

Flexible Micro Electrode Arrays
For Neuronal Stimulation and Recording

IWORID 2004

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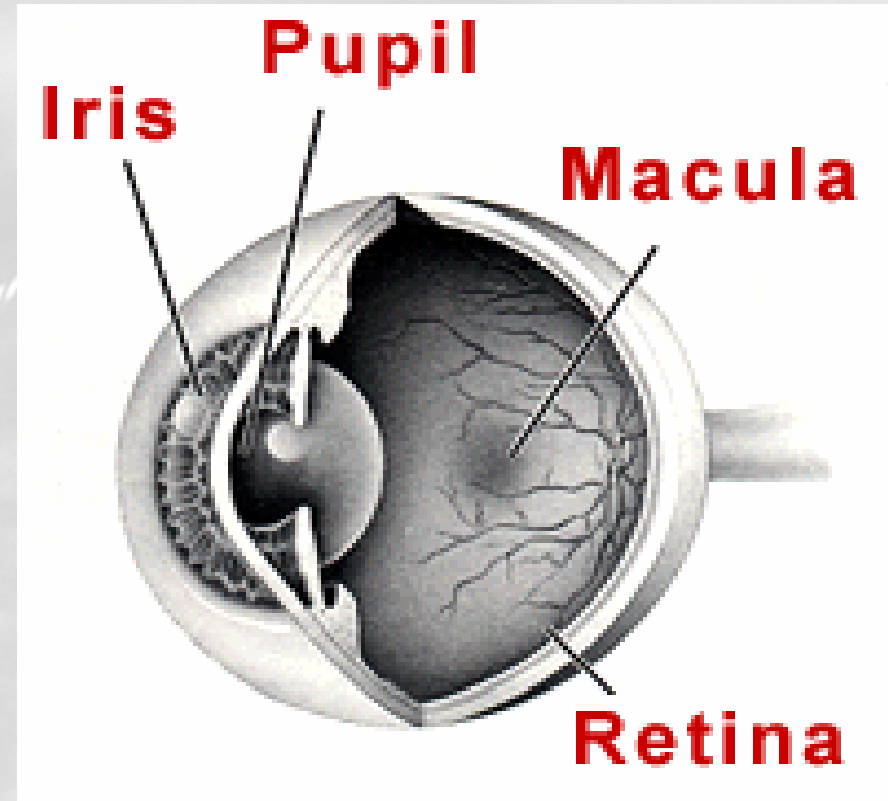
- Introduction
- Eye
- Bio - Synthetic model for artificial vision
- Active Pixel Sensor (APS)
- Neural Network.
- Array Development
- Cellular Stimulation
- Summary

Retinal Prosthesis

- Is it possible to develop microelectronics for a retinal prosthesis?
 - Restore partial sight to blind patients
- Several groups working on possible solutions around the world
 - USA – Retinal Implant Projects
 - MIT and Harvard (Rizzo)
 - USC (Humayan)
 - Implanted arrays in patients
 - Germany
 - EPI-RET and SUB-RET
 - Optobionics, Second Sight
 - developing commercial products
 - Exist around 40 groups looking at developing retinal prosthetics

The Eye

- Interested in diseases of the **Retina** (Macula).
- Visual acuity affected if the **light sensitive** cells (rods+cones) become optically less sensitive.
- Require that the **pathway** from the retinas output cells to the brain are **intact**.
- **Age related Macula Degeneration** - 200,000 new cases in USA each year.
- **Retinitis Pigmentosa** - 20,000 people yearly in the USA.

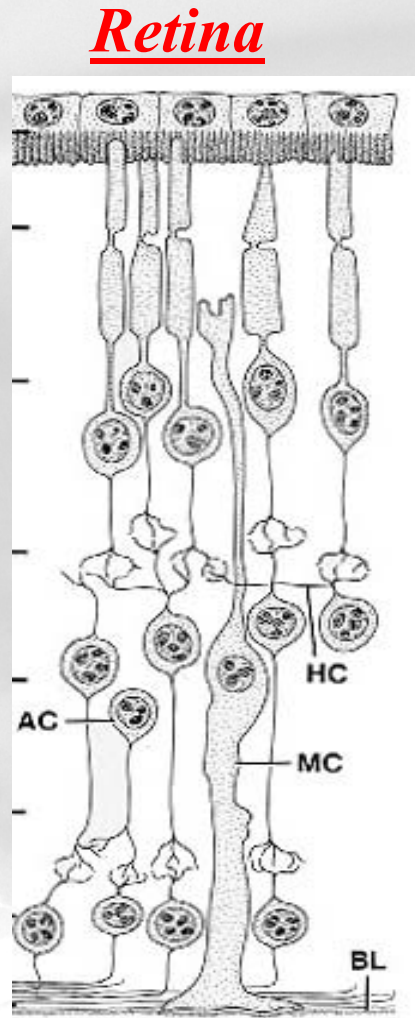


Bio - Synthetic Model

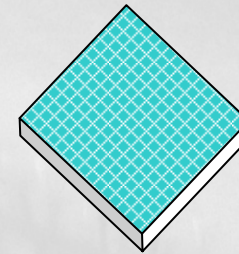
Photoreceptors
(light sensitive)
 10^8 Cells

Horizontal,
Bipolar and
amacrine cells
(processing)

Ganglion cells
(output)
 10^6 Cells



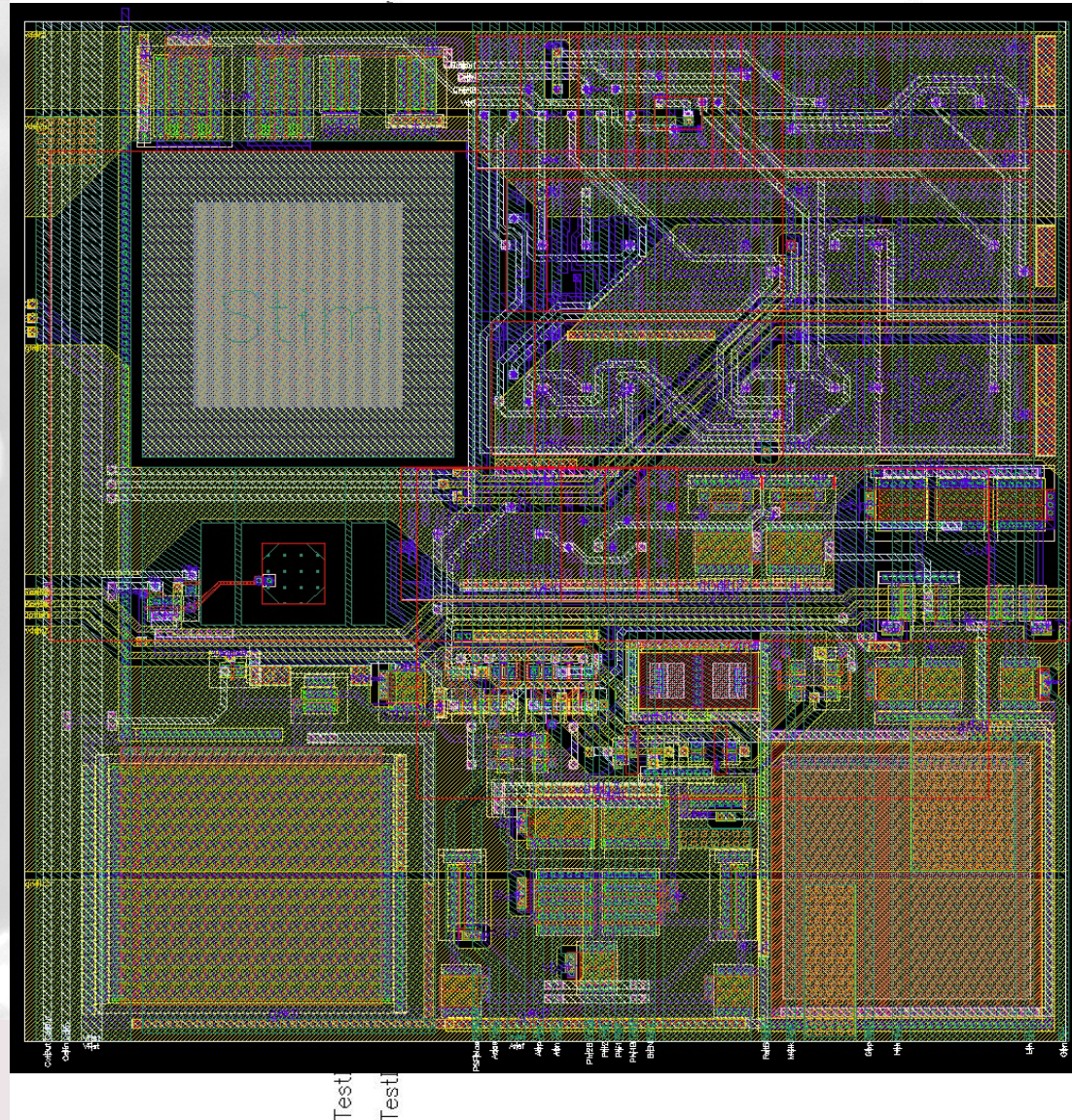
Implant



Pixel Sensor
(APS)

Active Pixel Sensor (APS)

- **10x10** pixel matrix
 - pixel pitch **100 μ m**
 - **0.35 μ m** technology
 - Each pixel contains a **voltage controlled oscillator (VCO)**, which creates signals capable of stimulating the ganglion cell. Frequency of VCO responds **logarithmically** to incident light.
 - **Bi-phasic** output
~50nC/phase
- Frequency range : **10Hz-1kHz**

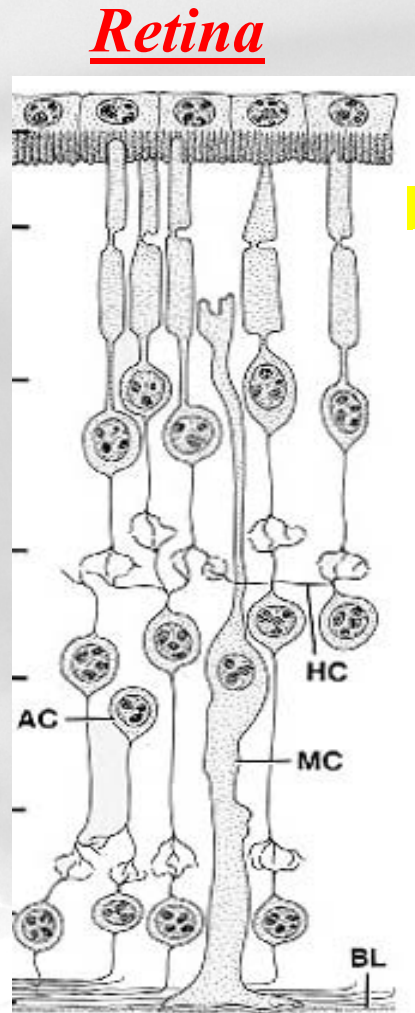


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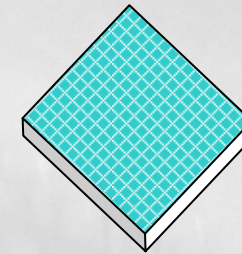
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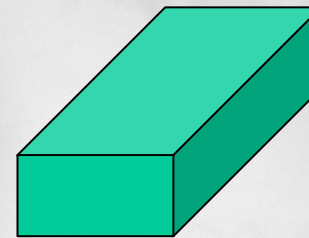
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Implant



Pixel Sensor
(APS)



Neural network

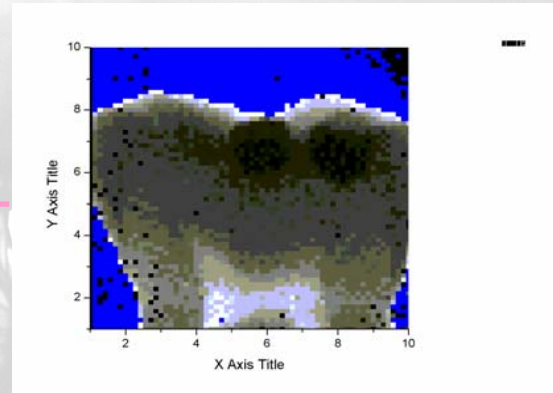
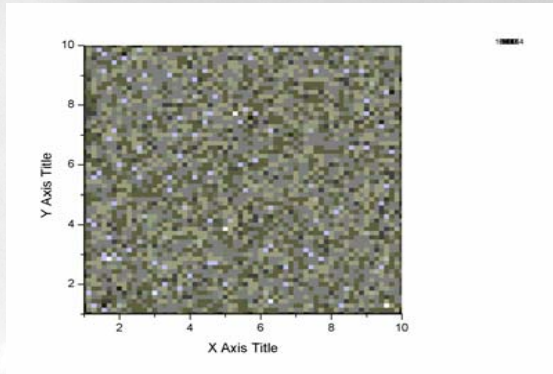
Neural Network

- 3 Layer, **reduced**, feed forward, nearest neighbour network architecture.
- Trained using GRID computing
- Discrete **pixel weighting matrix** as output
- Can be hosted on APS via on chip EPROM
- Aims to provide a correlated output of electrical potentials representing the optical scene

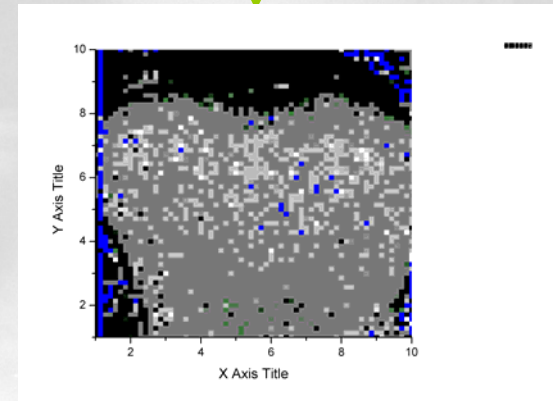
Neural Network Simulation

Known input image (64x64 pixel Medipix)

Untrained network
response



Trained network
response

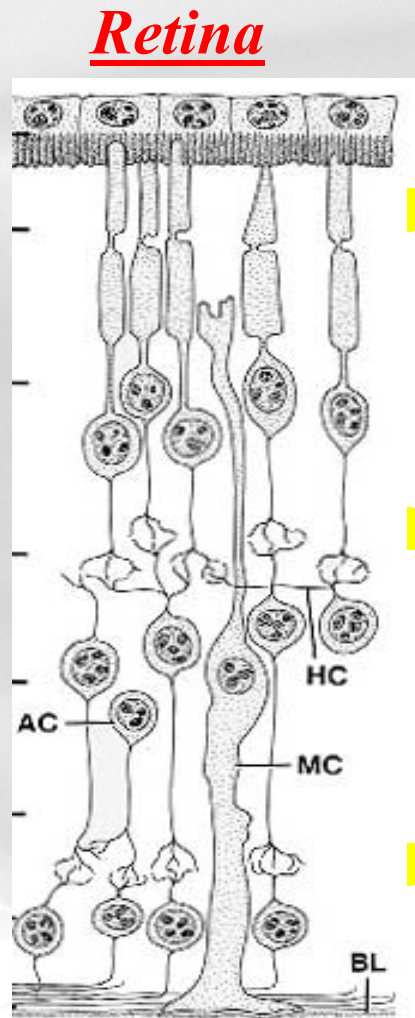


Bio - Synthetic Model

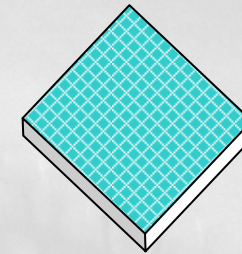
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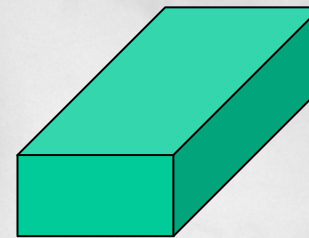
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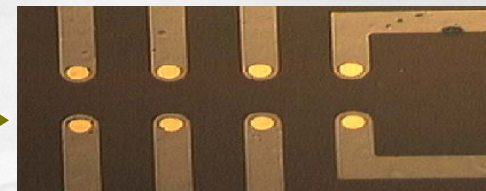
Implant



Pixel Sensor
(APS)

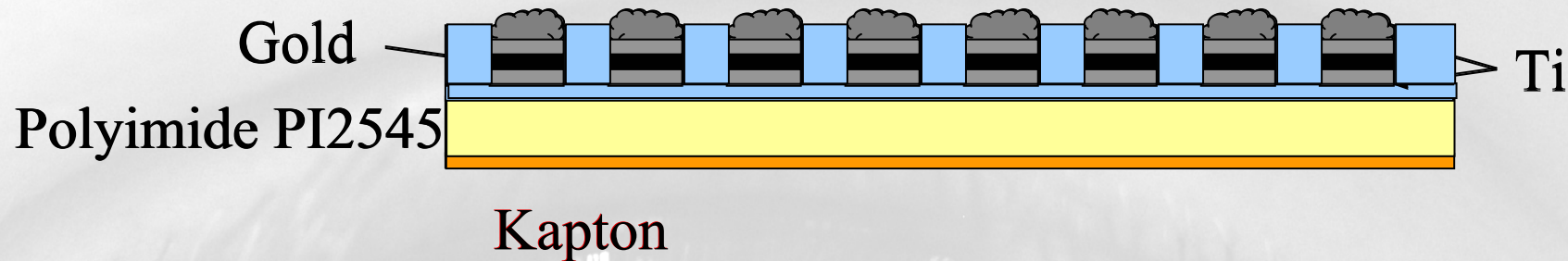


Neural network



Microelectrode array

Fabrication of Flexible Arrays



Thermal Planarising of Kapton

Spin coating of insulating Polyimide

Metal Adhesion promoting layer

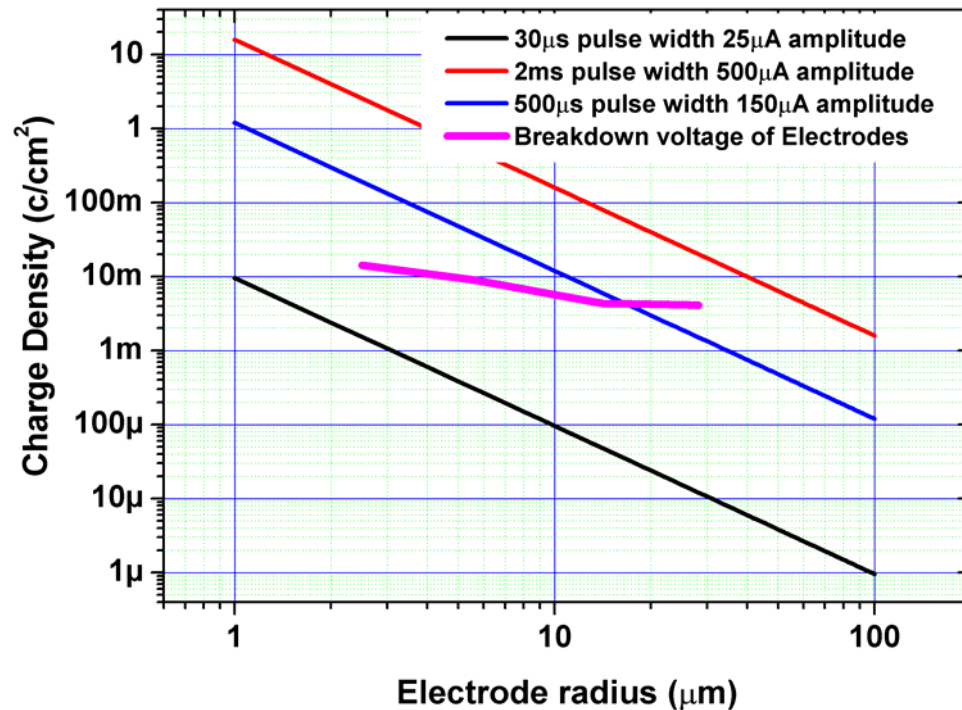
Metallisation : Titanium 30nm / Gold 150nm - Pattern

Surface passivation - Selective surface etch.

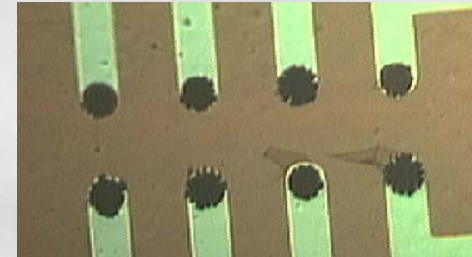
Platinisation - Impedance reduction measure

Flexible Stimulation Arrays

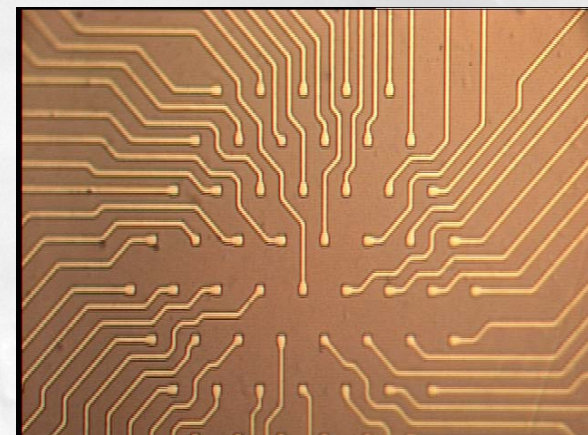
- **Polyimide** based flexible arrays successfully developed



8 Electrode Array



61 Electrode Array



Stimulation of cells

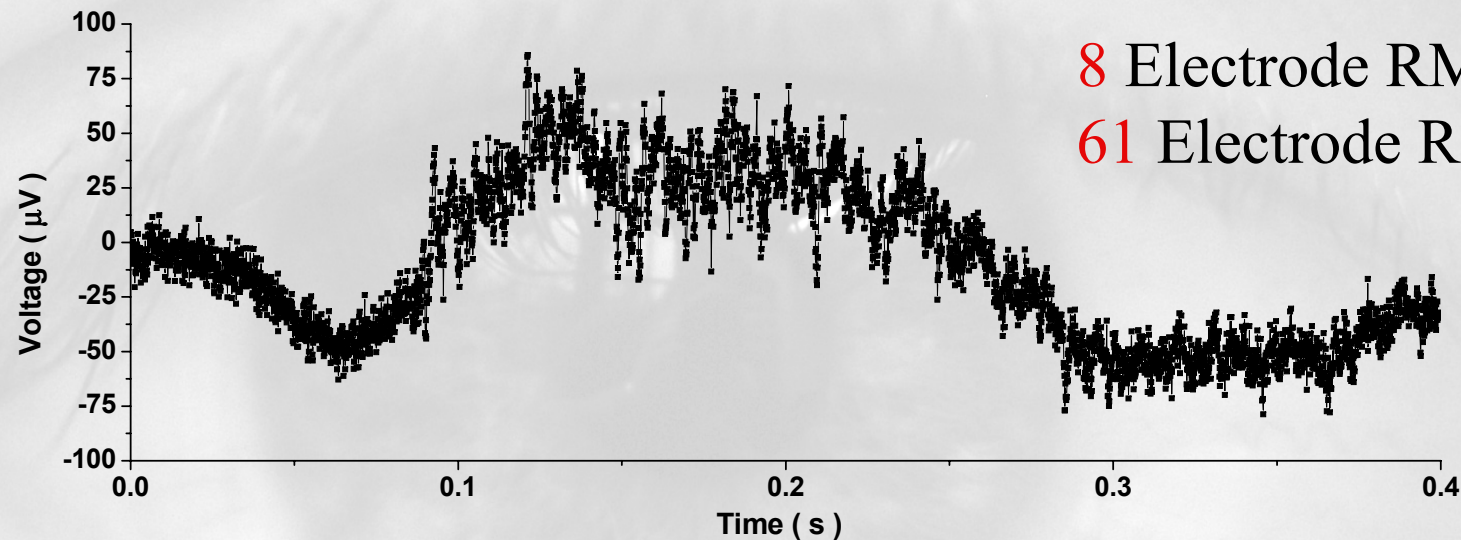
- Given the recorded ganglion cell AP **waveform** in response to light **incident** on the retina.
- Principally if we **reconstruct** the **spike** trains we are reconstructing the visual scene.
- Electronically recreate the AP's and pass to an electrode **coupled** to a **ganglion** cell, connected to brain through the optic nerve.
- *Main constraints include : Current densities, balanced biphasic pulses, frequency of AP's, heating, electrode charge injection limits and reproducing the retinal coding through spike trains.*

Results - Recorded signals

Typically Noise :

8 Electrode RMS = $2.6\mu\text{V}$

61 Electrode RMS = $3.1\mu\text{V}$



Retinal Response to **light stimulus** - Electroretinogram
Action Potentials (Spikes)

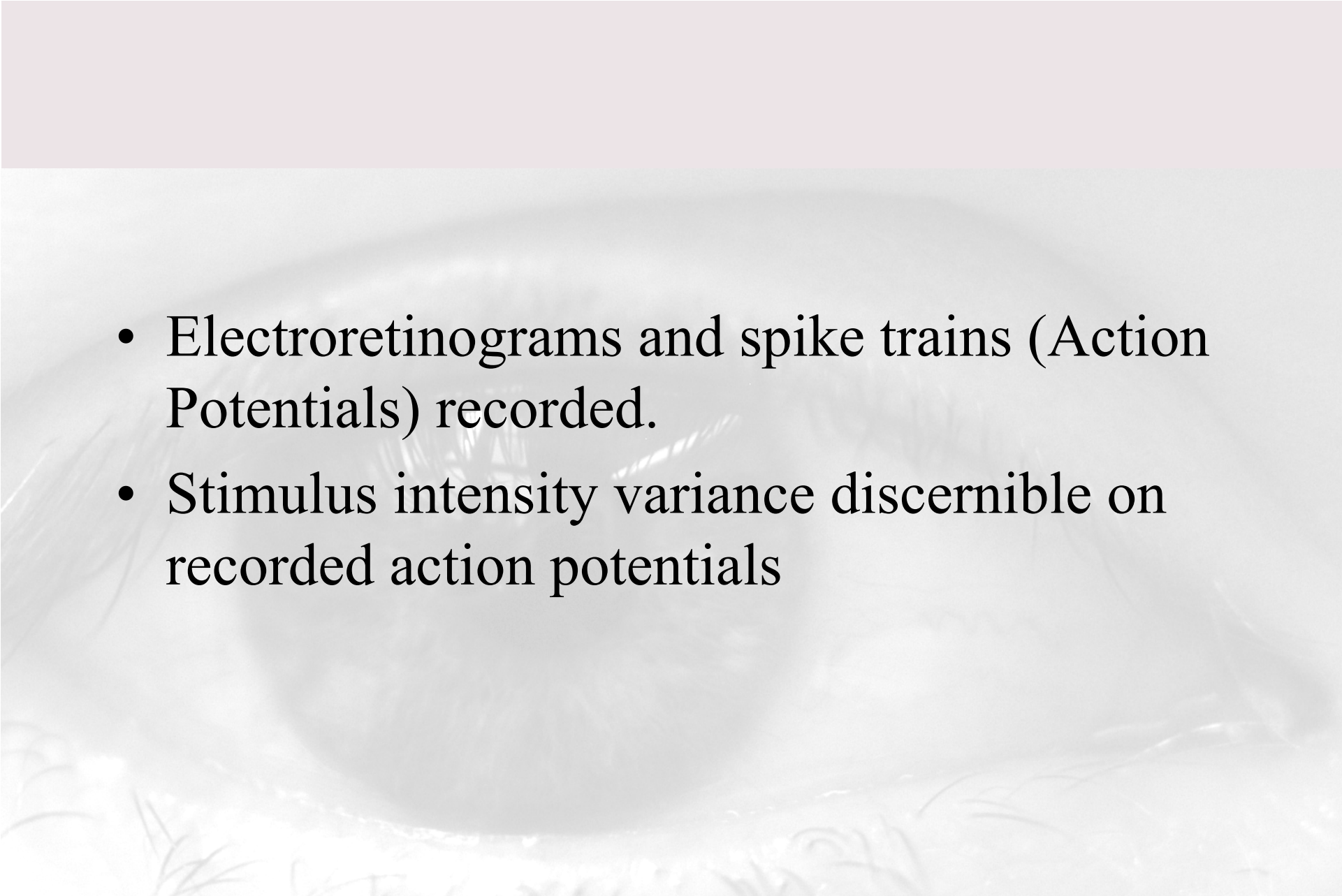
Conclusions

- Fabrication of **flexible** arrays successful on polyimide based substrates.
- Design for **APS** detector **complete**, foundry run in progress - Arrive mid August.
- 1st optimisation of neural network complete.
- Investigations of cell stimulation underway.
- **New** flexible **materials** in development stage.

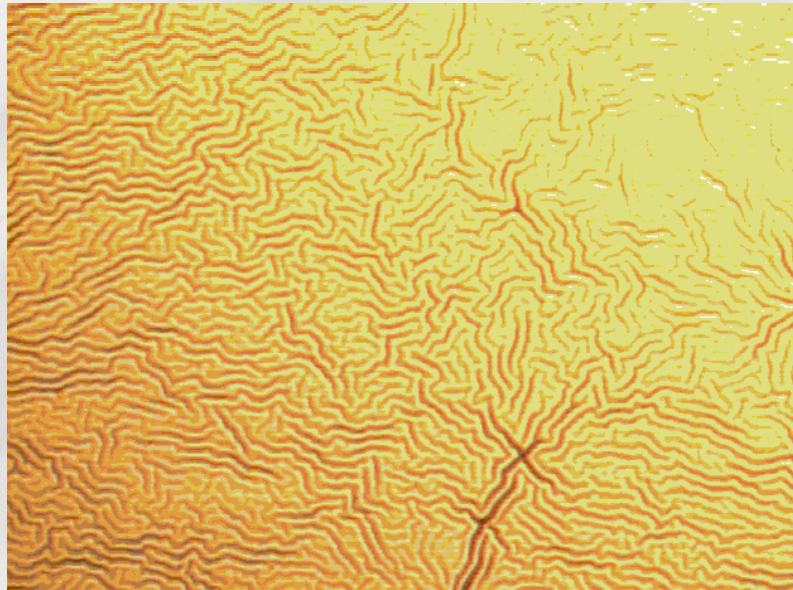
Thanks for listening 😊

The Eye

- Highly evolved detector
- Central retina has few micron detector pitch
 - =>High spatial contrast
- Refresh rate 40ms (25Hz)
- Large light intensity range

- 
- Electroretinograms and spike trains (Action Potentials) recorded.
 - Stimulus intensity variance discernible on recorded action potentials

PDMS Metalisation - Surface Ripples



2-D Surface contraction.

Evaporator $\sim 60^{\circ}\text{C}$

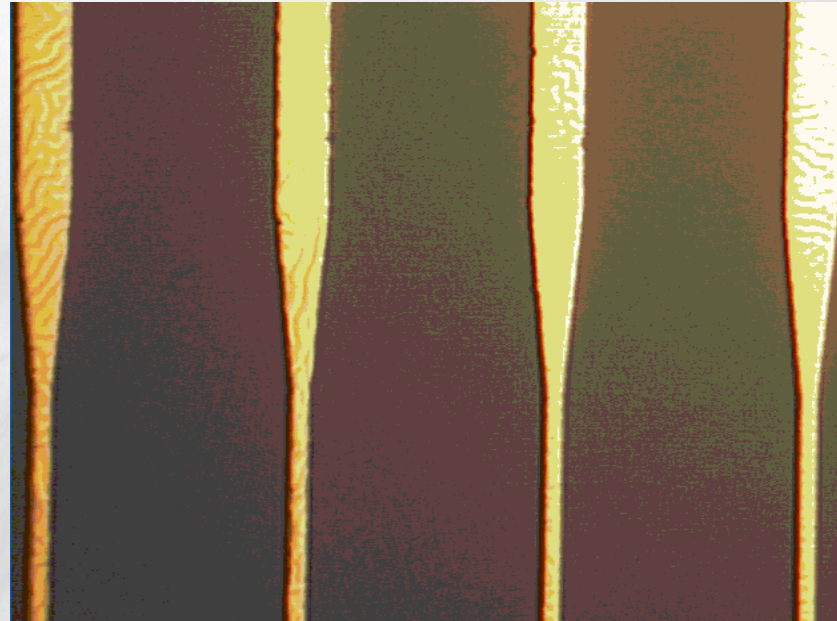
Room Temp $\sim 21^{\circ}\text{C}$

No breaks in film

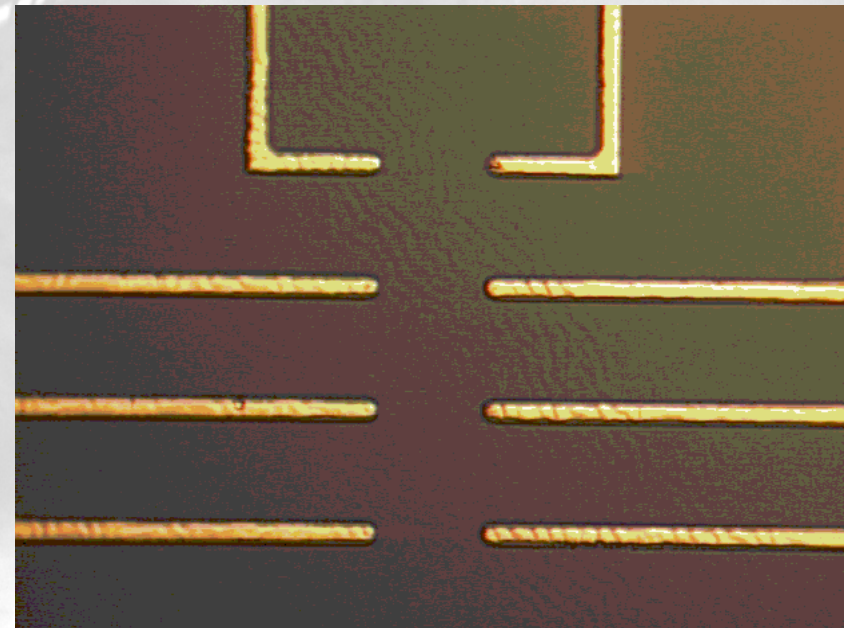
Common effect in many flexible materials

Can be an advantage - Flexing

PDMS Wire Fabrication

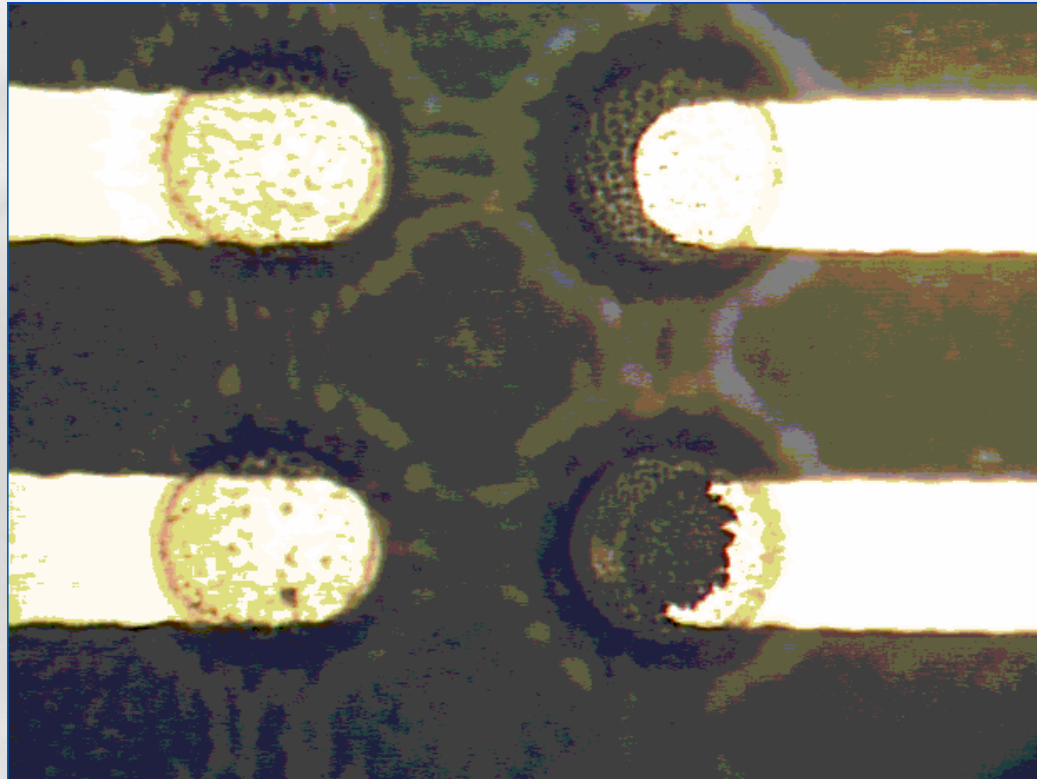


PDMS 45 to 14um



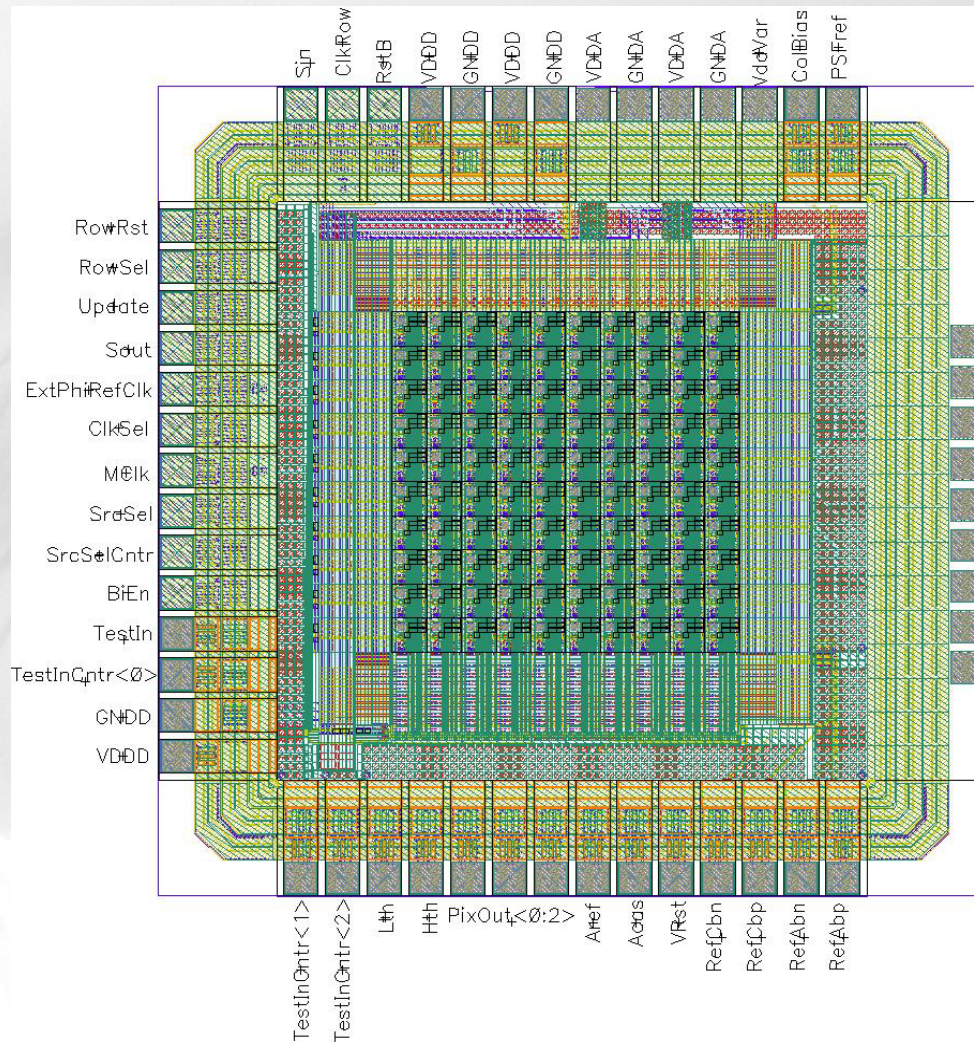
14 um Electrode region

PDMS Platinised Electrode



Small platinum deposit - Etch issues with other vias.

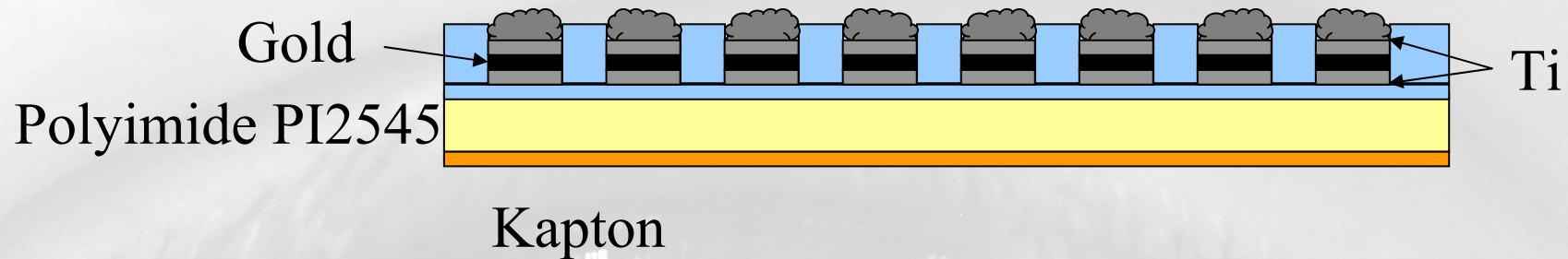
Active Pixel Sensor



42 Control Pins
9 Pixel readouts

$\pm 45\mu\text{A}$ to $\pm 140\mu\text{A}$
bi-phasic output current

Fabrication of Flexible Arrays



Thermal Planarising of Kapton

Spin coating of insulating Polyimide

Metal Adhesion promoting layer

Metallisation : Titanium 30nm / Gold 150nm - Pattern

Surface passivation - Selective surface etch.

Platinisation - Impedance reduction measure

Fabrication of Flexible Arrays(2)

- Require a scalable process
- Utilising biocompatible materials
- Need to comply with microfabrication techniques. - Etching, metalisation etc.