High Spatial Resolution 3D Probes for Neurobiology Applications

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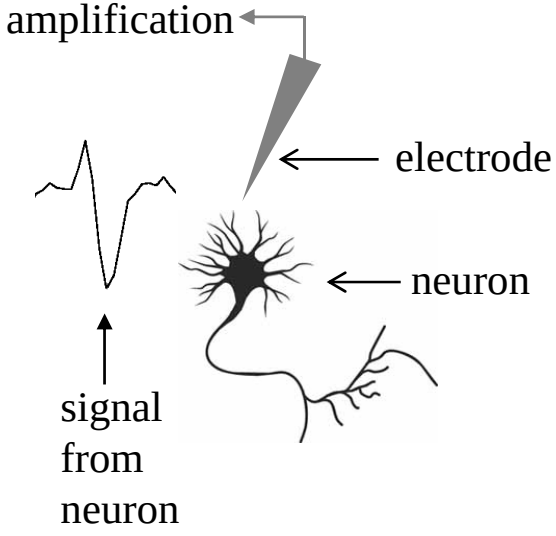
Outline:

- Background and motivation
  - Why are position sensitive detection probes needed to study neuronal behaviour?
- Arrays:
  - Design requirements
  - Developed fabrication process
- Characterisation
  - Mechanical
  - Electrical
- Next step
- Conclusions and future work

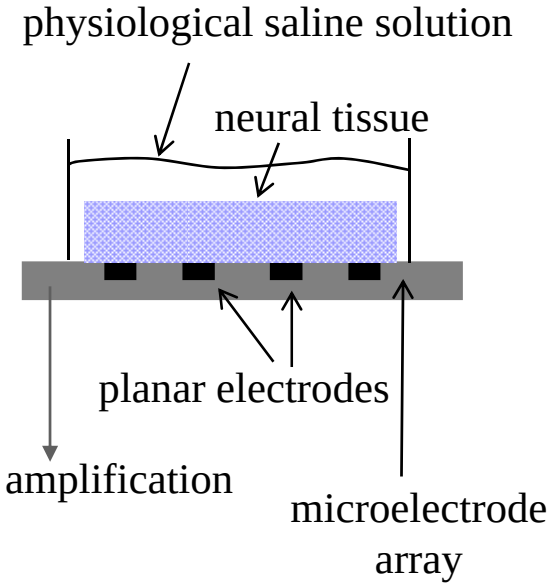
Background

Traditionally:



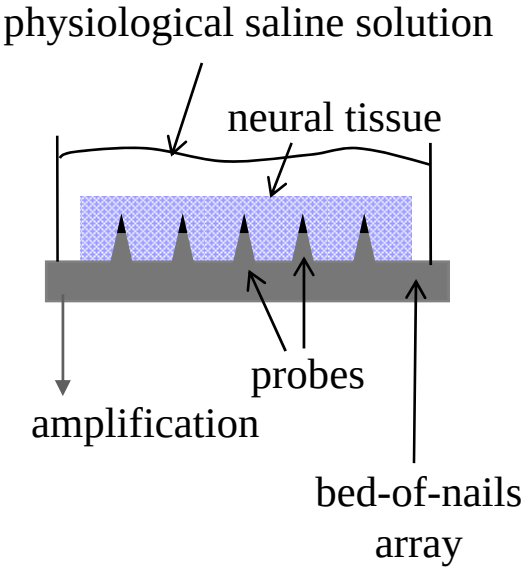
Ref: Hubel and Wiesel, Nobel prize winners 1981

More recently:



Ref: D.Gunning et al., Nuclear Instruments and Methods in Physics research, 2005.

Developing:

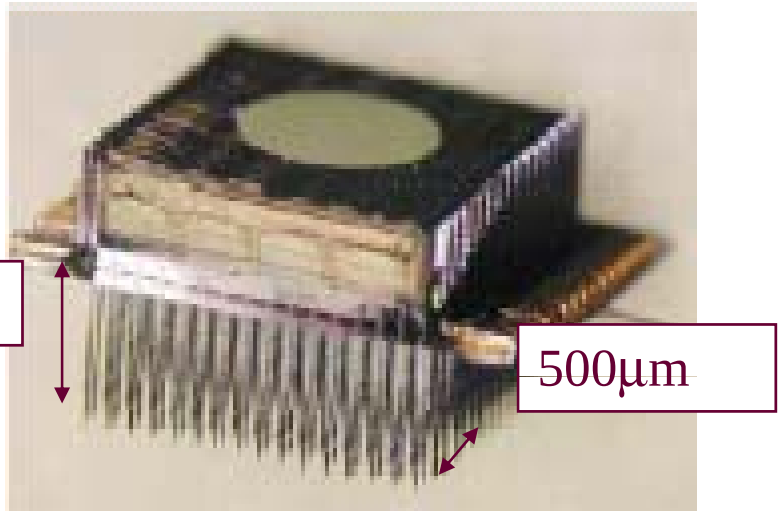


- Improve electrode/cell contact.
- Probe a 3-D distribution of cells such as found in brain slices

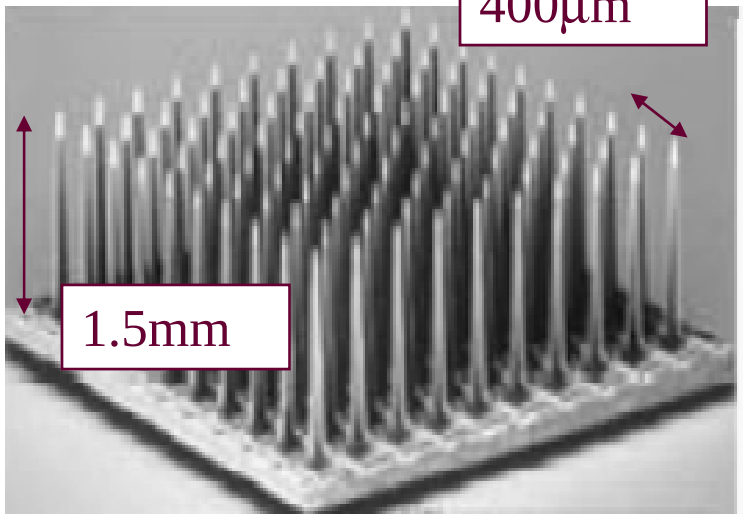
Background

- Current bed-of-nails devices:

Michigan Neural Probes:



Utah Neural Array:



LOW SPATIAL RESOLUTION!

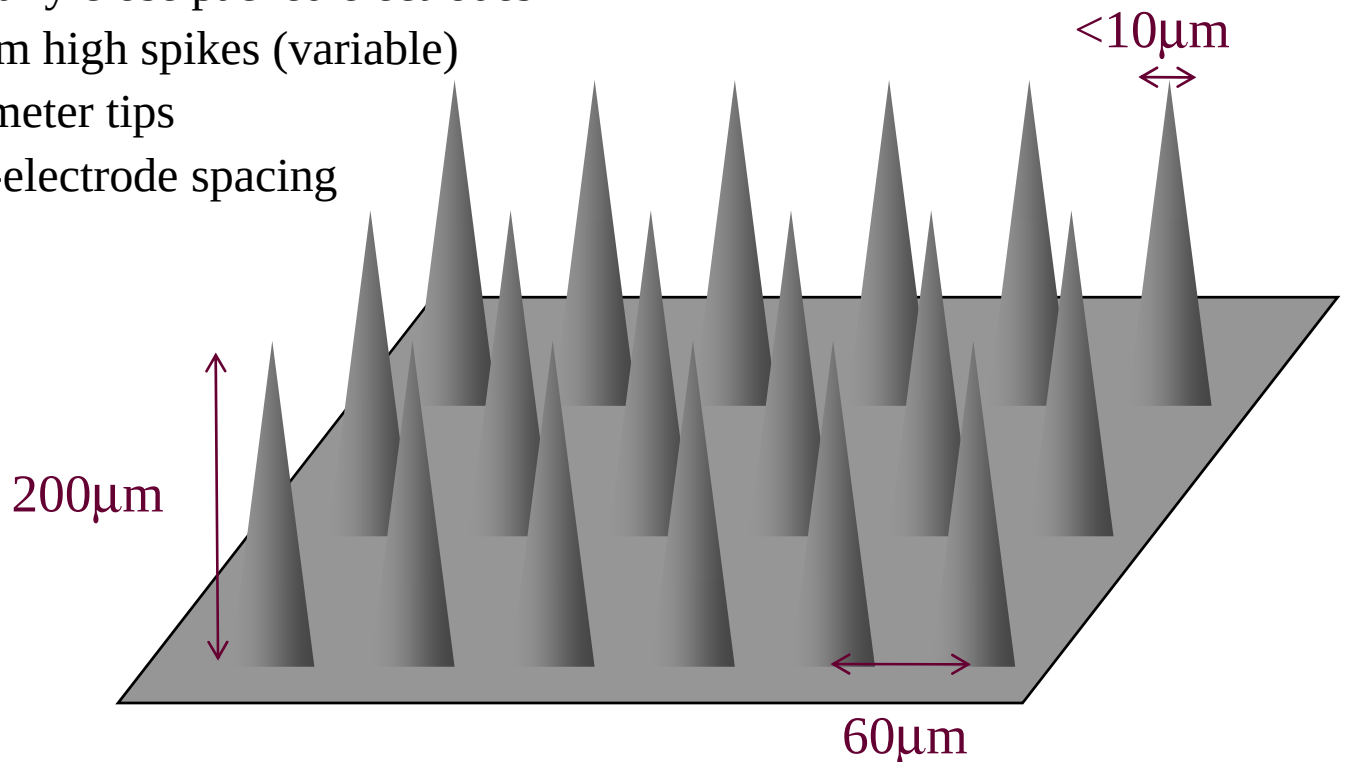
Bed-of-nails ~ design

Previous studies with planar arrays have shown that 30-60 µm provides excellent coverage of cells

Design requirements:

Unprecedented dimensions:

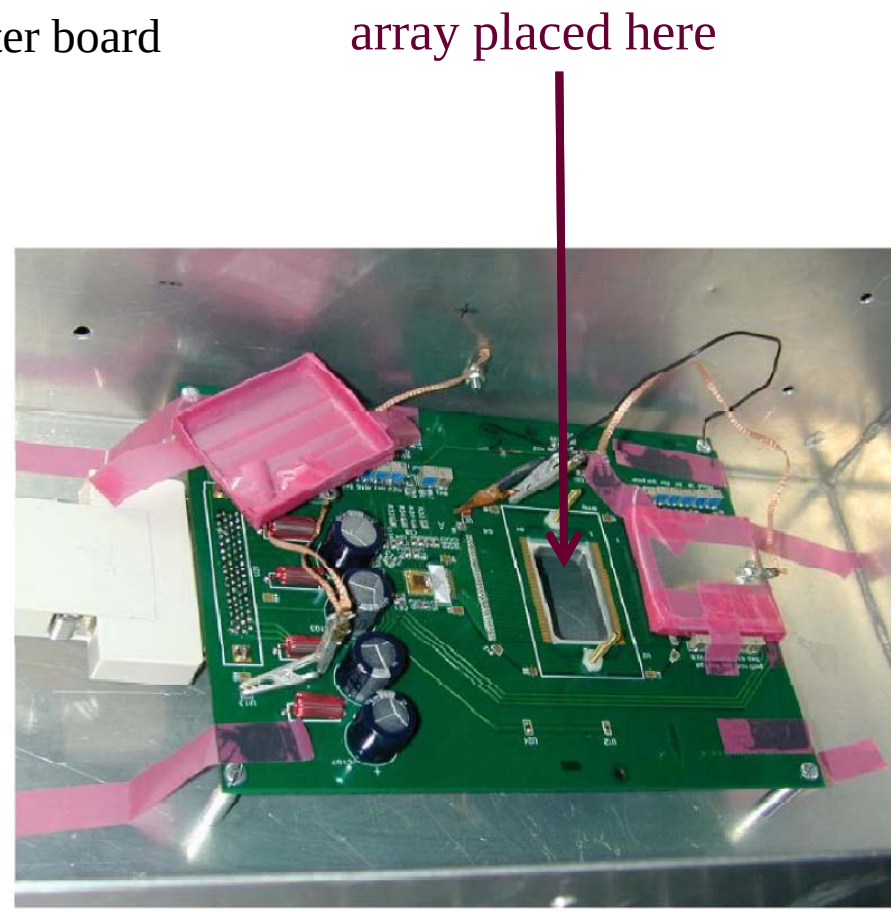
- Nanofabricated on silicon wafers
- 61 hexagonally close packed electrodes
- Up to 200µm high spikes (variable)
- <10µm diameter tips
- 60µm inter-electrode spacing



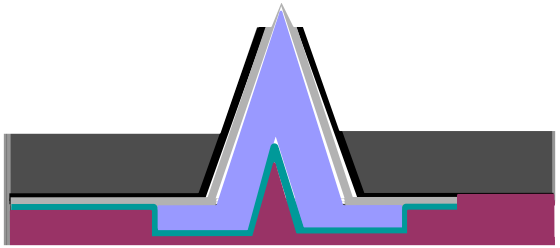
Bed-of-nails ~ readout system

- Existing 61 channel readout system
  - Extensive and successful use with planar microelectrode arrays
- Bed-of-nails compatible with system
  - Wire bonded in to custom made daughter board
- Specifications:
  - Bandpass filter 50 – 2000 Hz
  - Noise 5 µVrms
  - Sampling rate 20 kHz

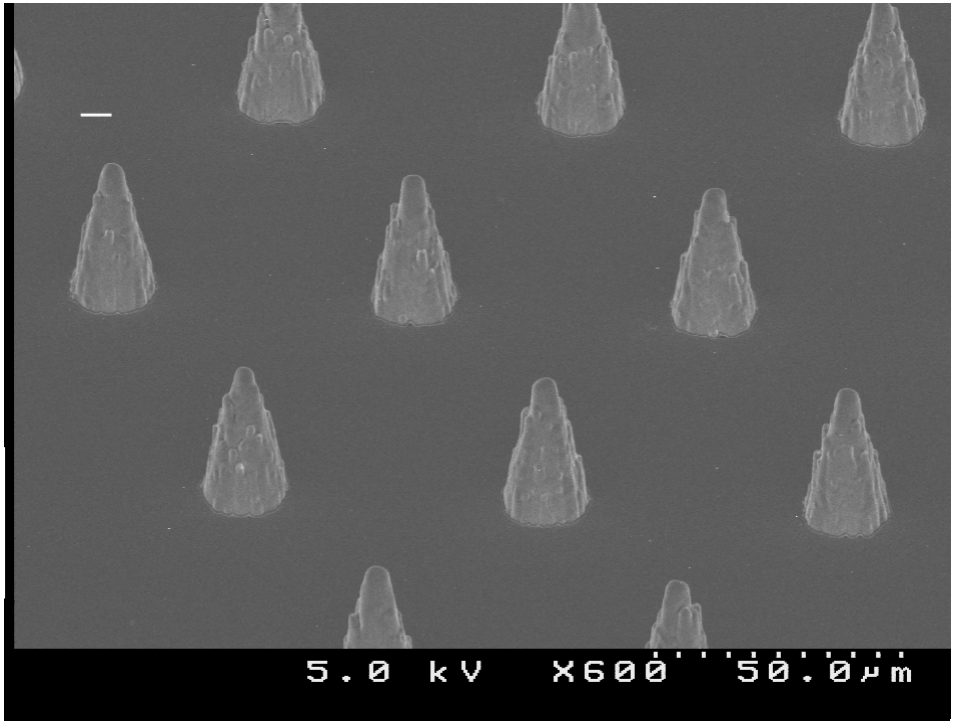
W. Dabrowski et al.,
Biosensors and Bioelectronics **19**, 2004



Bed-of-nails ~ fabrication

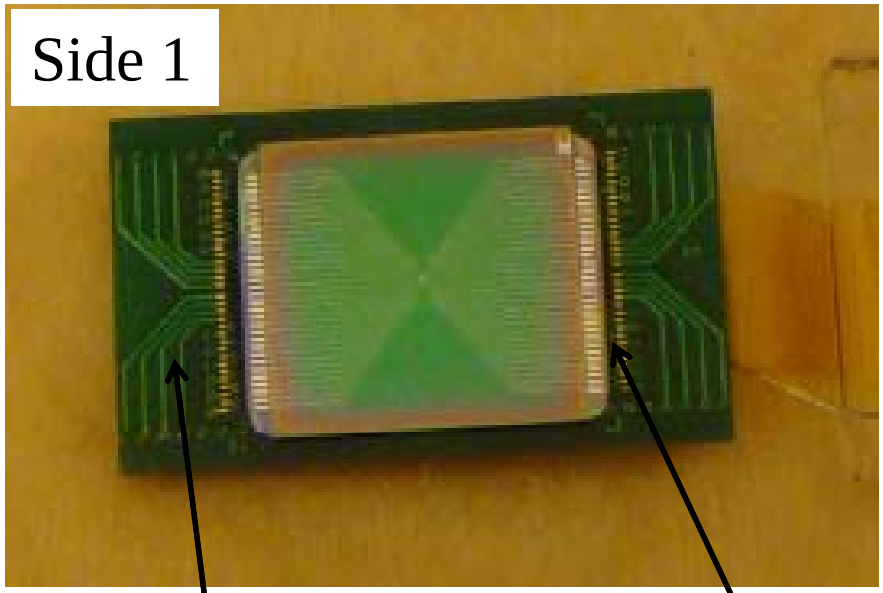


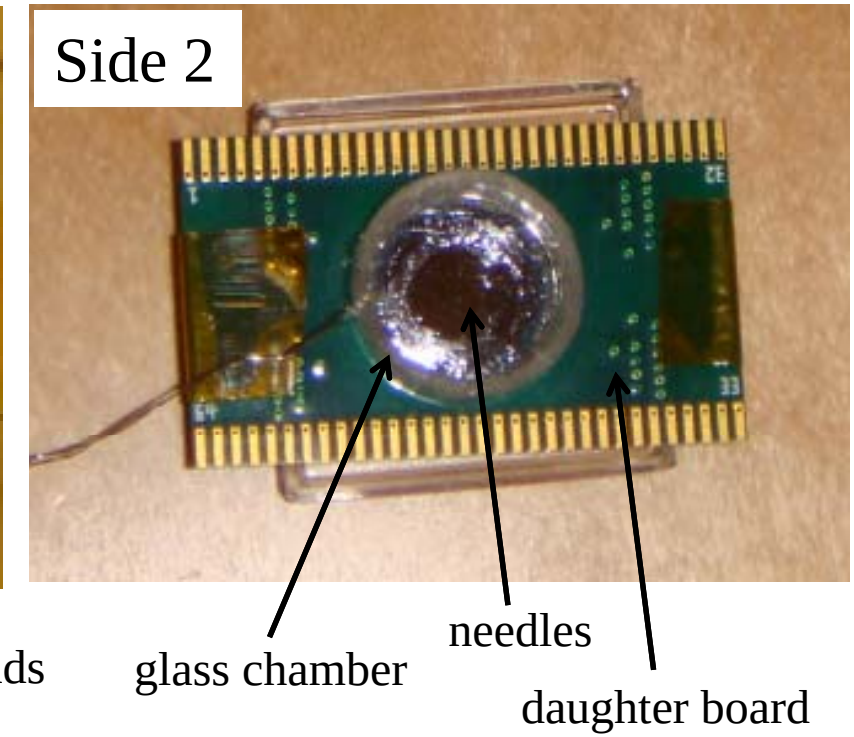
8. Etch more Si - defining length of needles



Bed-of-nails ~ fabrication results

Bed-of-nails ~ daughter board





- Side 1: Bed-of-nails wire bonded to daughter board
- Side 2: Chamber glued with grounding platinum wire

- Daughter board fixed to 61-channel readout system

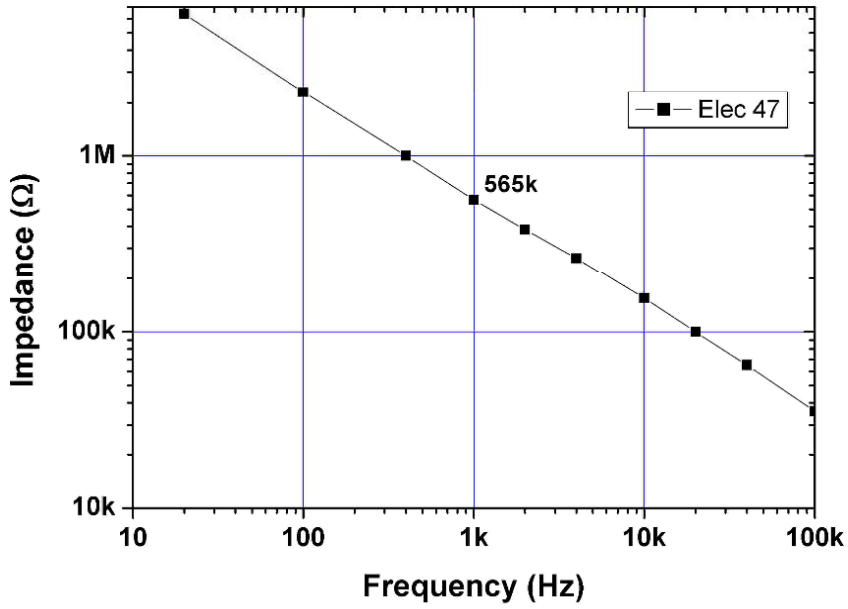
Electrical tests

- Tungsten tip needles – very high impedance (~5 MΩ)
  - Need ~300 kΩ at 1 kHz

- Lower impedance by platinising:
  - Apply current to electrode through platinic chloride solution
  - Tungsten electroplated with “platinum black”
    - Granular platinum formation increases surface area

- Preliminary result:

  565 kΩ at 1 kHz



Next step

- Placement of daughter board/bed-of-nails into 61-channel system

- Characterise:
  - Noise:

    noise compares with 61-channel system (8μVrms in saline)

    signal improvement on 61-channel system (>200 μV)

    signal to noise improvement

- Recordings from:
  - Mouse retina
    - Dr. A. Sher, Dr. D. Feldheim at UC Santa Cruz
    - More comprehensive study of retina
  - Cortical slices
    - Dr. J. Beggs, Indiana University
    - Further study neuronal firing behaviour and phenomena

Conclusion and future work

- Unique array developed to study neural networks
  - Unprecedented dimensions
  - Mechanically stable
  - Promising electrical characteristics

Future:

- Arrays of longer needles (up to 500µm)
- Arrays of multi-length needles
  - Proof of principle:
- Arrays on flexible substrates
  - *In-vivo* studies