Resistance Reproducibility & Thermal Coefficient of ALD coatings at Argonne

(LAPD project collaboration meeting 06-10-2010)

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Outline

- LAPD Project: Importance of atomic layer deposition (ALD)
- Development of novel resistive coatings by ALD at Argonne
- Electrical measurements and thermal coefficient study of resistive coatings
- Next plan and Summary

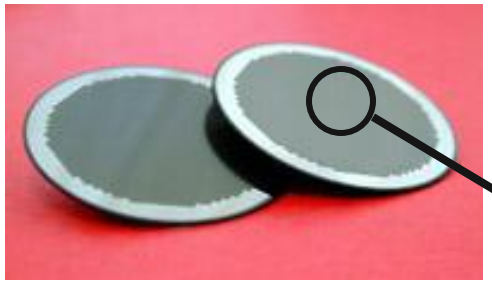
LAPD project background

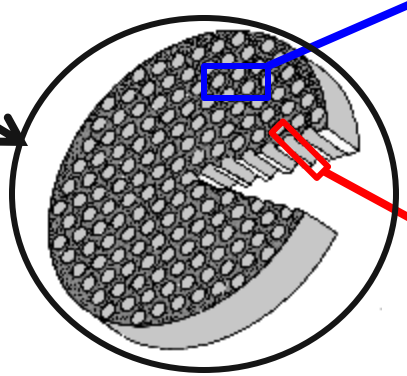
- Apply the basic concept of "micro-channel plate" (MCP) detectors to the development of large-area photo-detectors (LAPDs) [8"x8" MCP] with quantum efficiencies and gains similar to those of photo-tubes.

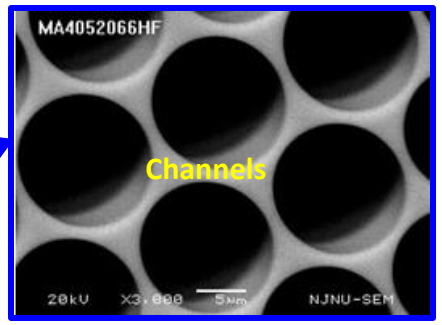
- To design and fabricate "economical" robust LAPDs that can be tailored for a wide variety of applications that now use photomultipliers.

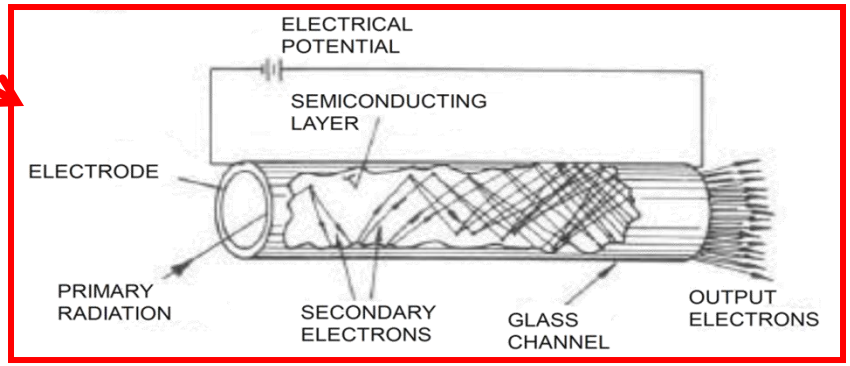
- LAPD fabrication divided into sub-projects:
  1. Development of higher quantum efficiency photo-cathodes
  2. Use of Atomic Layer Deposition (ALD) to control the chemistry and surface characteristics of resistive and secondary emission surfaces on MCPs
  3. Electronics
  4. Assembly
  5. Testing

“Microchannel plate” detectors

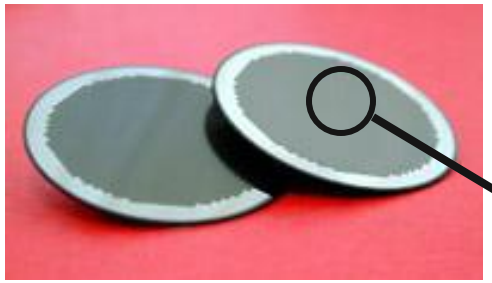


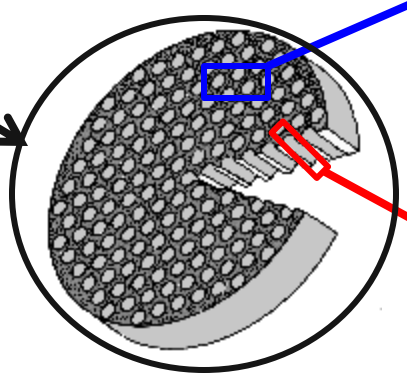


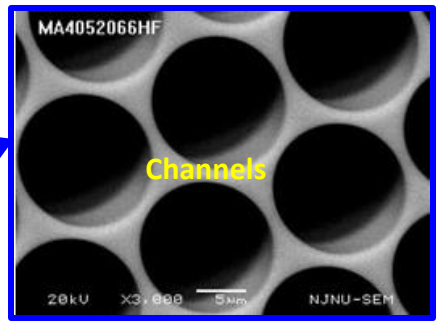


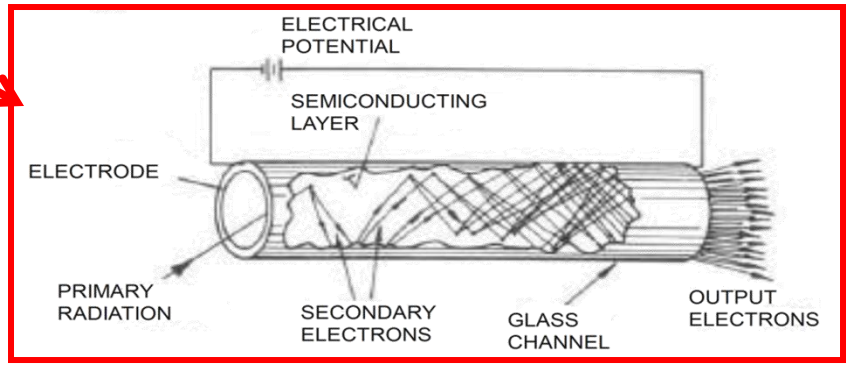


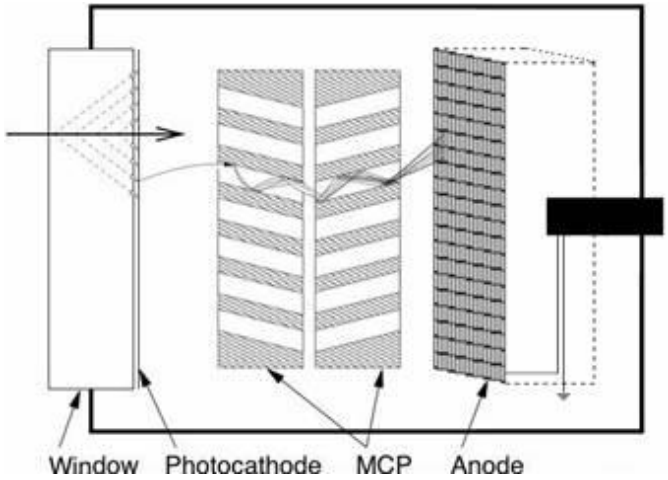
“Microchannel plate” detectors





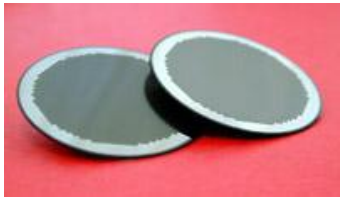






- **Continuous-dynode electron multiplier in presence of a strong electric field (~ 1kVA/MCP)**
- **Electron amplifier (x10^4-10^7)**

MCP fabrication

Conventional MCP Fabrication
➢Draw lead-glass fiber bundle
➢Slice, polish, chemical etch
➢Heat in hydrogen
➢Top/Bottom electrode coating (NiCr)
Drawbacks
➢Expensive
➢Resistance and secondary emission properties are linked
➢Limited optimize MCP performance for applications where lifetime, gain, substrate size, composition and thermal runaway are important


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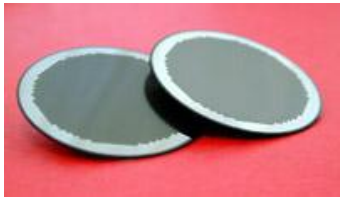
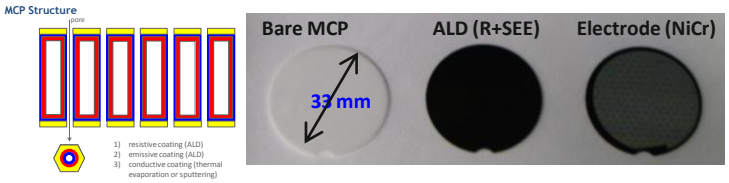
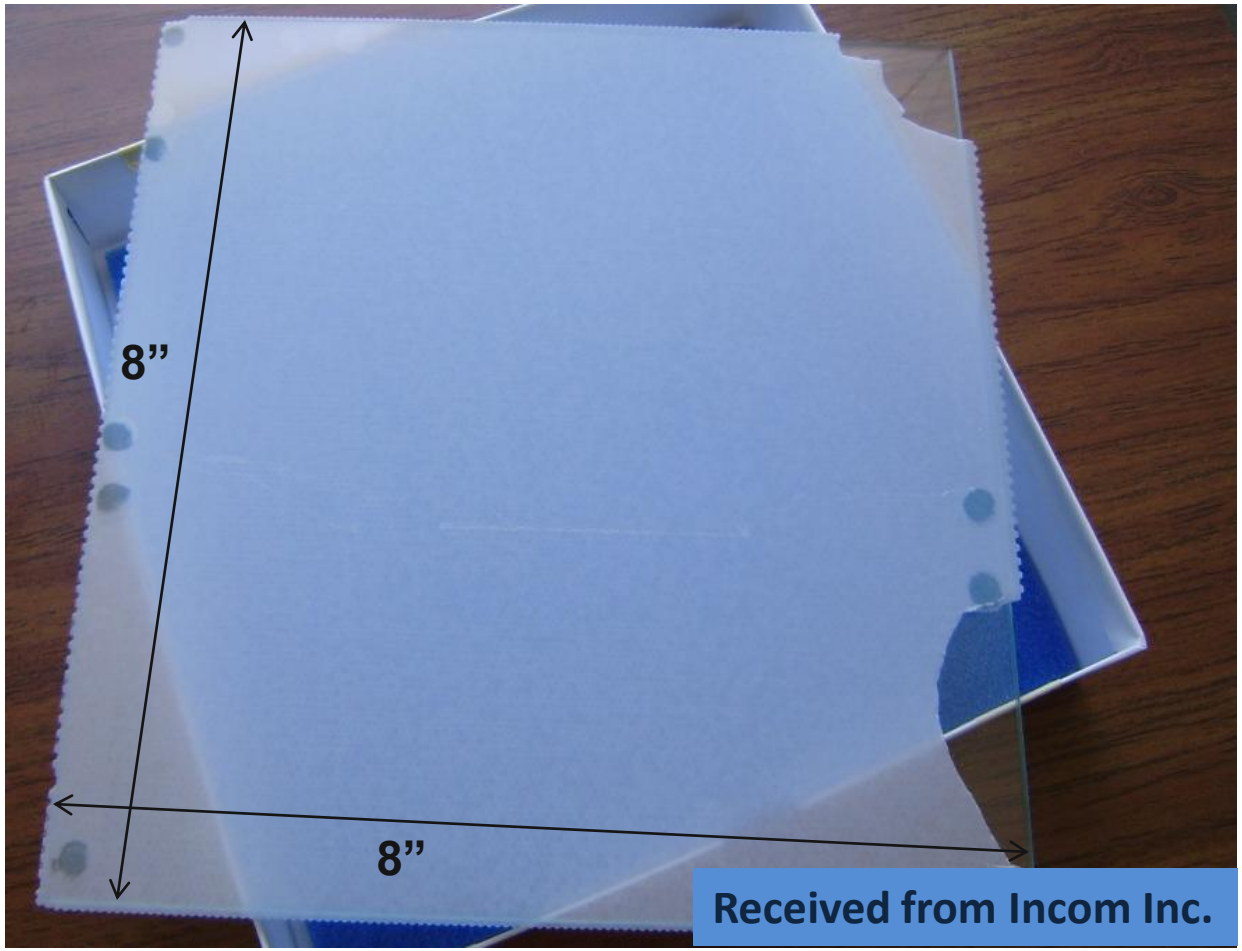


LAPD Approach
➢Start with porous, non-lead glass
➢ALD (resistive + SEE layer) coating
➢Thermal treatment
➢Top/Bottom Electrode coating (NiCr)
Advantages
➢Independent control over composition of Resistive and SEE coating
➢Low thermal coefficient of resistance
➢Applicable: Ceramics, SiO2, plastics, polymers MCPs
➢Low cost (No major issue for scale-up with ALD)


Ultimate goal

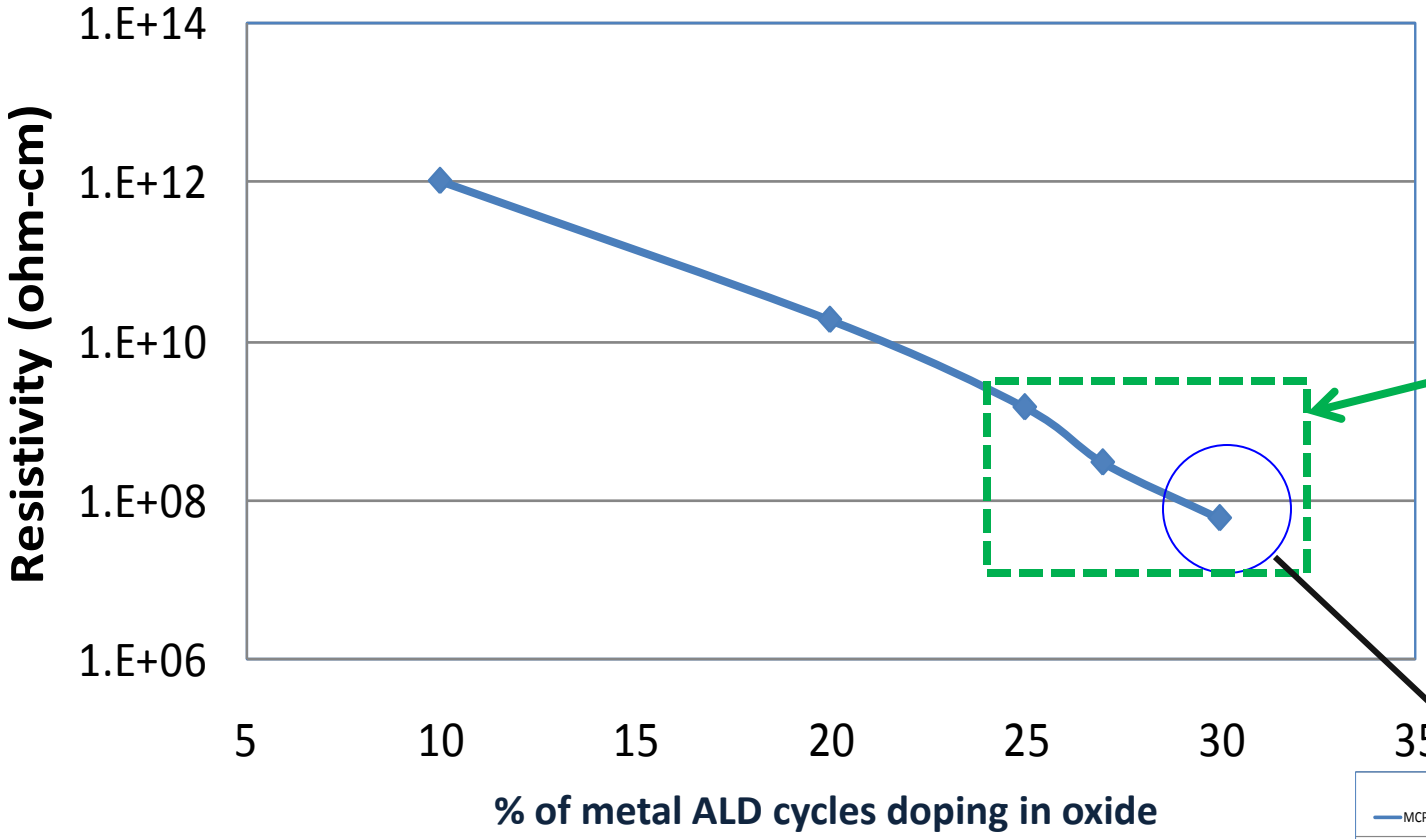


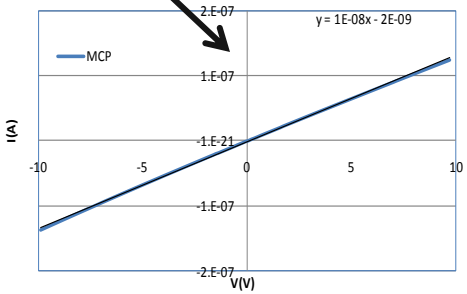
Create workable 8”x8”MCP with ALD

Materials selection for functionalisation of MCPs

- **Secondary electron emission coating:**
  - **Al2O3, MgO, Diamond, MgF2, ……**
- **Resistive coating: Composites of Metal and insulator**
  - **Variety of material**
  - **Reliability**
  - **Scaling and Cost**
- **Why ALD process?**
  - **Atomic level control over composition, thickness,**
  - **Excellent uniformity and conformal coating on very high aspect ratio (>98%)**
  - **Large area deposition, batch processing (low cost)**
- **Developed workable few novel resistive coatings by ALD process:**
  - **Submitted patent application**
  - **Here after named as Chemistry-1, 2, ….**
  - **Tested with different ALD grown SEE layers**

ALD coating on MCP: Chemistry #1 Resistivity

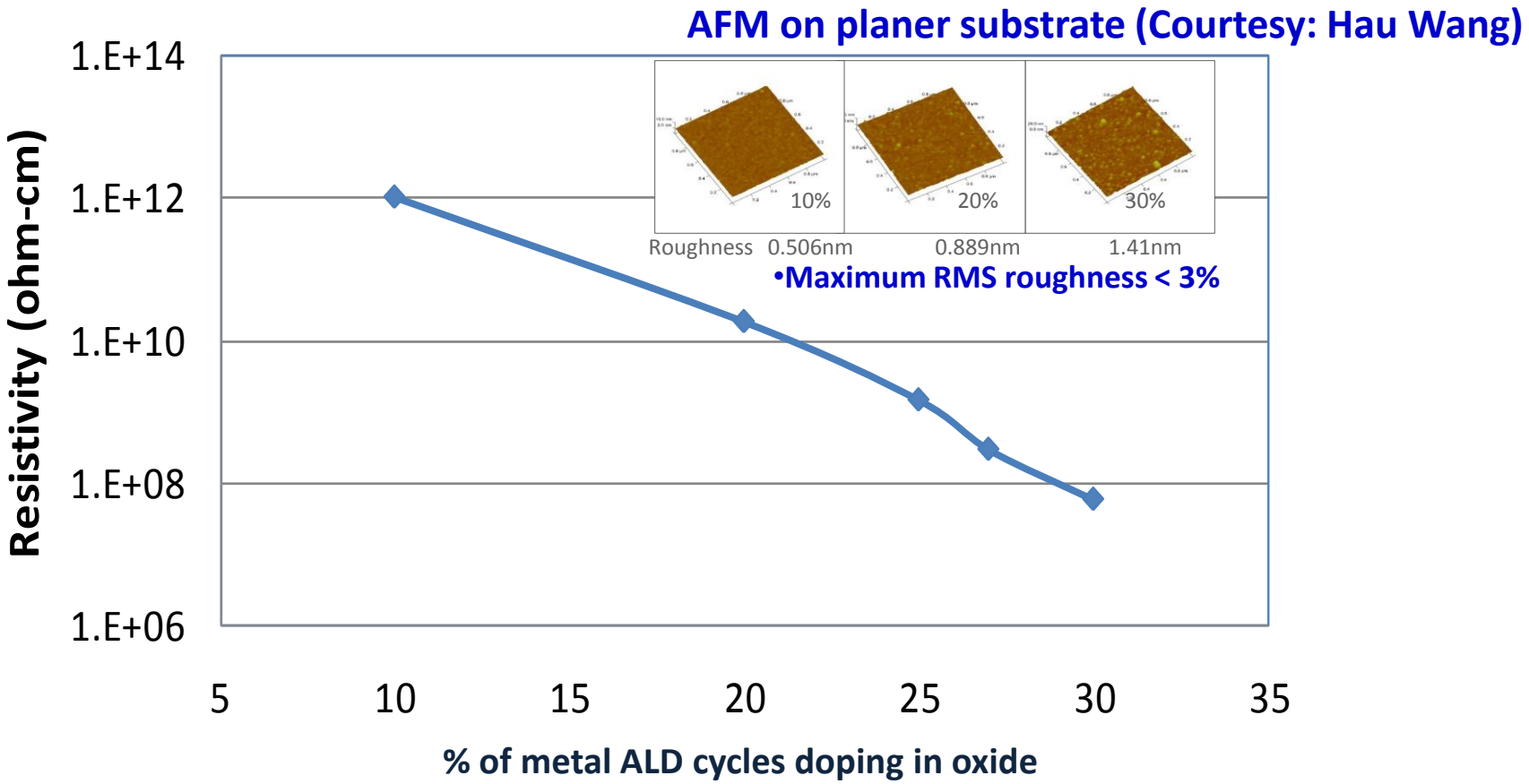




- Good control over resistivity
- Several MCP pairs shows good "Gain data"
  - -Matt Wetstein will present status later

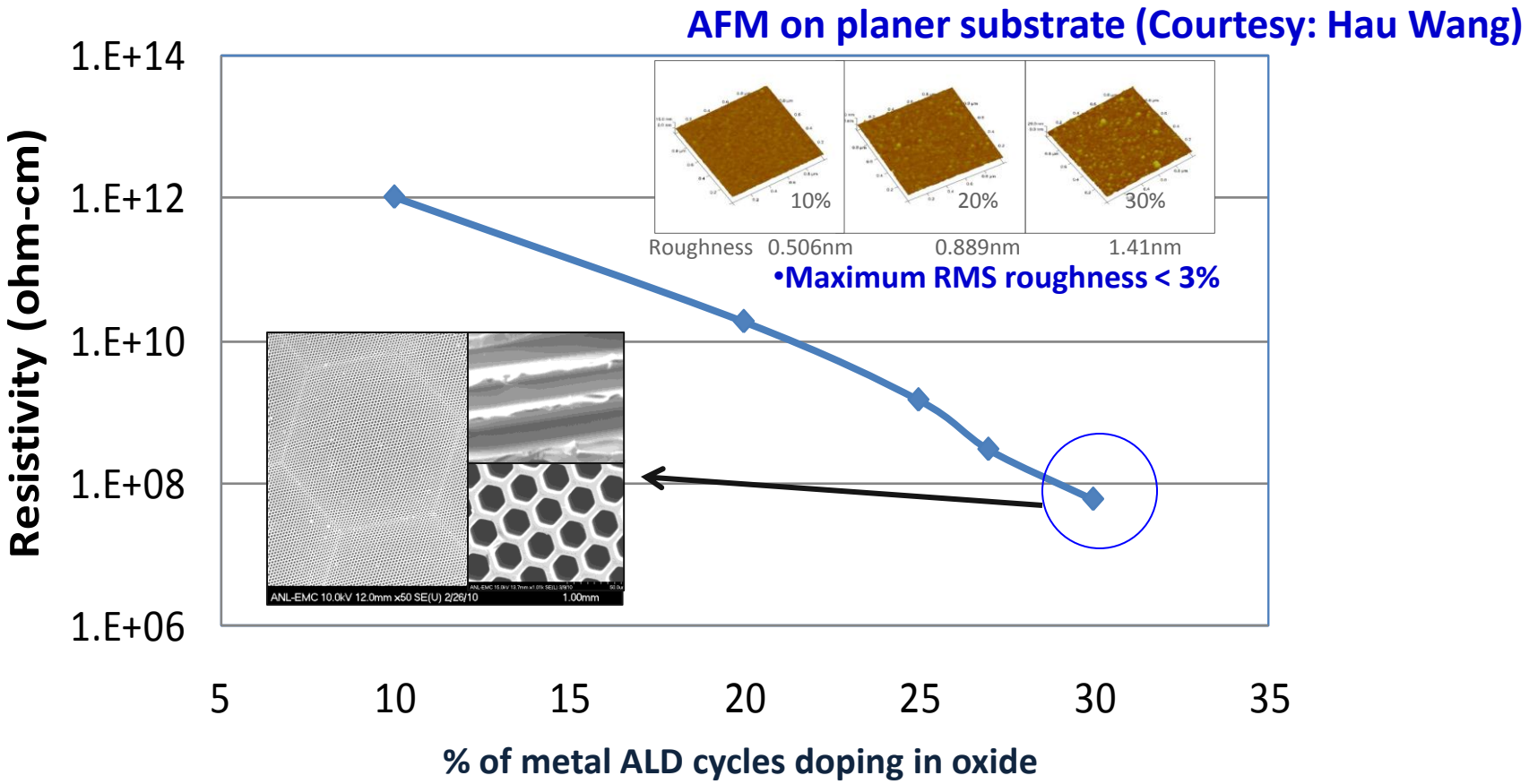
•Linear I-V on MCP

ALD coating on MCP: Chemistry #1



- **Uniform and smooth ALD coating on Si(100) surface**

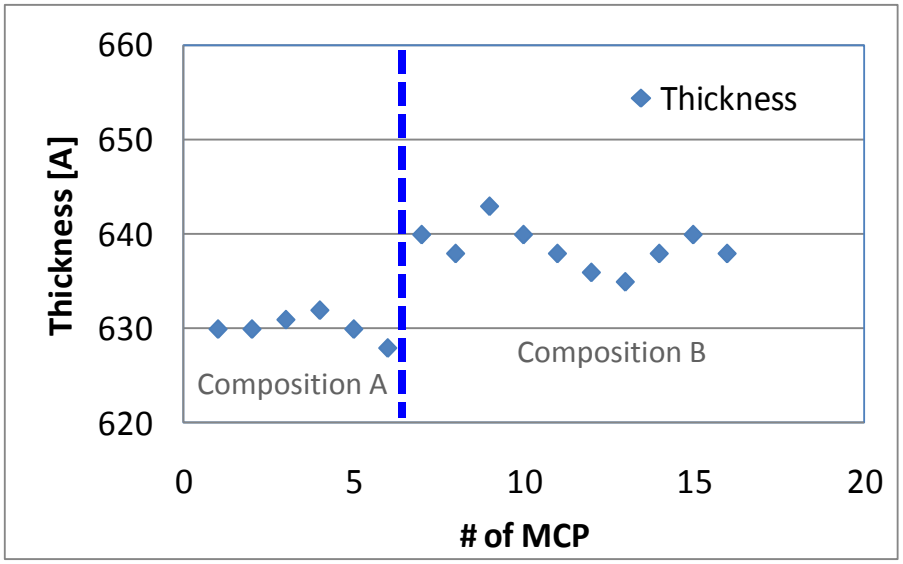
ALD coating on MCP: Chemistry #1



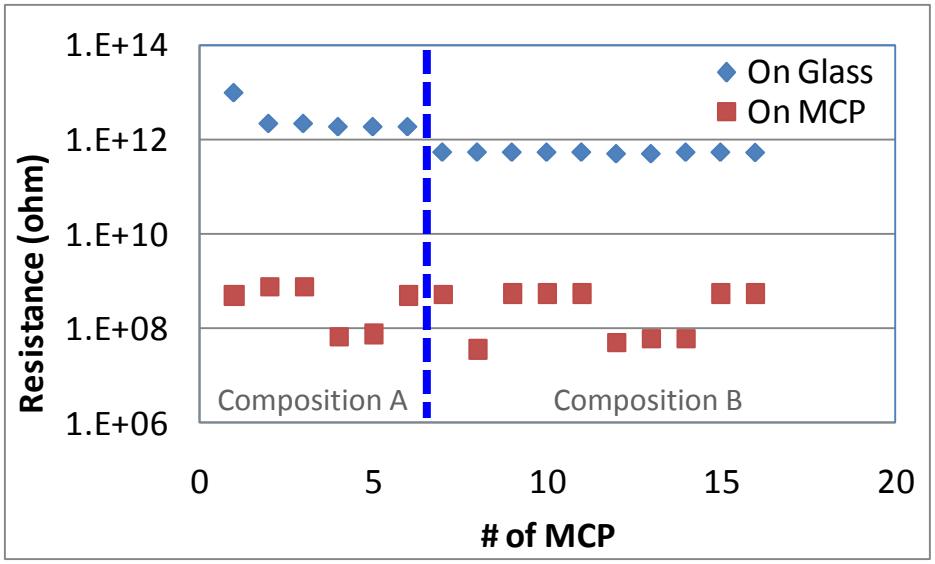
- **Uniform and smooth ALD coating pores of MCP**

Reproducibility: ALD Chemistry #1

Thickness on Si(100)

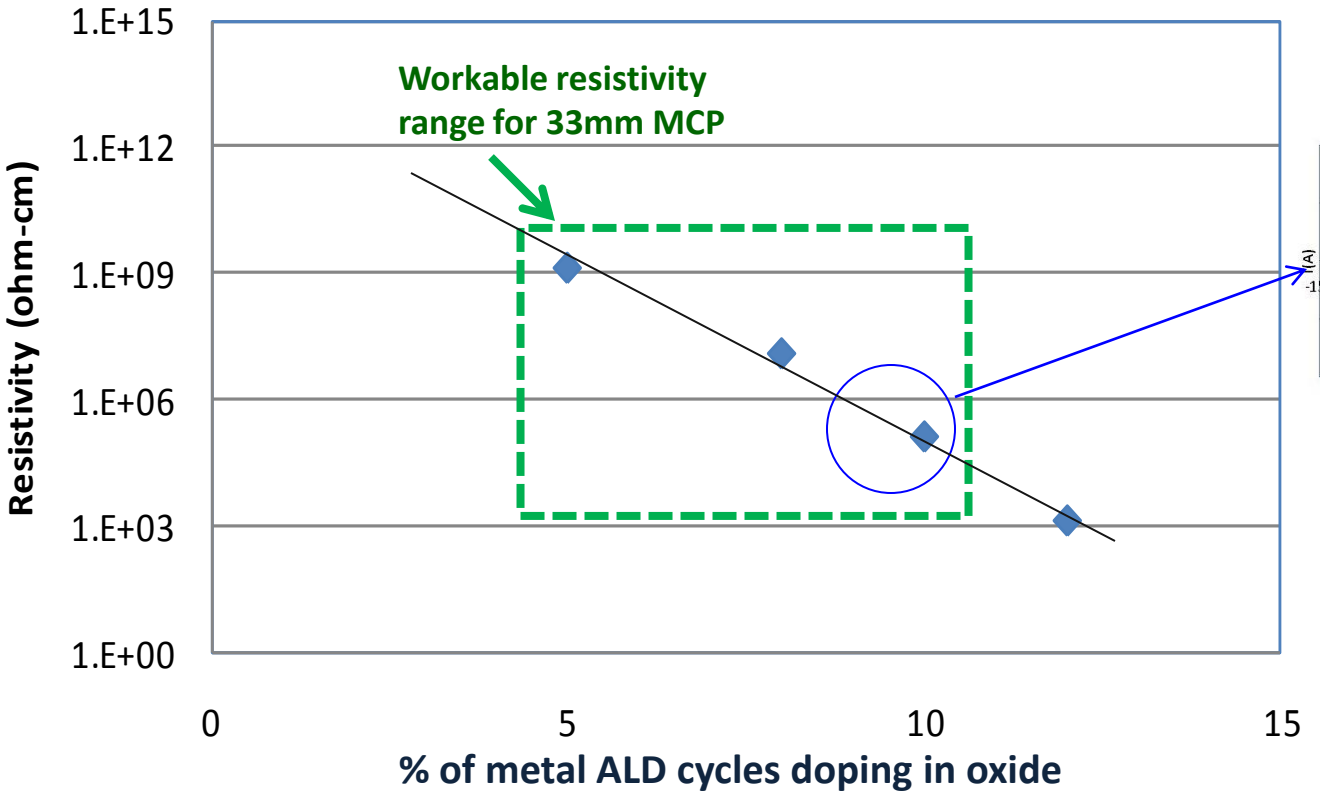


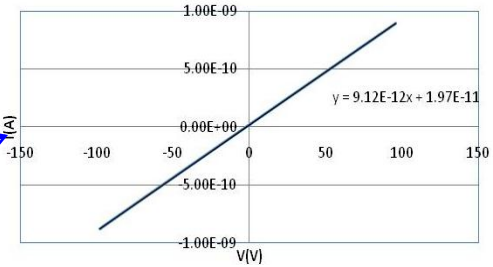
Resistance



- **Excellent reproducible thickness and resistance on Glass**
- **Resistance variation on MCP cause by electrode "end spoiling"**
  - **Electrode coating plays very crucial role and need reliable source**

Resistivity of ALD coating on Glass: Chemistry #2

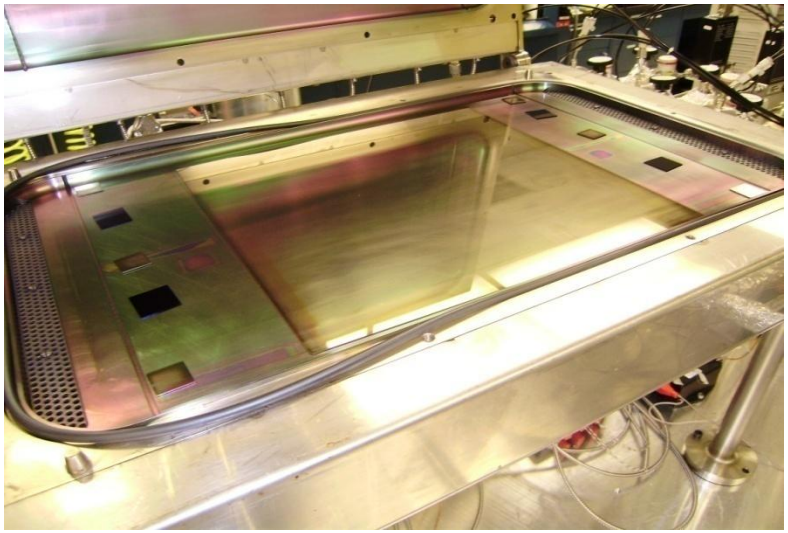


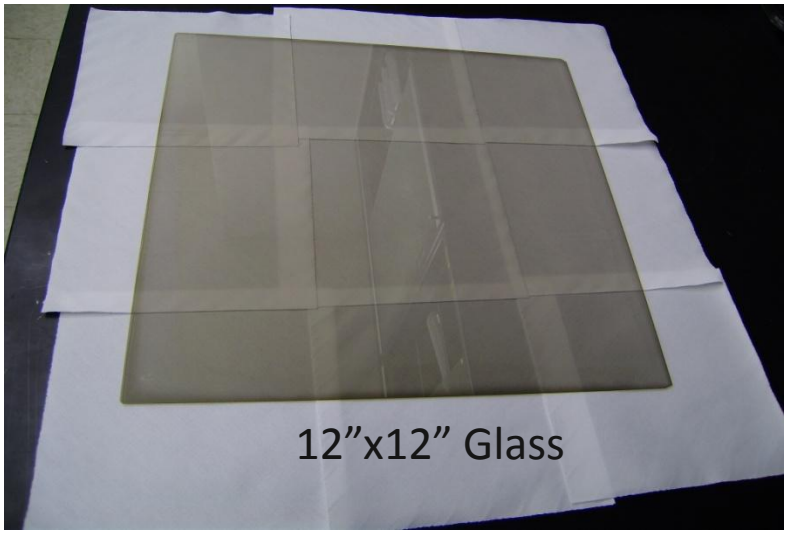


•Linear I-V on Glass

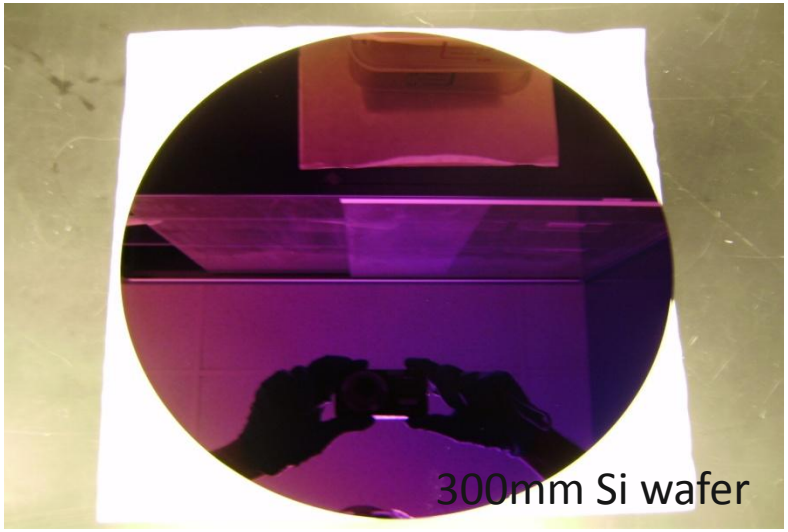
- Better control process than chemistry 1: uniform and smooth ALD coating
- Similar resistivity range (like chemisty-1) with low % of metal doping
- Process tested on large substrates capable ALD reactor

Process scale-up test: ALD chemistry #2

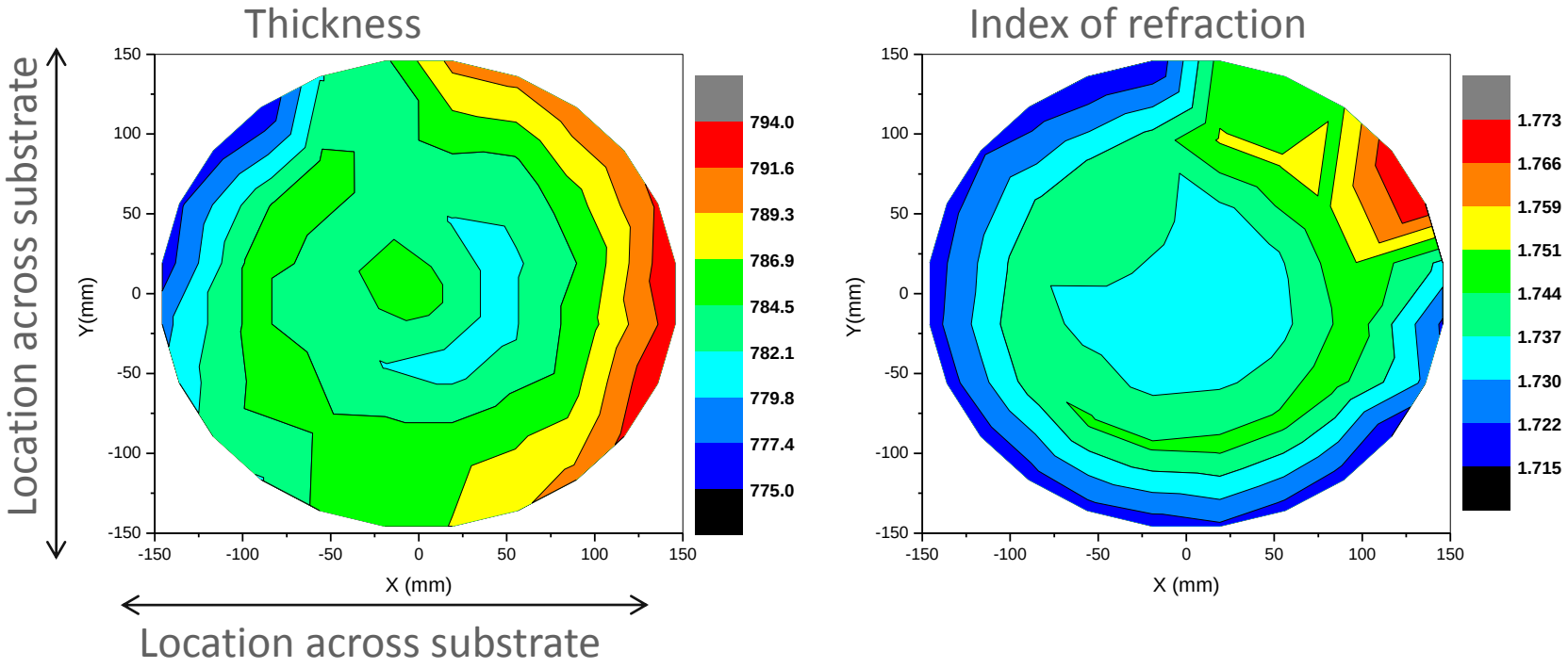




Resistive coating process tested on custom made large substrate processing ALD reactor



Large substrate testing: ALD Chemistry #2

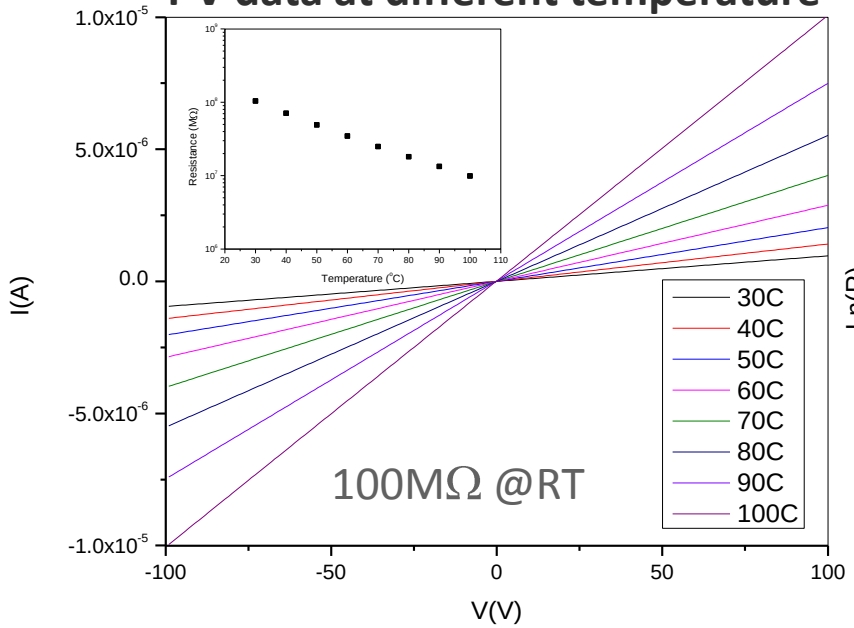


Item	Thickness [A]	Index of refraction (n)
Minimum	775	1.72
Maximum	794	1.77
Average	785	1.73
% STDV (1σ)	**0.57**	**0.84**

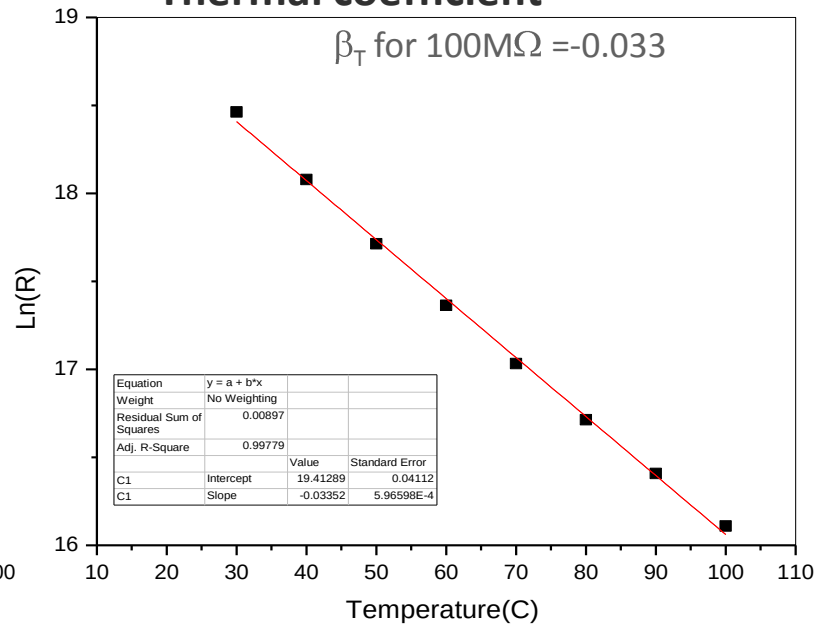
Thermal characteristics: ALD of Chemistry #2 on MCP

Thermal coefficient of resistance = $R_{mcp}=R_0\exp(-\beta_T(T_{mcp}-T_0))$

I-V data at different temperature



Thermal coefficient



MCP	Resistance (air)	β_T
Commercial (~0.7 cm^2)	6.5GΩ	-0.0451
With ALD Chemistry-1	500MΩ	-0.0337
With ALD Chemistry-2	100MΩ	-0.0335

- **Linear I-V characteristic for all temperature**
- **ALD coated MCPs shows lower β_T ➔ Reduced thermal runaway**

Summary

1) Developed several novel ALD of resistive coating processes

   -Excellent control over thickness, uniformity, resistance & thermal coefficient

2) Demonstrated the scalability of the resistive ALD process

3) Contact electrode plays crucial role in resistance tuning

   -Need attention especially for 8”x8” MCP

4) Achieved all Year 1 and some Year 2 LAPD project goals for ALD group

Next plan

- Gain test for several ALD functionalized MCP
- MCPs are extremely sensitive to moisture➔ Resistance optimization in vacuum
- Testing of alternative ALD grown SEE layer
- Process qualification on commercial ALD system
  -(Beneq TFS 500, Tool installation is in progress)
- Functionalization of 8”x8” MCPs on Beneq ALD system
- After patent, write few publications

☺ Thank you for your attention. ☺