Development of Bialkali Transfer Photocathodes for Large Area Micro-Channel Plate Based Photo Detectors

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Outline

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- Large Area Photocathode Growth and Characterization
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Motivation: LAPPD Approach

Based on existing Technology: Micro Channel Plate (MCP) photo-multiplier

New Aspect: reinvent the technology, exploiting advances in materials science and electronics, driven by science goals

- Fully Integrated Approach
- Gain an order of magnitude in at least one performance characteristic

![PMT](image1.png)  ![LAPPD](image2.png)
Motivation: Photocathode

Many fundamental detector properties such as dark current, quantum efficiency, response time, and lifetime are determined by the properties of the photocathode.
Resource: Infrastructure

Basic Sciences Program
- Growth and Characterization Facility
- General Lab-Infrastructure
- User facility use
  - APS
  - NSLS
  - Nano center BNL/ANL

Large Area Development
- Growth Equipment
- Source Development Infrastructure

Production Unit (8”X8”) (not yet existing)
- Test Facility for Recipe optimization (industrial standard)
- Detector integration Facility

Microscopic Property

Macroscopic Property

Industrial Fabrication
In-Situ Structural and Chemical Characterization

In-situ X-ray Scattering (by K. Attenkofer and S. Lee)

Movie like characterization during the growth:

- Macroscopic film properties
  - Film thickness
  - Roughness
- Microscopic composition
  - Which phases are present
  - Lateral and transversal and homogenuity
  - Crystalline size
  - Preferential crystal growth
- Surface composition
  - Local workfunction
  - Chemical composition

- An Sb phase transition was observed from amorphous to crystalline at 7~8 nm by XRD.
- In-situ Sb layer growth and K inter-diffusion process were monitored by real-time XRR.
Small PMT Photocathode Growth Process

- Oxygen discharge cleaning and oxidation;
- Sb deposition monitoring via reflectivity measurement;
- Bake out temperature, deposition temperature;
- Control of alkali metals deposition.

Apply these to the fabrication of large area photocathode.
Commissioning of Optical Station

- Movable optical station can be used for both in situ and ex situ optical and electrical measurements.
- QE measurement by Hamamatsu and ANL optical station agree well with each other indicating the home-built optical station is reliable.
Cathodes exhibit characteristic I-V behavior, with QE as high as 24% at 370 nm. The quick drop at short wavelength is due to glass absorption.
The Chalice Design

- Design is based on the small PMT tube, the chalice can be seen as a LARGE PMT tube.
- Top glass plate is replaceable for reuse.
- Chalice structure is supported by external legs.
- An X-Y scanner was designed and built for QE scan.
Sb Beads Arrangements for the Chalice

- Numerical simulation of Sb thickness as a function of Sb beads arrangements and distance from window;
- 4 Sb beads arrangement
- 2.5” distance from the window;
- This arrangement produces sufficient uniformity on a 4”x4” window as our starting point;
- This assumes all the beads perform identically.
Chalice Photocathode Characterization

- Plasma was not performed properly, due to low plasma power supply.
Chalice Photocathode Deposition

The QE mapping is obtained at 350 nm wavelength, scan step size: 0.2 inch

- The blue area is the 4″X4″ window edge.
- QE is uniform (15%) at a large area.
Comparison of QE Map and Sb Transmission Map

QE Map

Center X: Lighting rod, which affect the Sb film deposition

Sb Film Transmission Map

4 beads

1 bead

Sb bead
Film transmission with known QE were measured and plotted.
- Film transmission increases as wavelength increases without regarding the QE value.
- The film transmission values at 400 nm were chosen to plot the relation between KCs-Sb cathode QE and film transmission.
- The highest QE is around 78% Sb transmission (400nm beam).
Summary

- Photocathode growth and characterization instruments were set up.
- PMT photocathodes with QE as high as 24% have been produced.
- Large area (4’’X4’’) photocathode with uniform QE (15%) were achieved even without proper oxygen plasma cleaning and oxidation.
- All photocathodes show typical I-V characteristics.
- QE of the photocathode is related to base Sb layer thickness.
- The optimized Sb thickness for KCs-Sb photocathode is around 78% transmission (400nm beam).

Next Steps

- Work out the plasma configuration to obtain uniform photocathode.
- Complete absolute reflection measurement of Sb films and relate to the film transmission data.
- Study the effect of plasma cleaning and oxidation to the photocathode QE.
- Optimize the process for higher QE cathode based on the micro and macro studies.
Back Up
Relation between Cathode QE and Sb Film Transmission

Relate the QE of the KCs-Sb cathodes with the Sb film transmission at 400 nm.

Note that the highest QE is around 78% Sb transmission (400nm beam), similar to that of Cs-Sb cathode at around 82% Sb transmission (blue light) as reported.

Fig. 5. Photoresponse in arbitrary units of Cs—Sb under reverse illumination vs transmission in percent of the original antimony

MARTIN ROME, J. Appl. Phys, 26, 166, 1955