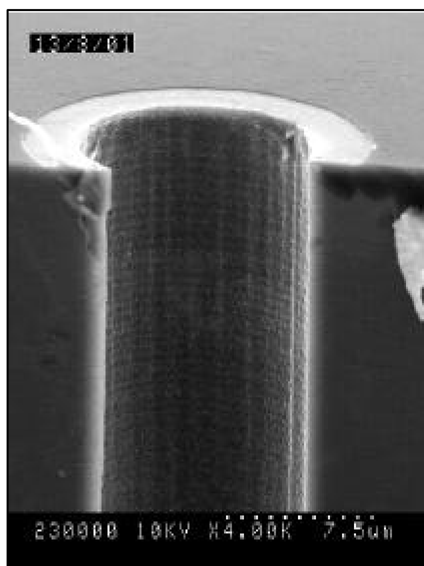
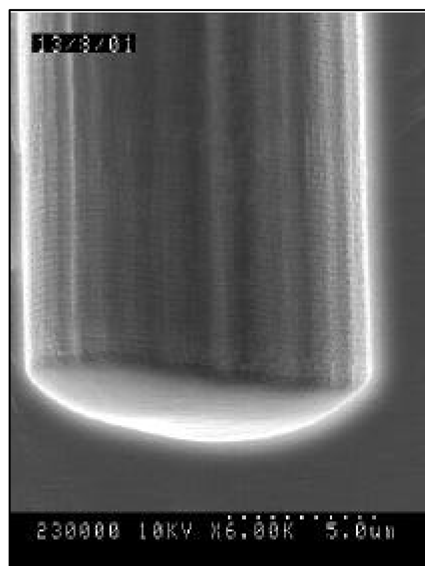








Inductively coupled plasma

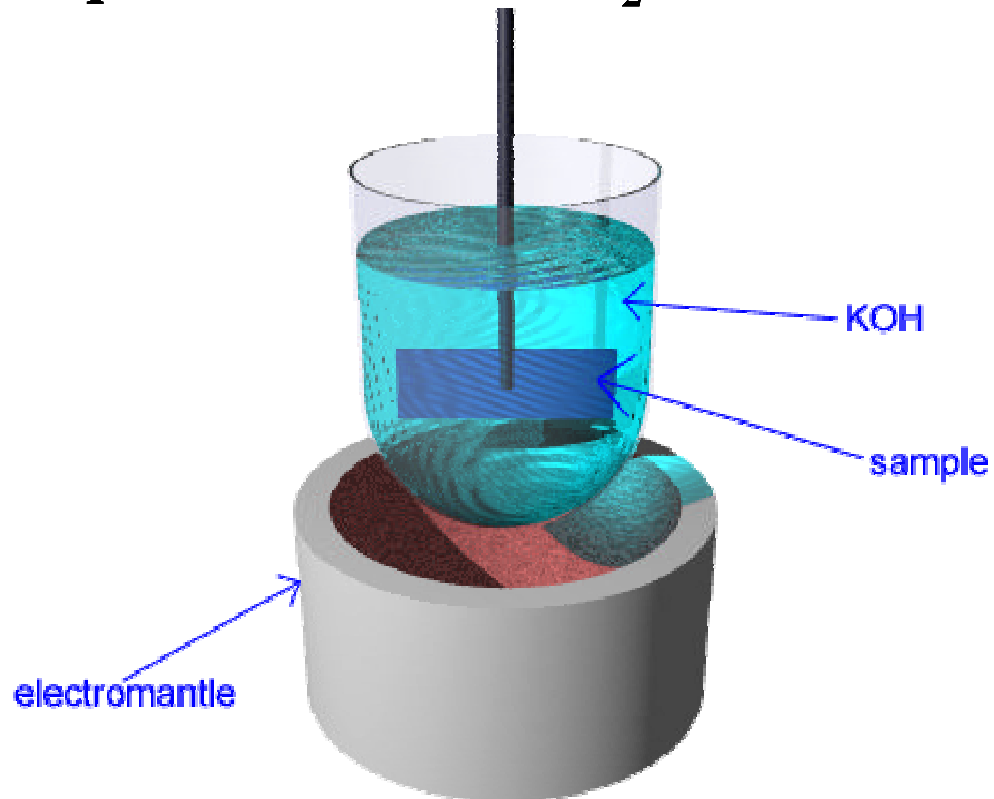
- Plasma etcher : SF_6.
- Mask coating : C_4F_8.

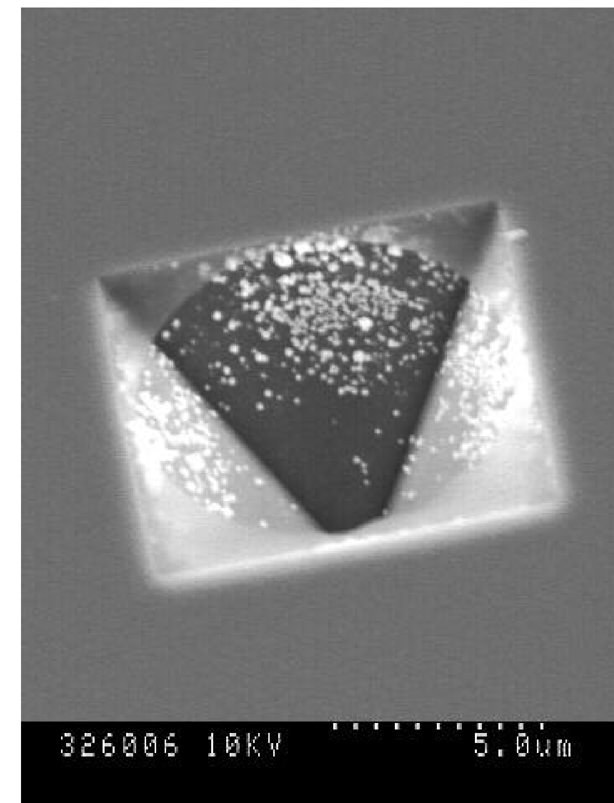
100 minutes of dry etching

- 10µm holes in diameter
- 130µm deep.

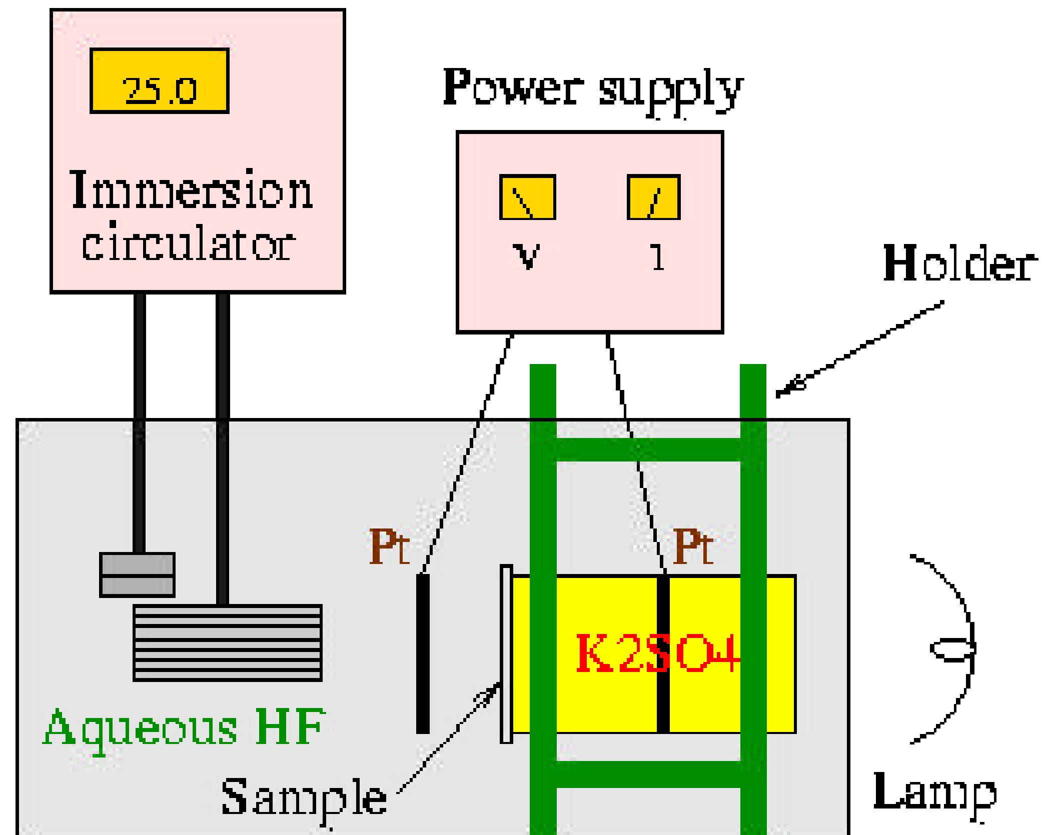
KOH etching

Standard deposition and photolithography techniques to obtain a SiO_2 or SiN mask

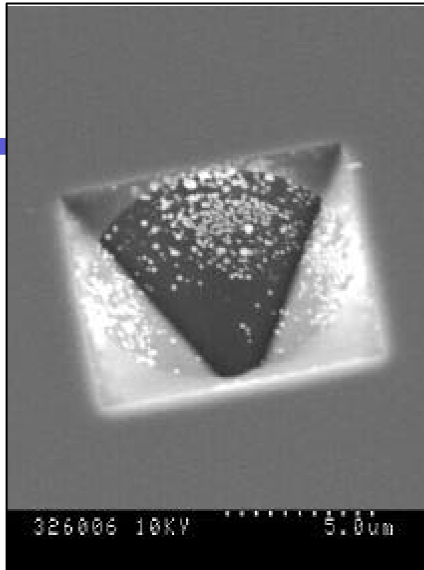


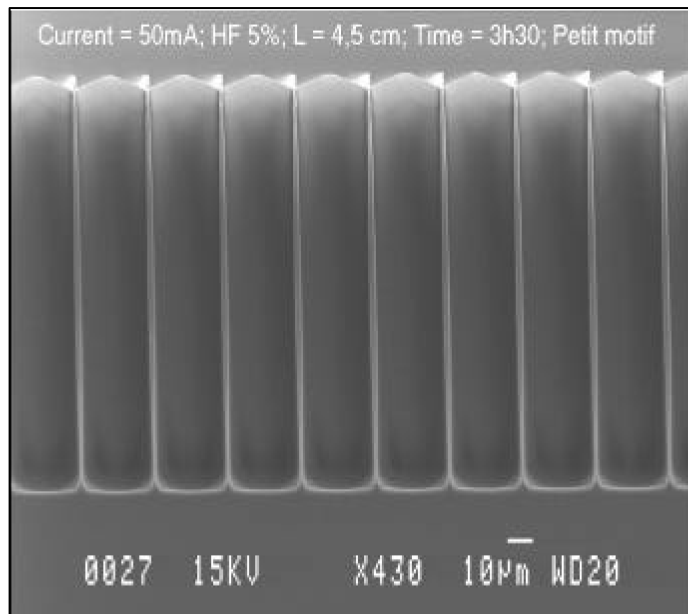


Photoelectrochemical etching



Photoelectrochemical etching





1) Standard photolithography to create a mask in SiO_2 on the surface.

2) Creation of dimples in hot KOH.

3) The silicon etching process is a primary dissolution reaction of the silicon induced by the hydrofluoric acid and the photogenerated holes.

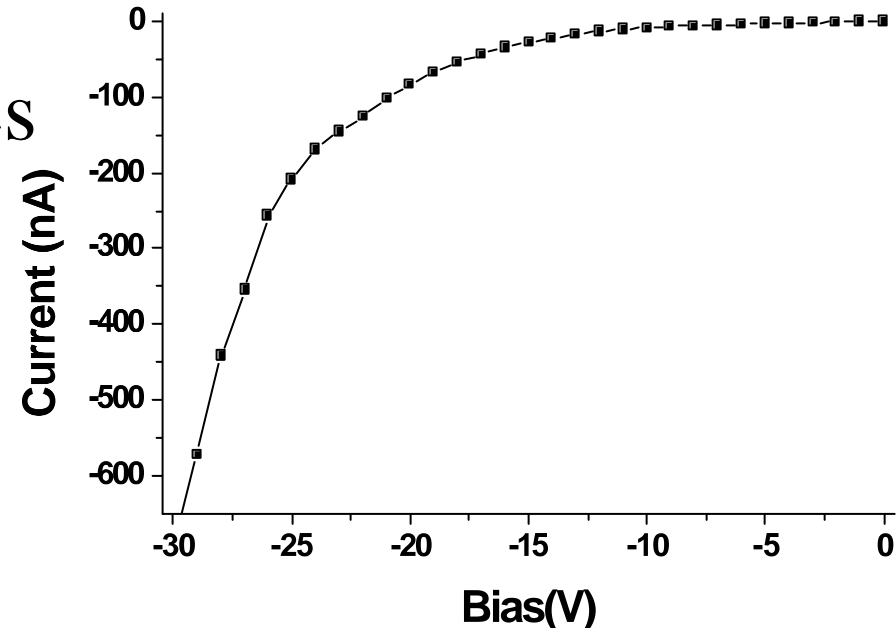
Royal Institute of Technology KTH Stockholm.

PEC results (KTH)

- 5% HF
- dia. 30 μm
- 3h30

Electrical Characteristics

- Gold Schottky contacts
- IV and CV characteristics
  - reproduced with Medici
  - included surface defects prior to anneal



- Am-241 α CCE ~ 50% due to voltage drop on defects

Future Work

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- Improve Laser ablation for GaAs & SiC
- RIE
  - Wet etch + anneal
  - Improve aspect ratio
- PEC etching of GaAs
- Better contact technology - B/P implants