Optimizing Cesium Antimonide Photocathode Performance Using Real-time *In-situ* Monitoring of Photoemissive Properties

M.A. Hoffbauer[1], S.J. Celestin[2], V. Pavlenko[1], F. Liu[1], and N.A. Moody[1]
[1]*Los Alamos Nation Laboratory, Los Alamos, NM 87545*
[2]*Chem. Eng. Dept., Northeastern University, Boston, MA 02115*

Alkali antimonide semiconductor photocathodes like Cs_3Sb or K_2CsSb are promising electron sources for use in next-generation light sources such as advance Free Electron Lasers (FEL) due to their high quantum efficiency in the visible spectrum, short response time, good lifetime, and the ability to produce high-brightness beams with a relatively low emittance. Traditional methods of alkali antimonide photocathode growth, sequential deposition, dates back to 1960s when quantum efficiency (QE, number of electrons emitted per incident photon) was prioritized over other parameters. Sequential deposition allows fabrication of acceptable photocathodes, but the crystalline quality is always low and surface roughness is high. Photocathodes for next-generation light sources must be smooth and have high crystalline quality in order to generate "colder" electron beams (low emittance). Recently, a co-deposition alkali antimonide growth technique was introduced that mimics MBE but, lacking meaningful feedback, fails to achieve acceptable control over the growth parameters. Understanding the correlation between growth conditions (substrate temperature, fluxes of alkali metals and Sb), film characteristics (stoichiometry, crystal structure, roughness), and cathode metrics (QE, emittance, and response time) is necessary for developing reliable growth procedures for alkali antimonide photocathodes.

We have performed detailed studies on the growth of Cs_3Sb photocathodes using a new MBE growth capability at LANL with better control of the growth kinetics for optimizing photoemissive properties. The growth capability utilizes a Sb effusion cell and a custom-built Cs evaporator assembly for precise control of their fluxes. A multiple wavelength laser assembly is used to illuminate the surface of the growing cathode and measure the spectral response (QE vs. wavelength) in real-time. These *in situ* measurements were used to tune the growth parameters (fluxes, temperature, etc.) and attain the spectral response indicative of a stoichiometric Cs_3Sb film. Our results demonstrate the ability to fine tune the Sb and Cs fluxes in a co-deposition film growth mode and improve the overall spectral response. Improved photoemissive properties can be correlated with initiating the film growth under conditions for forming Cs_3Sb at the earliest stages and maintaining the film stoichiometry throughout the growth. These films can be grown over a range of substrate temperatures and show excellent long term photoemission stability. Selected as-grown photocathodes were transferred under UHV conditions into a surface science system for detailed characterization and then transferred into a planar gap electron gun assembly and illuminated by a laser to measure their emittance properties. The relationship between the optimized growth conditions and the photocathode emittance properties will also be discussed.

[+] Author for correspondence: mhoffbauer@lanl.gov