CMOS Technologies for Retinal Prosthesis

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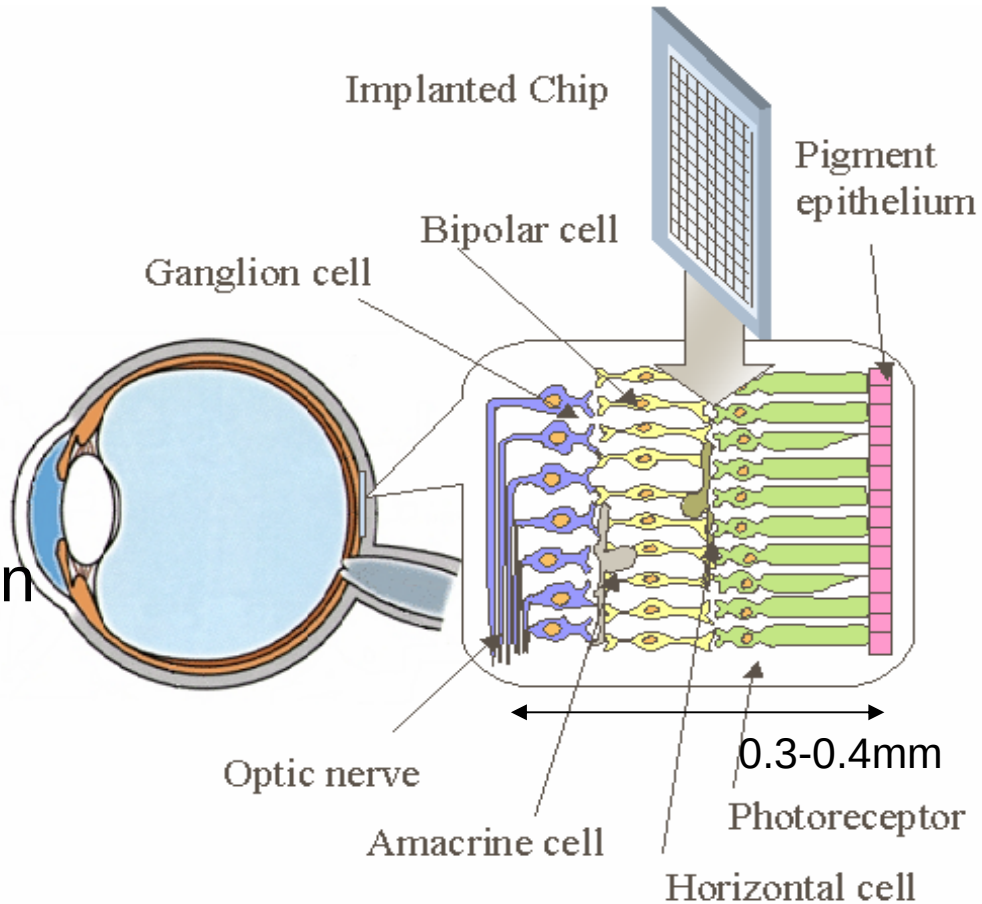
Overview of retinal prosthesis

- Enables blind patients to partially regain their vision.
- Retinitis pigmentosa (RP), Age-related macular degeneration (AMD)
  - Most of retinal cells are alive
  - Photoreceptor cells are degenerated
  - No remedies

→ Electrical stimulation to the rest of retinal cells causes visual sensation (phosphene)



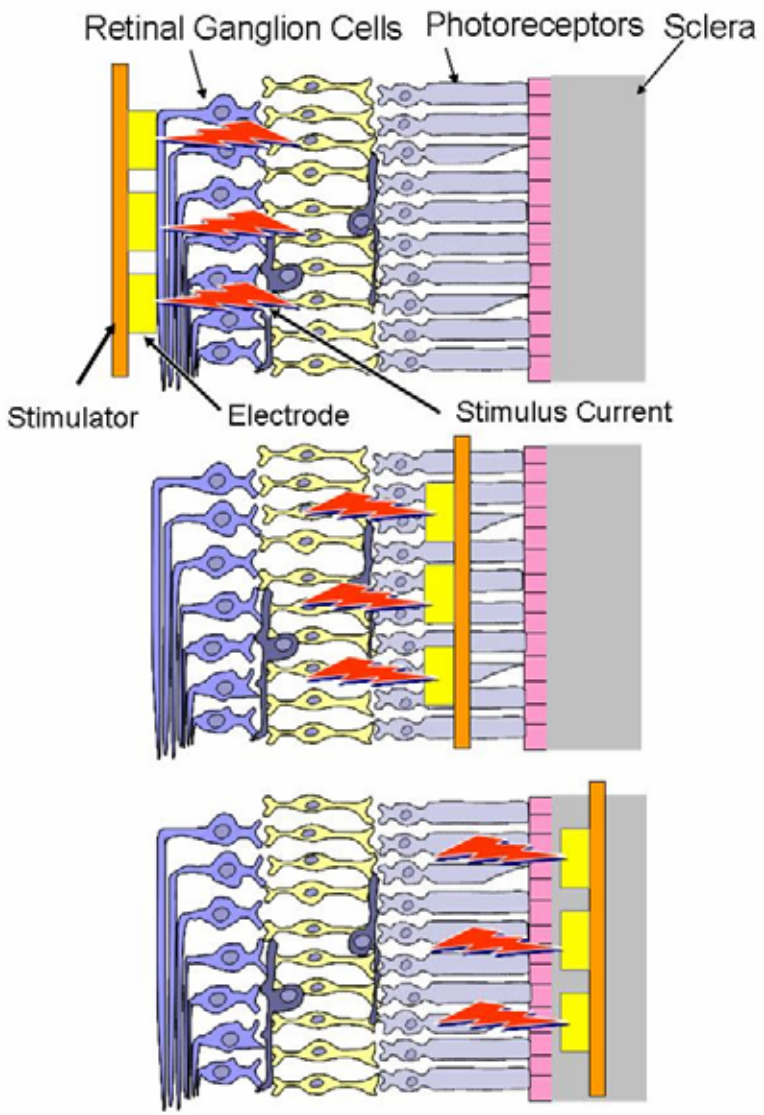
Retinal prosthesis devices

- Implantation place
  - Epi-retina
  - Sub-retina
  - STS
    (Suprachoroidal transretinal stimulation)
    (Sclera pocket)
- Advantage of STS
  - Easy to implant
    - No need to insert a stimulator into an eye ball

Epi-retina

Sub-retina

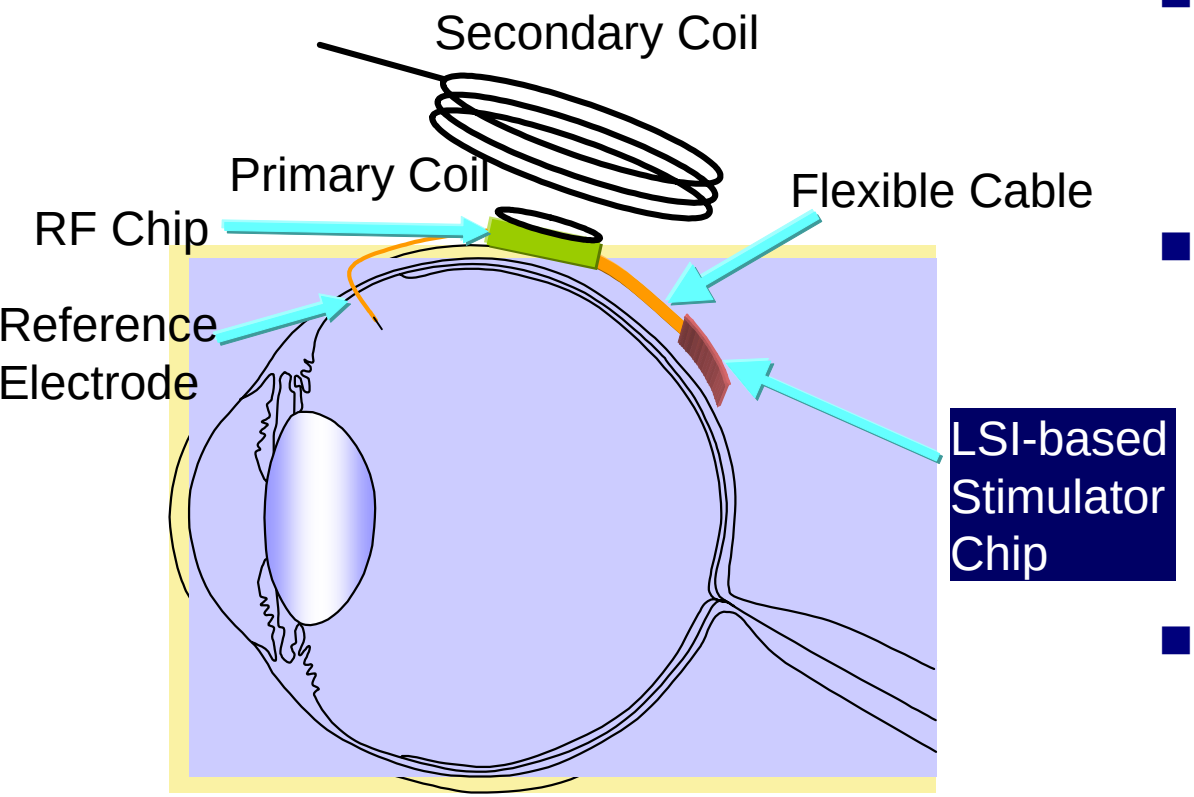
STS



Goal and challenge

- Advantages of STS
  - Less complicated implantation surgery
  - Less invasive to the retina and chip
  - Replaceable
  - Choroid as an effective heat sink
  - Wider area of retinal stimulation
    → Suitable to large number of stimulus electrodes
- Goal
  - 1000 electrodes
    - Enough to see objects clearly
- Present status
  - Successful acute clinical trial by Osaka Univ. Medical School with 9-electrode
    - Threshold current is comparable with that of epiretina.
- Challenge
  - Bendable stimulator with large number of electrodes

CMOS Retinal Stimulator Device



- Approach: Implantation in sclera pocket
  - STS (Suprachoroidal Transretinal Stimulation)*
- Introduction of LSI →versatile functions
  - photosensors
  - MUX/DMUX
  - signal processing...
  - Power/data supply →RF
- Issues
  - Electrodes on flexible substrate → Bendable
  - Packaging

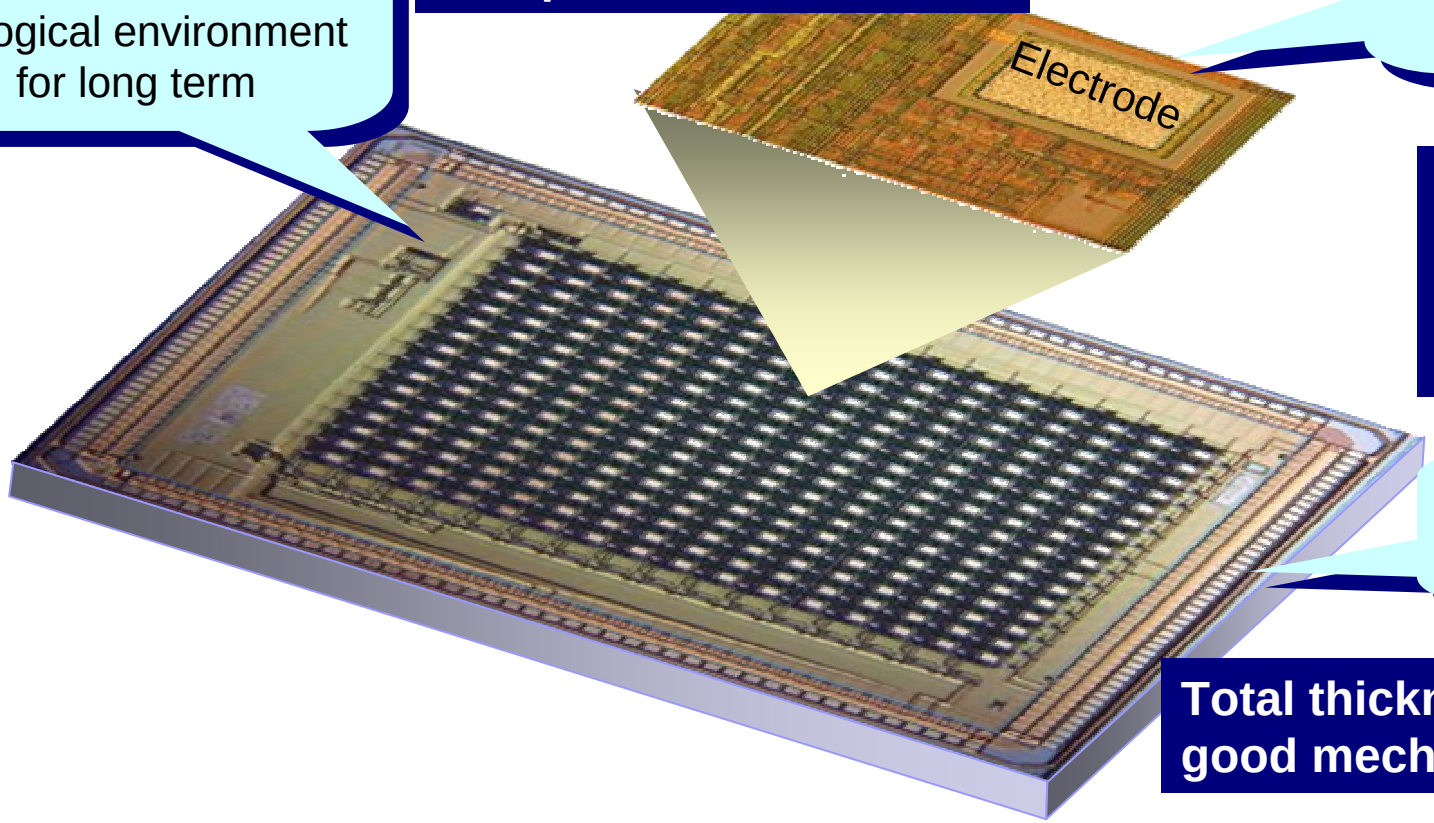
* H. Kanda, T. Morimoto, T. Fujikado, Y. Tano, Y. Fukuda, H. Sawai, "Electrophysiological Studies of the Feasibility of Suprachoroidal-Transretinal Stimulation for Artificial Vision in Normal and RCS Rats," Invest. Ophthalmol. Vis. Sci., **45**, 560, 2004.

Issues for implantable CMOS retinal stimulator

Packaging with biocompatible materials except for electrodes

Chip surface: SiN
→ dissolved in biological environment for long term

Electrode: Al
→ No biocompatible Electrolysis



Electrode material with enough charge capacity (Pt, TiN, IrOx ...)

Thick substrate (~500 μm)

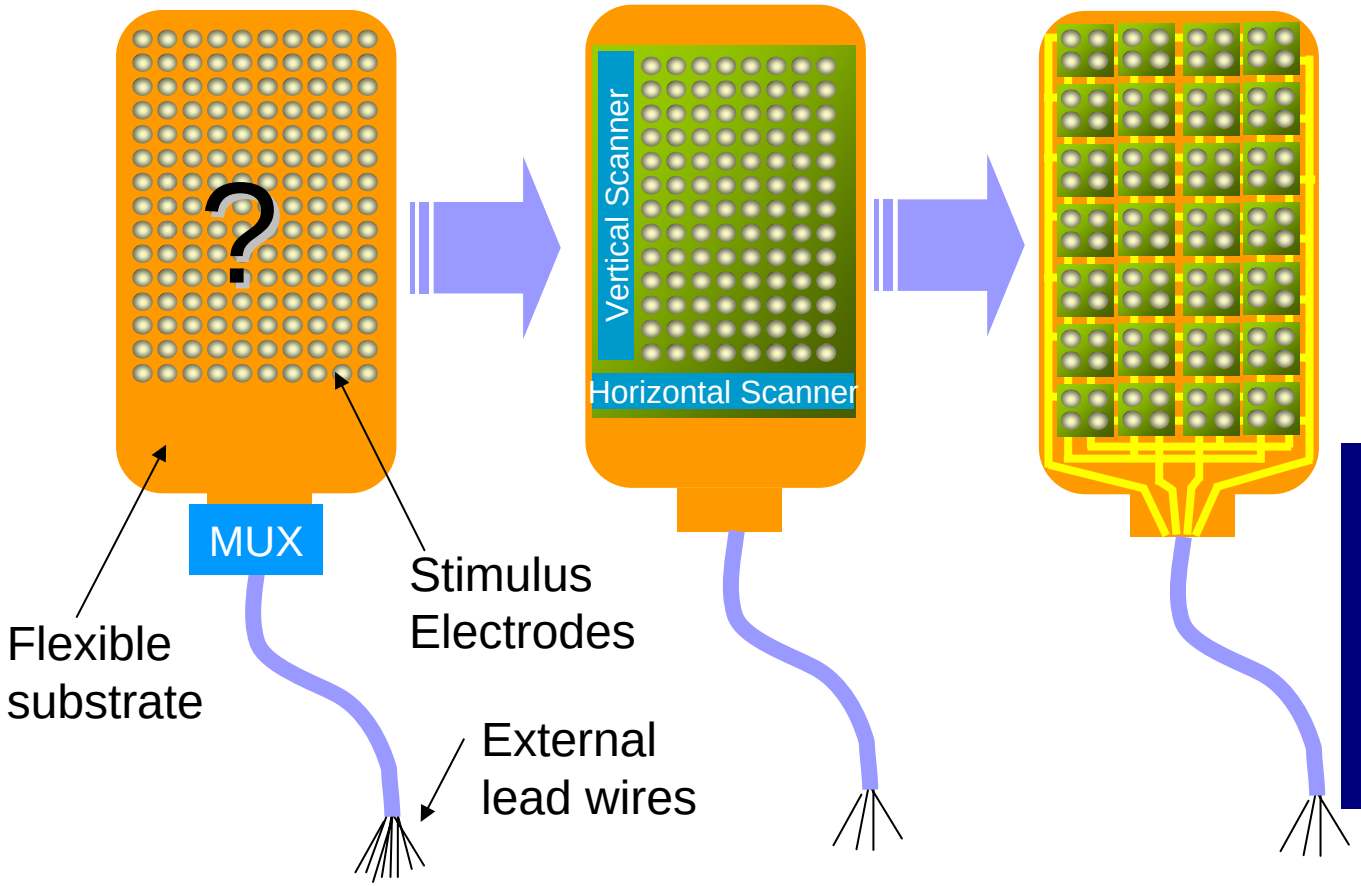
Total thickness < 200 μm with good mechanical strength

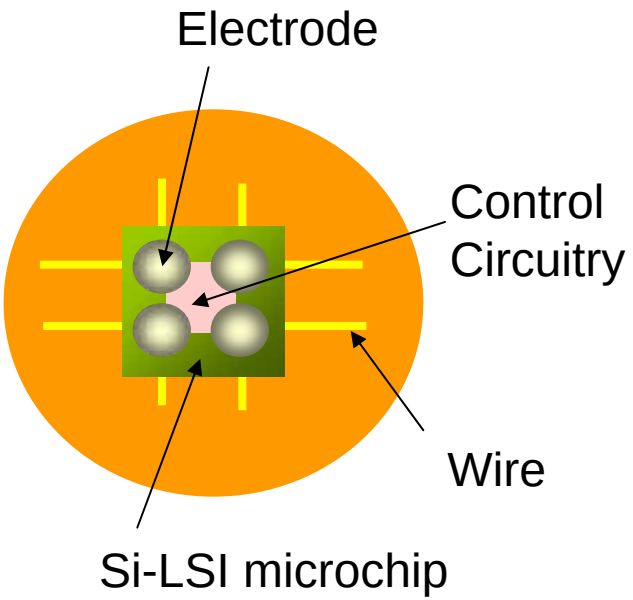
J. Ohta *et al.*, IEEE Eng. Med. & Biol. Magazine **25** (5), 47-59, 2006.

Multiple microchip architecture – Smart electrode –

Limit of lead wire from electrode

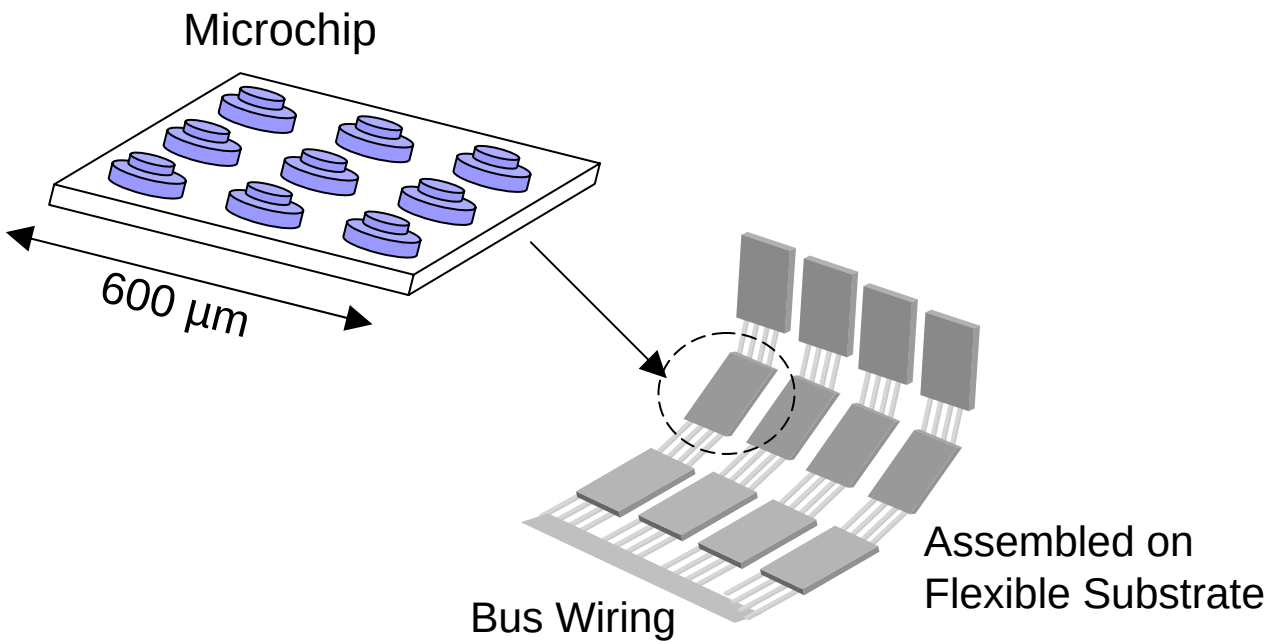
Si-LSI is fragile when thinned.





Si-LSI microchip:
Control circuitry & Electrodes
→ Decode the signal and relay it to the next microchip
→Only small number of wiring needed (4 in this case).

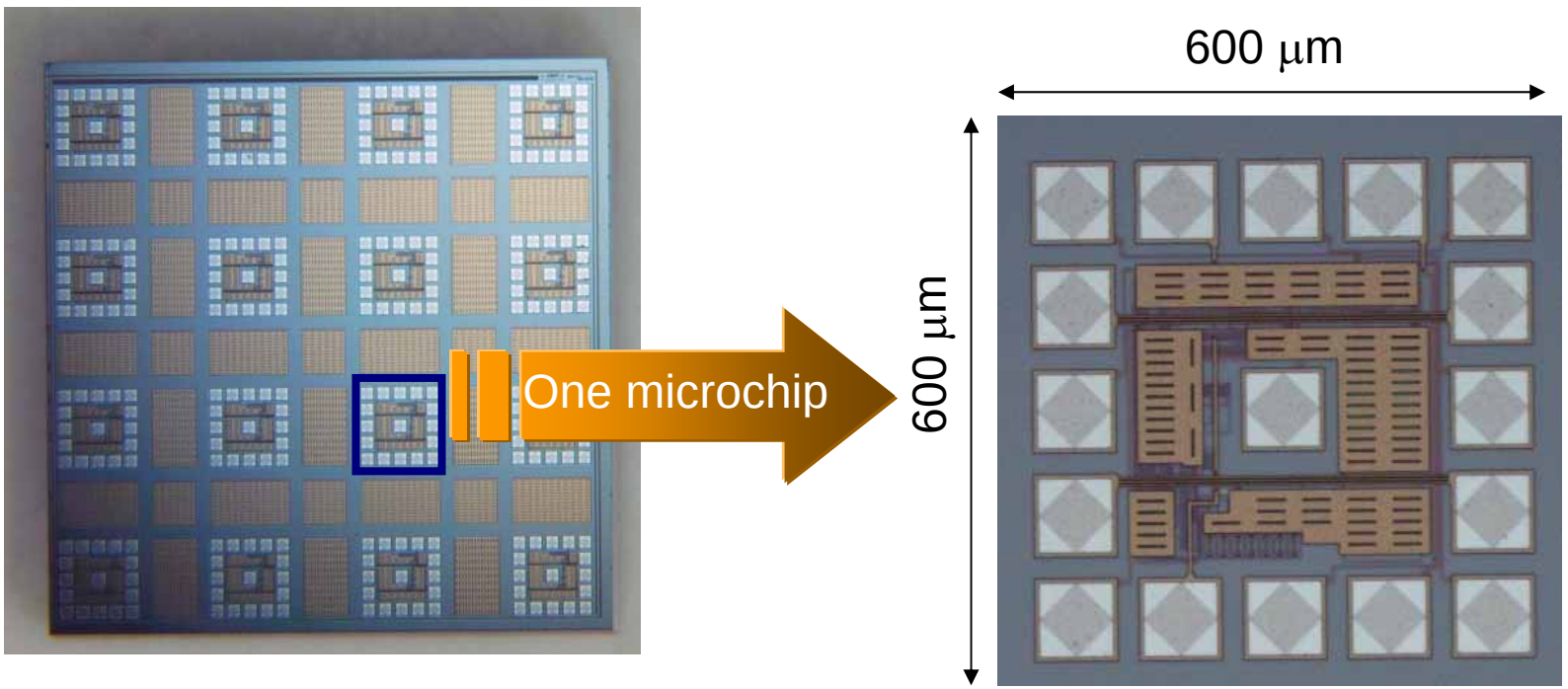
Multiple microchip architecture - extendible and flexible stimulator-



Place number of microchips on a flexible substrate
Each microchip is connected through bus wiring.
→Extendible and flexible stimulator

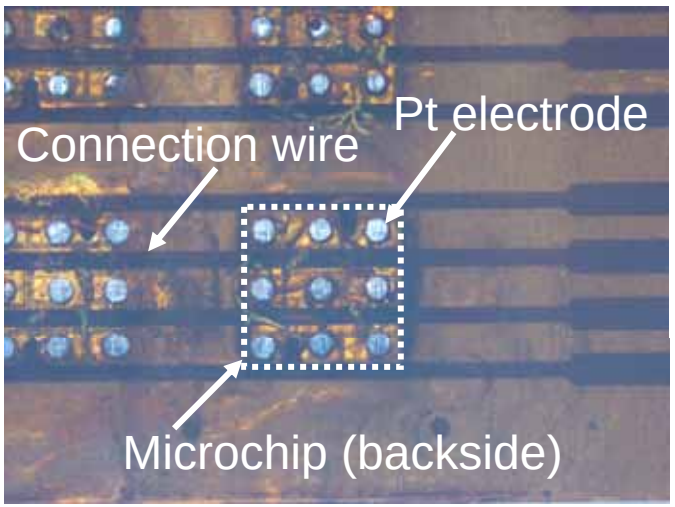
Microchips fabricated in standard CMOS technology

Die with 16 microchips



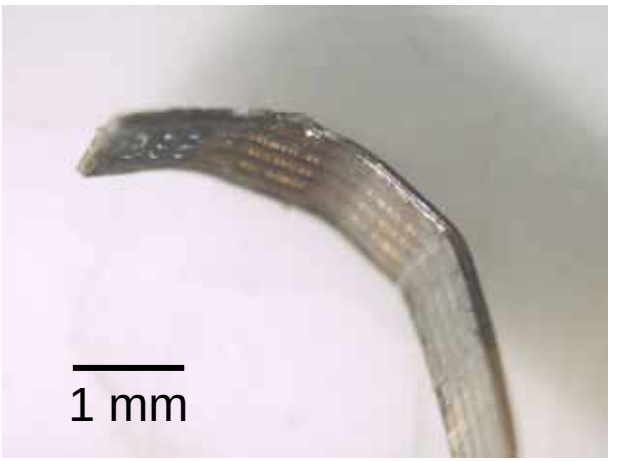
0.35 μm standard CMOS technology

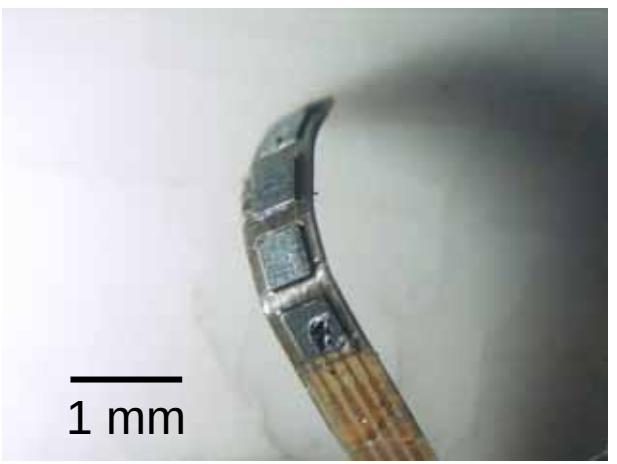
Fabricated Multi-Chip Flexible Stimulator



View from stimulus side

Pt/Au electrode: ~75 μmϕ





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Summary

- LSI-based multi-chip flexible stimulator for retinal stimulation
  - Multiple microchip-based stimulator
  - Flip-chip bonding of microchips
  - Large number of electrodes over 500-ch
  - Extendible, reliable and reproducible
  - Successfully evoked EEP in rabbit experiments
- Next steps
  - Ensure more reliability and bio-compatibility
  - Experiment with a stimulator integrated with larger number of electrodes
  - Improve charge injection performance with TiN or IrOx

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