University of Twente

An integrated single photon detector array using porous anodic alumina

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IWORID 2006, July 4th 2006

NIKHEF

University of Twente
The Netherlands

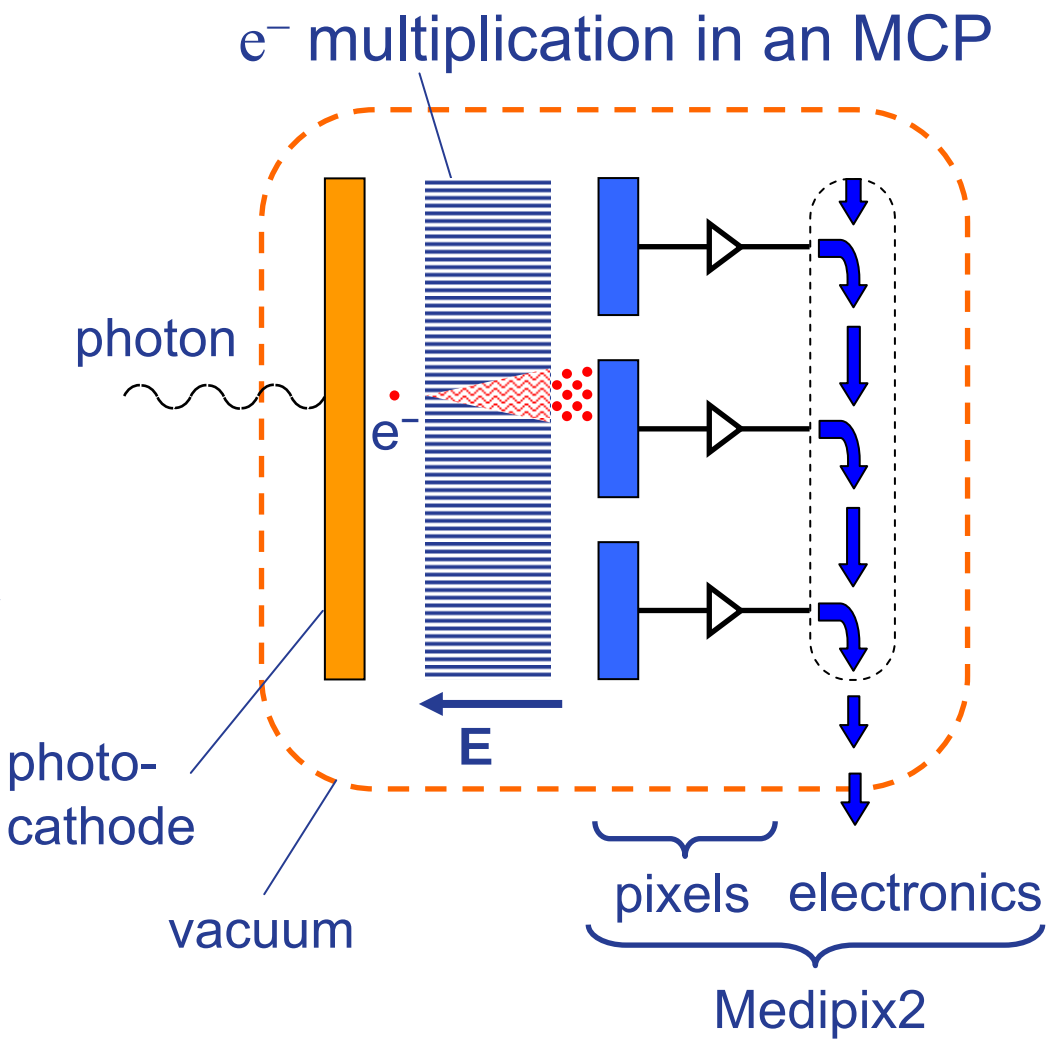
Overview

- Goal:
  A prototype single photon detector array manufactured monolithically on an imaging ASIC like Medipix2
- Idea and motivation
- Requirements of the MCP
- First experimental results
- Conclusions and outlook

The idea

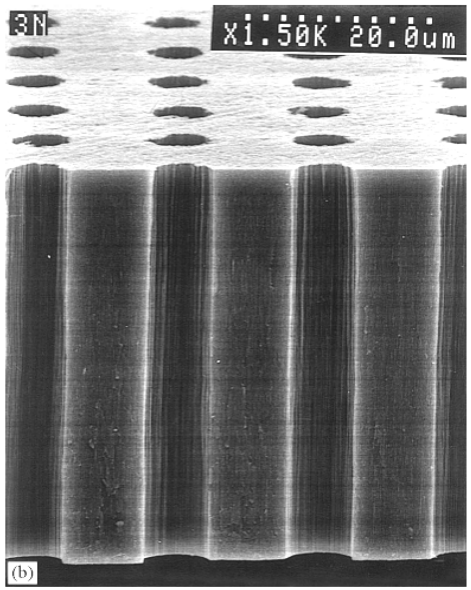
Detector system:

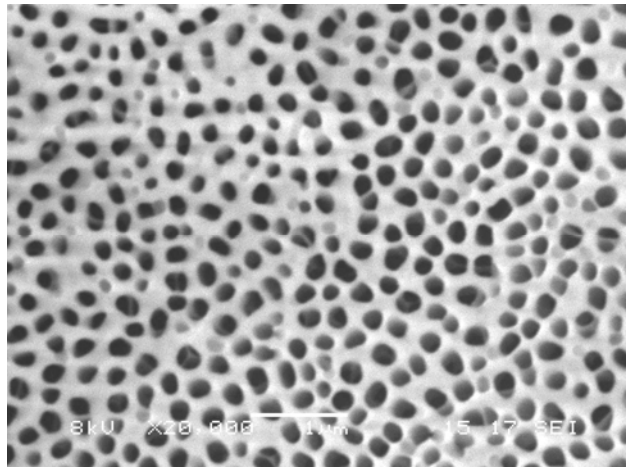
- Photo-Cathode
- Electron multiplication structure
- Medipix imaging ASIC



Existing Knowledge

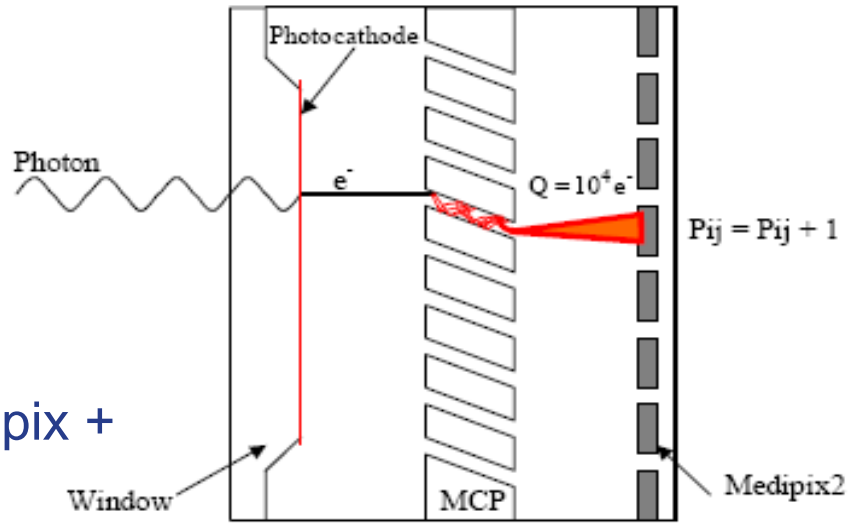
Belarus academy of science +
Samsung Research:
Alumina MCPs



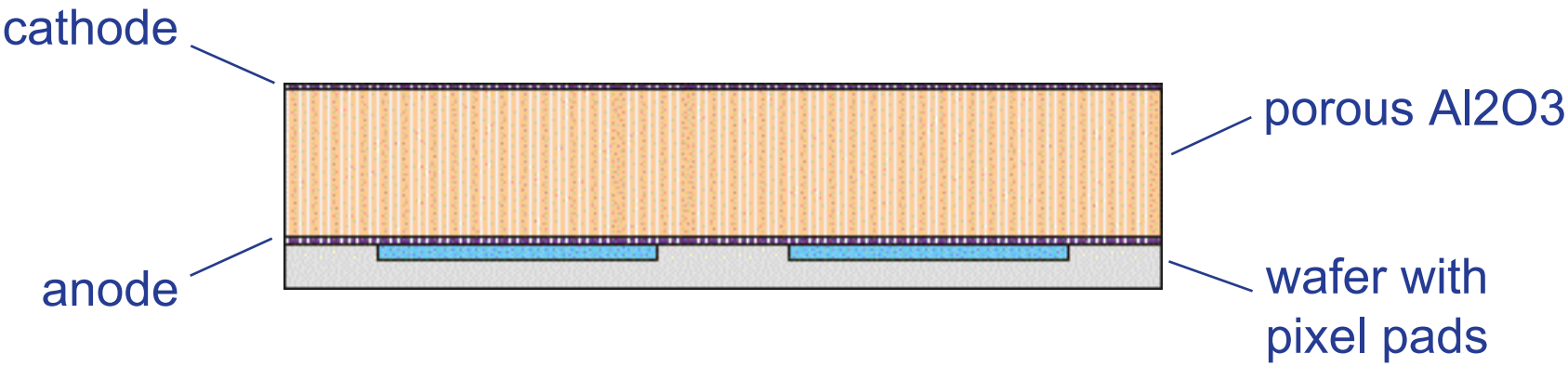


Anodic alumina made in
MESA+ (Univ. Twente)

Vallerga *et al. (UC Berkeley):* Medipix +
discrete MCP + photo-cathode



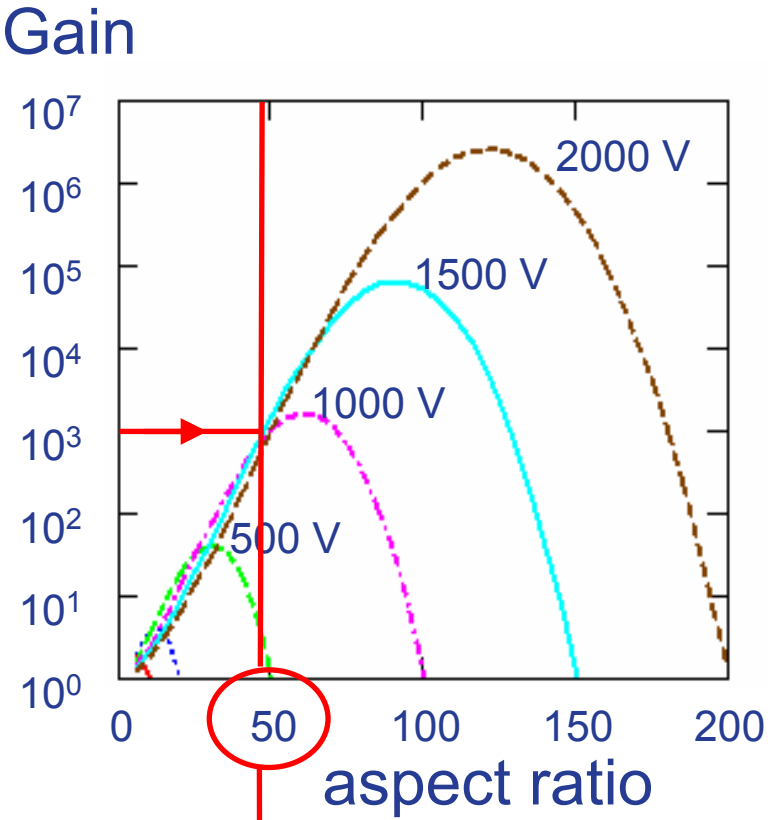
The porous alumina MCP detector



Using micro-electronics technology:

- other geometries
- structural integrity (substrate)
- different materials
- different voltages ?

Geometry Requirements I



- Saturation at gain-diameter ratio of around 10^{11} -/m
- Lower limit: 10 nm
  → No Nano-Channel Plate
- MCP with G > 1000
  → d > 0.1 μm and α > 50
  → L > 5 μm

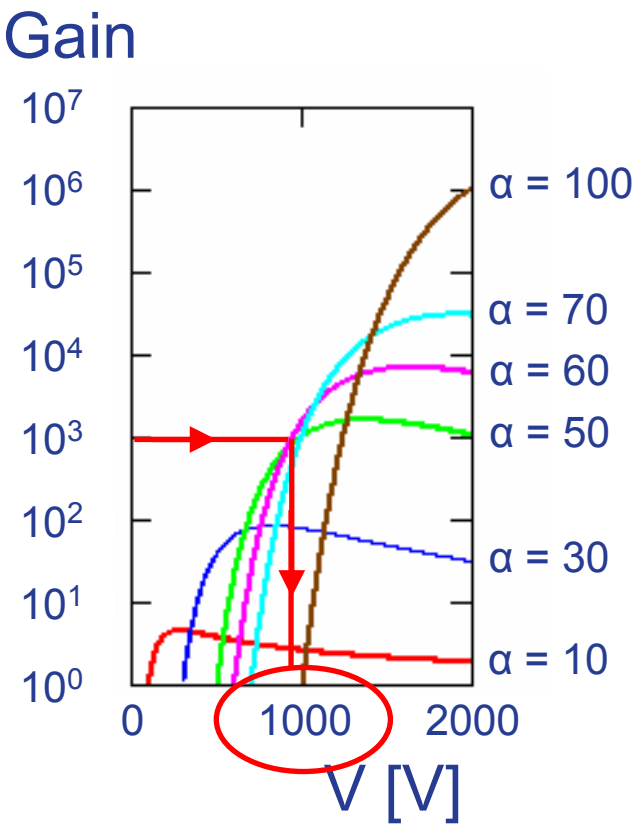
Technology: α lower

Gain limit: α > 50

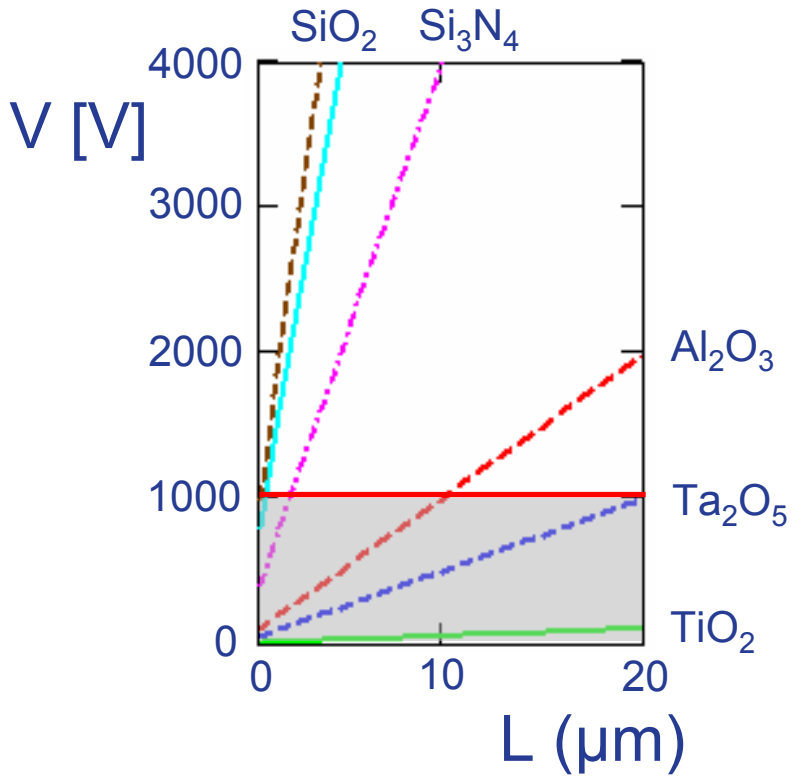
Standard models by Wiza (NIM '79) and Eberhardt (Appl Opt. '79)

Geometry Requirements II

Varying aspect ratio (α)



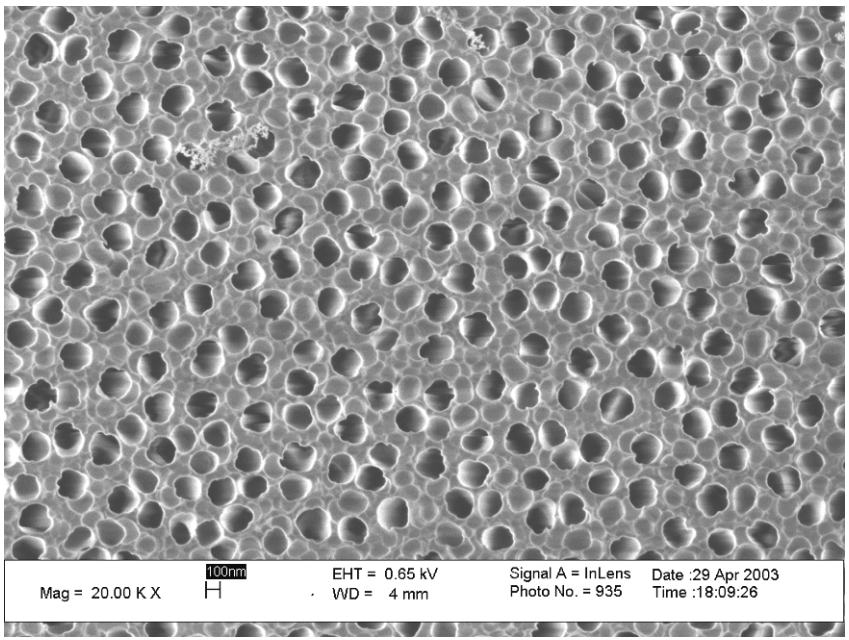
Dielectric strength limits voltage

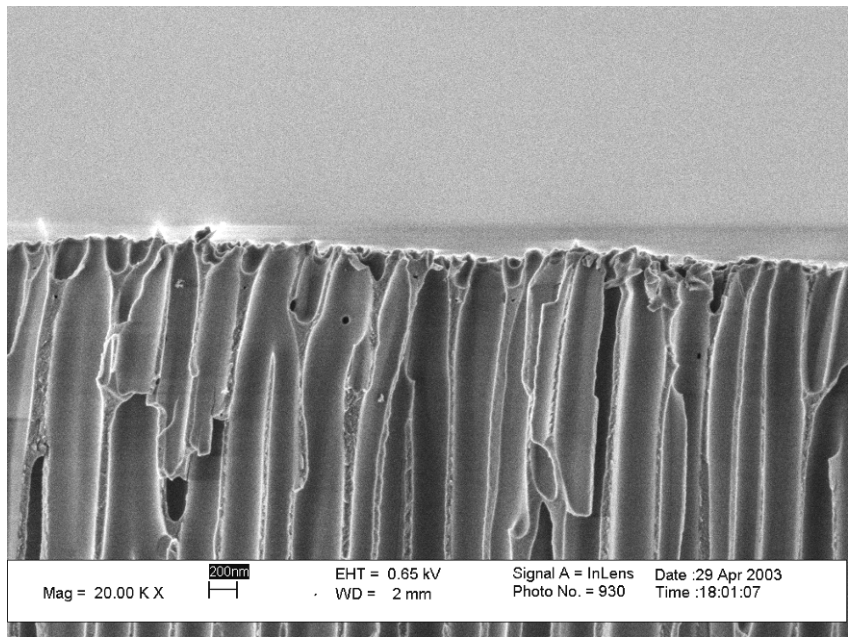


Standard models by Wiza (NIM '79) and Eberhardt (Appl Opt. '79)

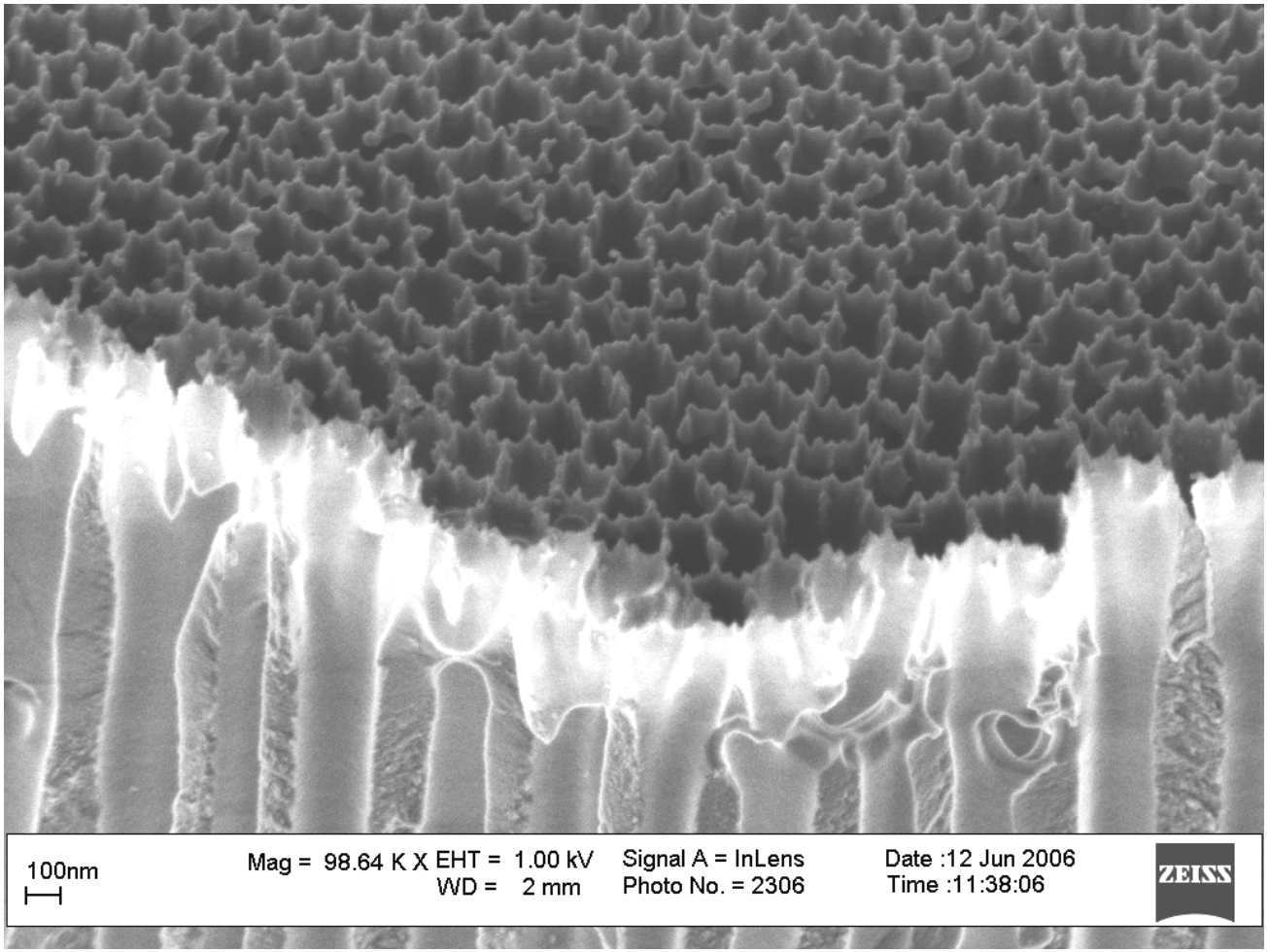
Discrete porous alumina disks

- Available from Whatman for fluid filtration, 60 µm thick, 0.2 µm pores





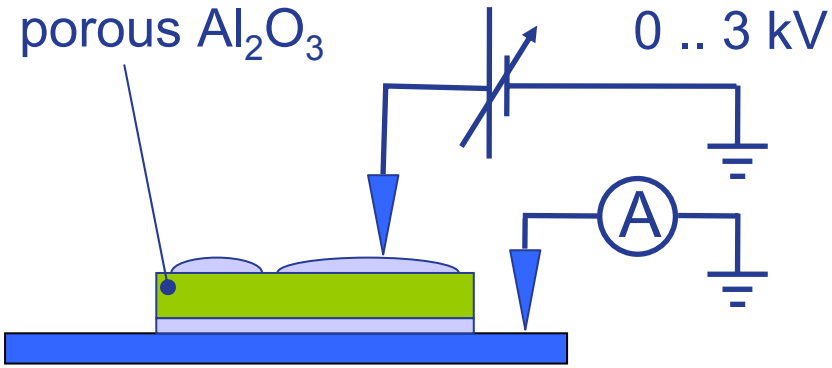
Metallization of alumina disk

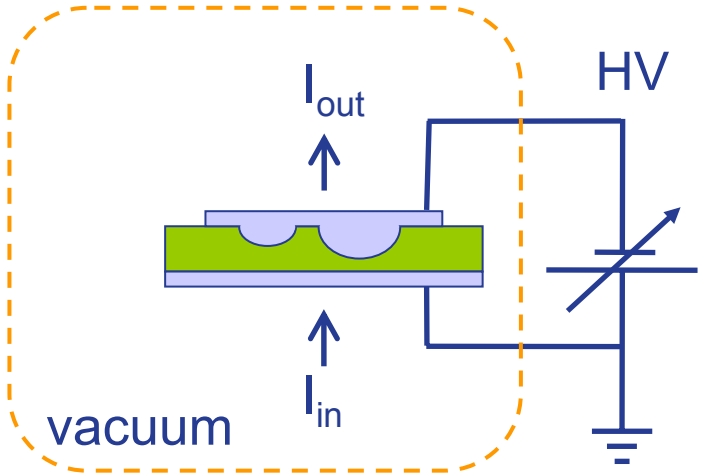


- 10 nm Au/Pd
- Pores still open
- Au penetration around 0.2 µm

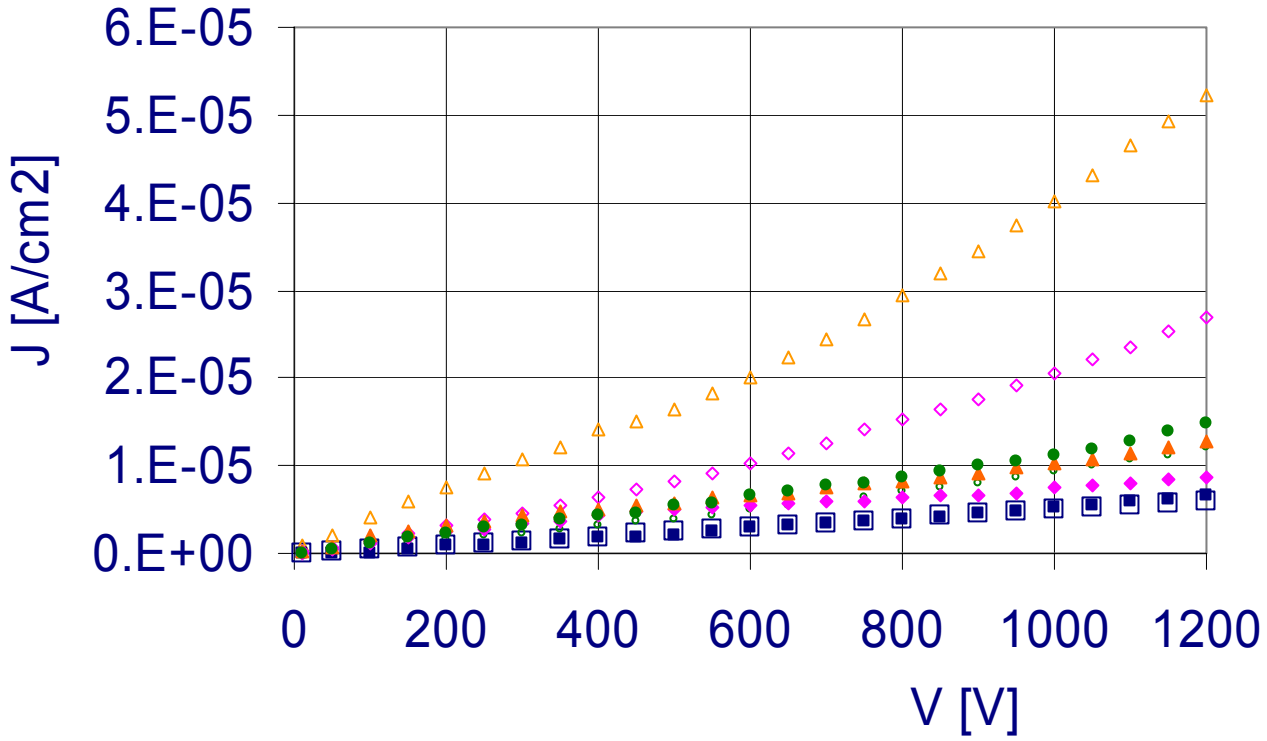
Measurements on alumina disks

- Metal contacts defined
- Capacitance-Voltage measurements prove functionality
- Investigation of bias capability
- Functional measurement on dimpled disks



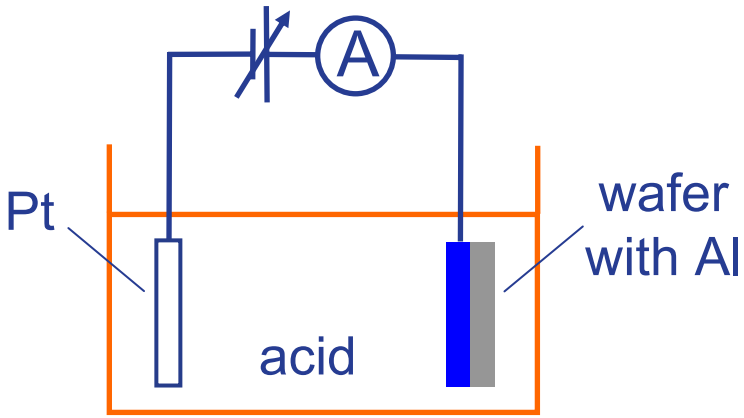


Bias curve for alumina disks

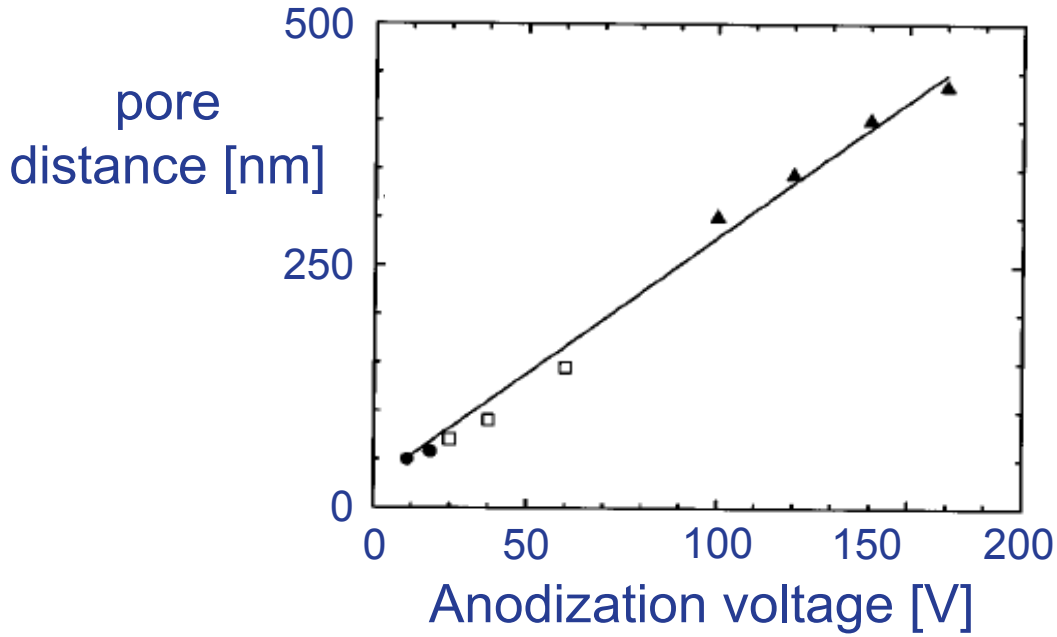


- Some samples are clearly more leaky than others
- Current densities not excessive
- Area of Medipix2 pixel (55×55 μm^2) → current < 0.6 nA

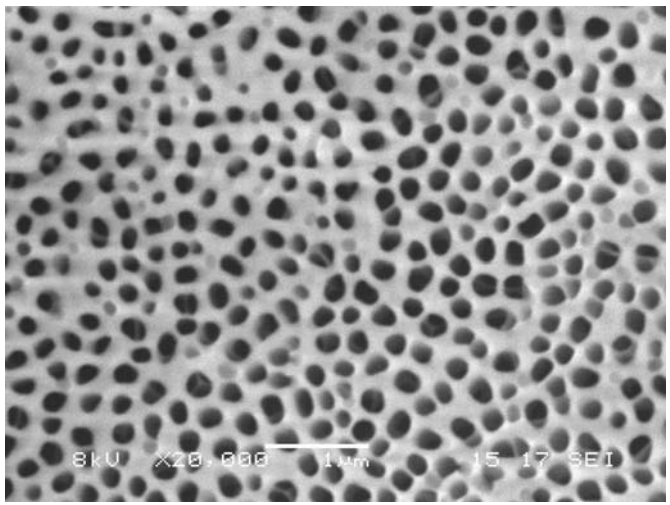
Porous Al_2O_3 made by anodization



$2\ Al + 3\ H_2O \rightarrow Al_2O_3 + 3H_2$



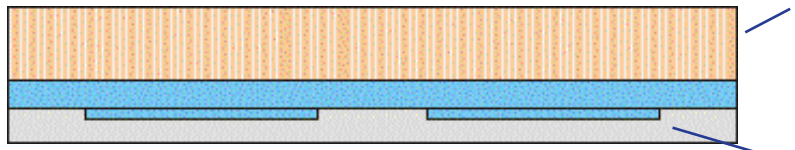
A.P. Li *et al.*, *(MPI Halle), J. Appl. Phys. 1998*



3 wt% Phosphoric acid

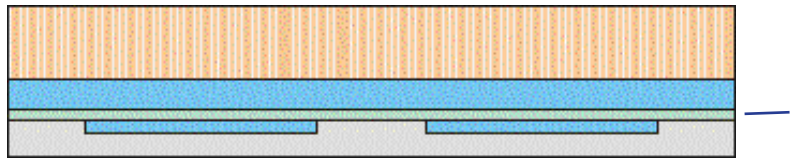
~ 100 - 150 V → 200 nm

Integration challenge



☹ Anodization into bond-pads

☹ Incomplete anodization

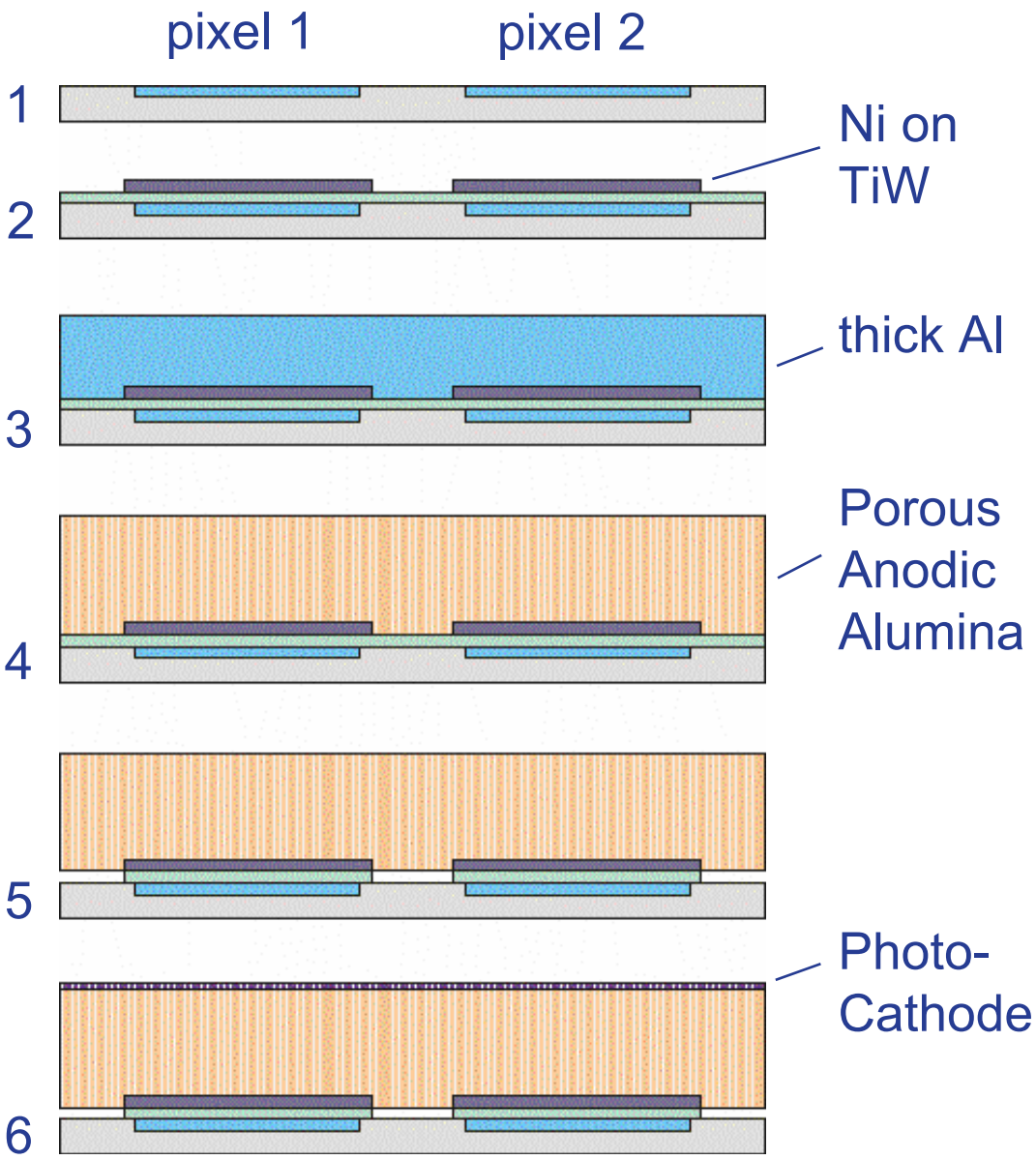


☺ Sub-electrode acts as stopping layer

☹ Sub-electrode shorts all pixels

😐 No photo-lithography

Compound sub-electrode



- Etch Ni selective to TiW with HCl or HNO_3
- Ni and TiW both act as counter-electrode
- Etch TiW selective to Ni with F plasma (dry) or H_2O_2 (wet)

Conclusions

- Integrated MCP based on porous alumina
- Promising experiments on discrete disks
- Functional metallization
- Reverse bias > 1500 V, limited leakage
- First anodization experiment successful
- Integration scheme for wafer-scale post-processing

Acknowledgements:
Victor Blanco Carballo
Max Chefdeville
Harry van der Graaf
STW

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University of Twente
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