Argonne NATIONAL LABORATORY

Next Steps for Atomic Layer Deposition (ALD) in the LAPPD Project

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with the LAPPD collaboration

U.S. DEPARTMENT OF ENERGY

Outline:

- **Background**
- **Production of LAPPD components to meet the photodetector tube production schedule**
- **Complete technology transfer / commecialization of the baseline process to industry**
- **R&D of ALD nanostructured materials for advanced MCP's**
- **Summary**

Background: ALD functionalization of LAPPD components

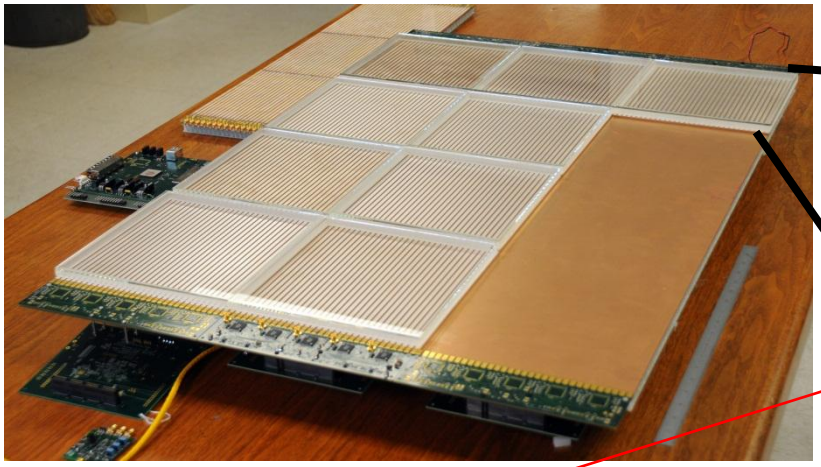
- **What we have done over the last 3 years with LAPPD funding?**
  - **Created in-house, unique technical expertise**
  - **ALD fabrication facilities for LAPPD components**
  - **Necessary infrastructure and testing facility for LAPPD components**

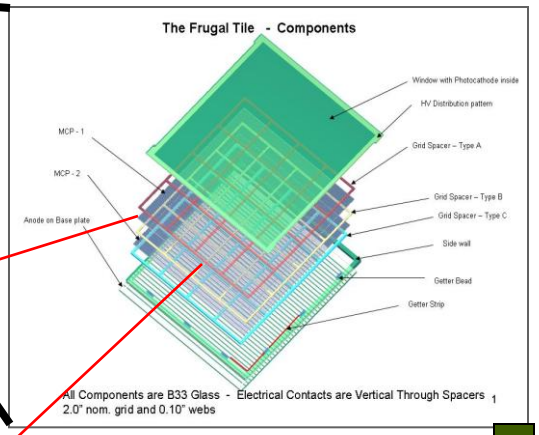
- **What we have learned?**
  - **Several working unique ALD recipes for MCPs (W and Mo based Al_2O_3)**
  - **Effect of ALD process parameters on MCP performance**
  - **Speedy ALD process and hardware troubleshooting**
  - **Reliability, stability, and robustness of ALD coatings**

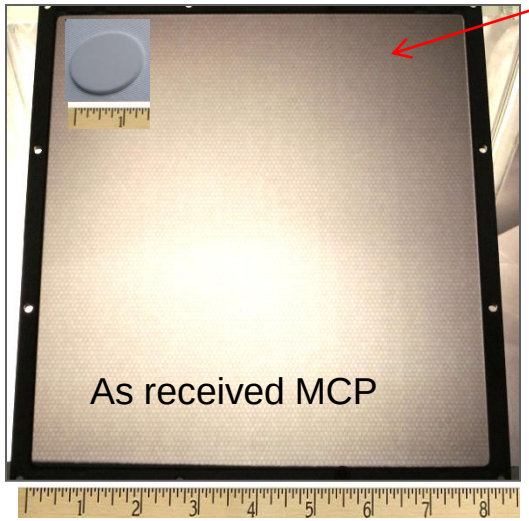
- **Accomplishments?**
  - **Worlds largest ≤(8”x8”) MCPs with excellent performance**
    - **Independent control over resistive and SEE properties**
    - **(High gain ~ 10^6-10^7/pair, Time resolution ~10x, Spatial resolution ~1mm)**
  - **Very little scrubbing time (major time/cost saver)**
  - **>90% flat stable gain response during life test (>7 C/cm^2)**
  - **Low background counts (<0.1 events cm^{-2} sec^{-1})**
  - **Working ALD grid spacers for high voltage distribution scheme**

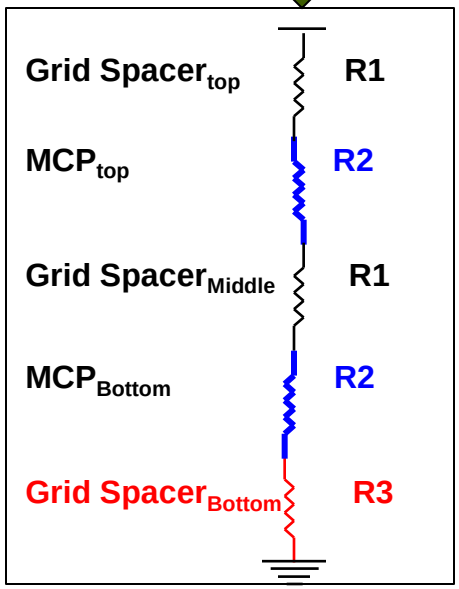
Background: LAPPD components

•Needed: MCPs and grid spacers







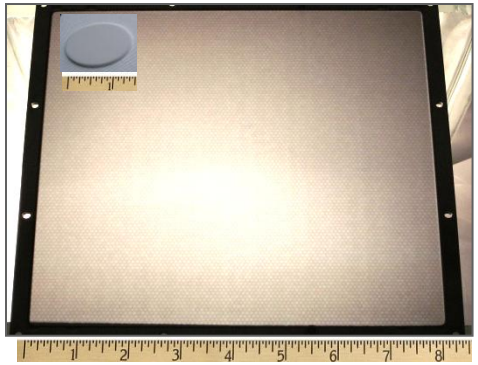


•Voltage divider scheme drastically simplifies tile construction (no HV feedthroughs)

• Requires tight control over ALD resistive coating process

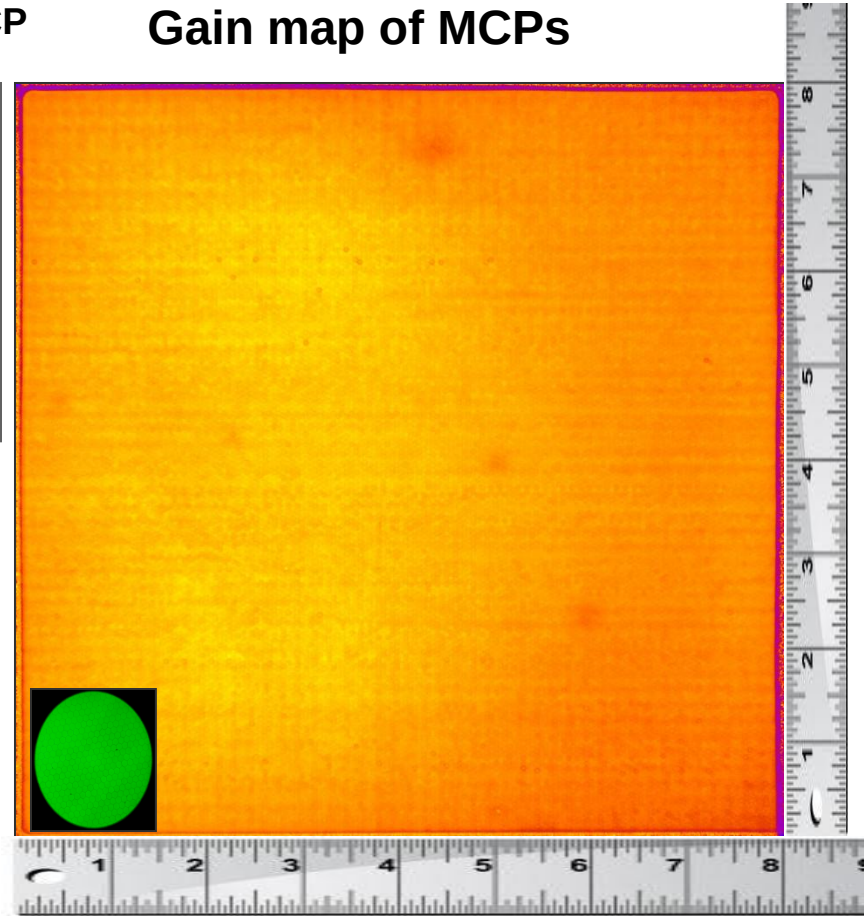
Background: ALD functionalization outcomes

Bare borosilicate glass plate

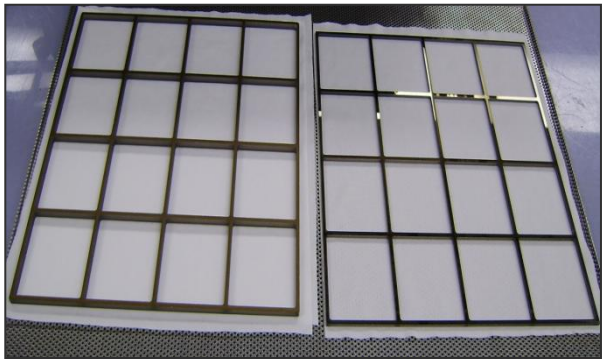


Fully functionalized MCP

Gain map of MCPs



Bare grid spacer



ALD functionalized grid spacers

Parallel efforts over the next 3 years:

- **Continue production of LAPPD components to meet the photodetector tube production schedule**
- **Complete the transfer of production-worthy technology to industry**
- **R&D of ALD nanostructured materials for advanced MCP's**

Supply of LAPPD components:

- **Production of MCPs and HV-distribution grid spacers to support the 8”x8” tube production schedule**
  - **Current “Best known ALD process flow” can produce one MCP/day**
  - **Batch production with suitable hardware (Target= 4 MCPs/day)**
  - **Batch production of Grid spacers (Target = 15 Grid spaces/day)**

- **Batch production of 33mm MCPs for performance studies**
  - **MgO vs. Al_2O_3 SEE thickness optimization**
  - **Improved thermal properties**
  - **Reduced background counts**

- **Throughput optimization to reduce manufacturing cost**
  - **Precursors dosage optimization**
  - **Minimum thickness of both resistive and SEE layer**
  - **Duration of thermal treatment (Current duration = 4 hrs)**
  - **High temperature depositions ➔ higher GR for + we can avoid the thermal treatment**

Technology transfer / Industrialization:

- **Begin transfer of process knowledge**
- **Demos on various MCPs**
- **Hands on training @ ANL on ALD and MCP testing to industry people**
- **Suitable hardware recommendation**
- **Install and commision ALD growth and characterization facilities**
- **Demonstrate working MCP process flow at industry site**
- **Onsite support to industry to ensure smooth production flow of MCPs**

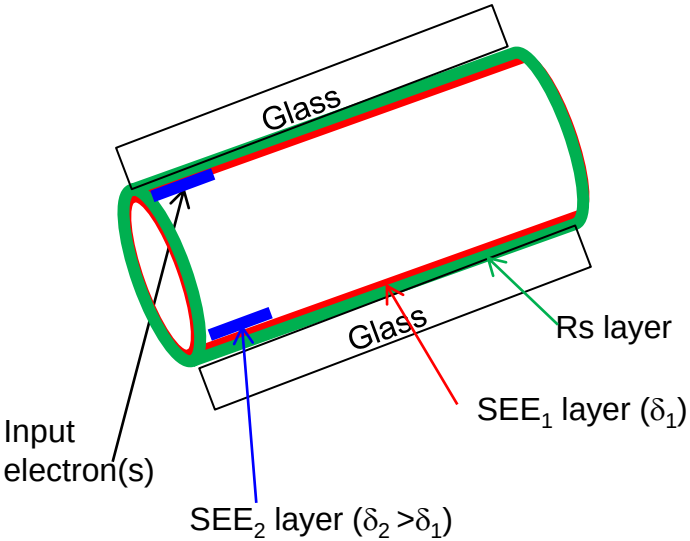
R&D ALD materials for advanced MCP's:

Resistive layer	SEE layer
•Current candidate: W:Al_2O_3 •Alternative candidates testing: M:MO (Metal Oxide=MO) ➔M=WN, MoN, TaN, TiN WC, NbC, TaC ➔MO=Al_2O_3 ,TiO_2, HfO_2, SnO_2, Ta_2O_5 •Built-in SEE properties •Improved thermal properties (Thermal resistance coefficient = β) •Testing best R layer on MCPs •Scale-up and Technology Transfer	•Current candidates: Al_2O_3 and MgO •Alternative SEE candidates by ALD: ➔CaF_2, MgF_2, SrO, SrF_2, SiO_2, Gd_2O_3, Y_2O_3, La_2O_3, HfO_2, ZnF_2 •Special SEE candidates: CNT by (dip-coating), diamond(CVD) •Less UV absorbing materials •Testing best SEE layer on MCPs •Scale-up and Technology Transfer

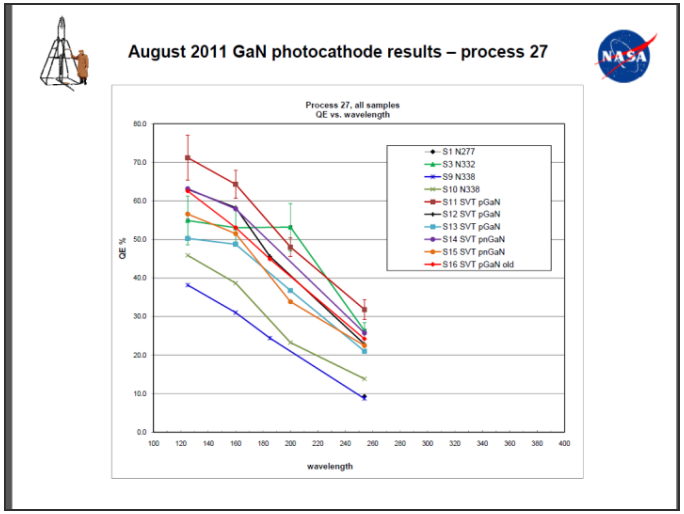
•ECRP proposal submitted

R&D ALD materials for advanced MCP's:

- **Defined first strike via material synthesis**
  - **CVD/PVD combination**
  - **Micro dose ALD**
  - **Selective ALD**
  - **Template approach (block copolymer)**



- **ALD of III-Nitride Photocathode on MCP**
  - **GaN, AlN, and InN**
  - **GaAlN, GaInN, and InAlN**
  - **Bandgap tuning**



http://www.kiss.caltech.edu/workshops/uv2011/woodgate.pdf

- **ALD of Gd_2O_3 or Boron materials on MCPs for neutron detection**

Summary

- ALD functionalized MCPs (up to 8”x8”) show excellent performance
- Continue production of MCP’s and HV-distribution spacers to support sealed tube production schedule
- Complete the transfer of production-worthy technology and knowledge to industry
- Continue R&D of advanced MCP's for higher performance and lower cost
  - Objective: In-situ growth (structural and compositional), transport and thermal properties

Acknowledgements

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