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
n-type GaAs $N_{\text{eff}} = 1 \times 10^{14}$ 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

MEDICI 3-D detector model

Unit cell

25 μm

Biased electrode

Grounded electrode
Potential distribution

**Full depletion**

at 50 V

**Over depletion**

at 75 V

Low field region in between pixel boundaries - eliminated by over-depletion
Movement of carriers

DEPLETED

0s  2ps  8ps  30ps  0.3ns  2ns

OVER DEPLETED

0s  1ps  2ps  5.5ps  13ps  31ps
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Oxidise and fill P and N electrodes with Boron or Phosphorus.

Silicon wafer

SiO₂ deposition, 200nm on both side.

Polishing and cleaning procedure.

Resist spinning, AZ4562.

Dry Etching.
Laser drilling.
Electrochemical etching.

N- doped

P - doped

Au (seed)

Al contact

Silicon wafer

Au

Sputtering and electroplating metal to make Schottky contact.

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# Fabrication options

<table>
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<tr>
<th></th>
<th>Advantages</th>
<th>Disadvantages</th>
<th>Time</th>
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<tbody>
<tr>
<td><strong>Laser Drilling</strong></td>
<td>• Any material. &lt;br&gt;• No photolithography. &lt;br&gt;• Good depth to diameter ratio (&gt;25:1).</td>
<td>• Slow process for big arrays. &lt;br&gt;• Sidewall damage. &lt;br&gt;• Tapering. &lt;br&gt;• Repeatability.</td>
<td>1 hole/3-5 sec.</td>
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<tr>
<td><strong>Dry etching</strong></td>
<td>• Standard photolithography process.</td>
<td>• Sidewall damage. &lt;br&gt;• Limited depth to diameter ratio (10:1). &lt;br&gt;• Si and GaAs only.</td>
<td>1 µm/min.</td>
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<tr>
<td><strong>Electrochemical etching</strong></td>
<td>• Good depth to diameter ratio (&gt;20:1). &lt;br&gt;• No sidewall damage.</td>
<td>• Si only (GaAs and SiC?). &lt;br&gt;• Complex photolithography</td>
<td>0.6 µm/min.</td>
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</table>
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: \(10\mu m\)
- depth: \(300-500\mu m\)

SiC
- diameter: \(8\mu m\)
- depth: \(300\mu m\)
Results in SiC (cut)

200 µm sample
Dry etching

Inductively coupled plasma
• Plasma etcher: SF₆.
• Mask coating: C₄F₈.

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

[Diagram showing setup with labels: Immersion circulator, Power supply, Holder, Lamp, Sample, Aqueous HF, Pt, K₂SO₄]
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.
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 $\alpha$ CCE $\sim$ 50% due to voltage drop on defects
Future Work

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