

**EWPAА 2022: European
Workshop on Photocathodes
for Particle Accelerator
Applications**

Report of Contributions

Contribution ID: 1

Type: **Presentation**

High brightness beams

Tuesday, September 20, 2022 2:20 PM (30 minutes)

Presenter: BACCI, Alberto Luigi (Istituto Nazionale di Fisica Nucleare)

Session Classification: Overview of Photocathode Research

Contribution ID: 2

Type: **Presentation**

Recent advancements on photocathodes

Tuesday, September 20, 2022 2:50 PM (20 minutes)

Presenter: MONACO, Laura Silvia (Istituto Nazionale di Fisica Nucleare)

Session Classification: Overview of Photocathode Research

Contribution ID: 3

Type: **Presentation**

Experience on polarized photocathodes

Tuesday, September 20, 2022 3:10 PM (20 minutes)

Presenter: AULENBACHER, Kurt (Institut für Kernphysik der Johannes Gutenberg-Universität Mainz)

Session Classification: Overview of Photocathode Research

Contribution ID: 4

Type: **Presentation**

Status of precise measurements of electron-beam polarization changes during long term operation

Tuesday, September 20, 2022 4:40 PM (20 minutes)

For the high-precision measurements in the experiments at the new Mainz Energy Recovering Superconducting Accelerator (MESA), it is necessary to know exactly the long-term spin properties of the electron beam. For this purpose, a test setup has been built at the Institute for Nuclear physics. Different preparation methods of a photocathode with nitrogen trifluoride and oxygen are compared. The aim is to examine the advantages of an oxygen-free preparation, especially with regard to the influence on the evolution of spin polarization during the experiment. The setup and the first preliminary results are presented here.

Presenter: Dr GROTH, Jennifer (Uni Mainz)

Session Classification: Photocathode Performance in Accelerator Applications

Contribution ID: 5

Type: **Presentation**

Photocathode performance at LCLS-II

Tuesday, September 20, 2022 5:40 PM (20 minutes)

Presenter: Dr VECCHIONE, Theo (SLAC)

Session Classification: Photocathode Performance in Accelerator Applications

Contribution ID: 6

Type: **Presentation**

Plasma photocathode

Wednesday, September 21, 2022 9:20 AM (20 minutes)

Presenter: BENEDETTI, Carlo (LBNL)

Session Classification: New Photocathode Ideas

Contribution ID: 7

Type: **Presentation**

Studies on the evolution of MTE for photocathodes subjected to controlled degradation by gas exposure

Wednesday, September 21, 2022 11:10 AM (20 minutes)

The electron beam quality of a photocathode-based electron source is limited by the achievable mean transverse energy (MTE). The Liouville theorem states that the total emittance of a beam cannot improve as it propagates through an accelerator, only manipulated using lattice optics. Therefore minimising the intrinsic emittance of a photocathode is important. This alongside other factors such as the quantum efficiency (QE) of a photocathode determines the ultimate beam quality. The chemical properties of a photoemissive surface affect the energy spread of any emitted electrons, and consequently the intrinsic emittance of that source.

The robustness of the photocathode is also a crucial performance aspect, as this helps determine the lifetime of a cathode. I will talk through the performance data on two photocathodes, subjected to progressive degradation by controlled exposure to residual gases typically found in a UHV system: an Ag polycrystalline cathode at 266 nm and a Cs implanted Cu polycrystalline cathode at 405 nm. The data crucially shows the effect of this progressive degradation on photocathode performance due to gas exposure.

Presenter: SOOMARY, Liam (The Cockcroft Institute / The University of Liverpool)

Session Classification: Metallic Photocathodes

Contribution ID: 8

Type: **Presentation**

Multi-alkali antimonide photocathodes for highly brilliant electron beams

Wednesday, September 21, 2022 2:00 PM (20 minutes)

The goal of the Sealab/bERLinPro project is to build a new generation superconducting RF electron accelerator at HZB. Therefore, a photocathode with high QE and long operation lifetime is required for this project. Multi-alkali antimonide photocathodes deposited on Mo substrate is chosen for this application due to its high QE (>1%) at visible wavelengths and good thermal conductivity.

Currently, Na-K-Sb photocathodes are produced in UHV preparation chamber at our photocathode lab. The influence of deposition parameters is studied in order to optimize the growth procedure and to achieve better stability at higher temperature (compared to photocathodes with Cs composition), which could benefit operational lifetime. XPS and QE measurements are performed, and the correlation between chemical composition and QE value are presented in this contribution.

Presenter: WANG, Chen (HZB)

Session Classification: Semiconductor Photocathode

Contribution ID: 9

Type: **Presentation**

Performance characterisation at Daresbury Laboratory of CsTe photocathodes grown at CERN

Wednesday, September 21, 2022 2:20 PM (20 minutes)

A UK X-FEL will require a high-performance photocathode to generate an electron beam with the necessary qualities. Caesium Telluride is a candidate material for this photocathode application.

The surface characteristics of a photocathode affect many important factors of the photoemission process including the photoemission threshold, the intrinsic emittance and the quantum efficiency. These factors in turn define and limit the achievable electron beam quality which is measurable using figures of merit like beam emittance, beam brightness and energy spread.

We present chemical analysis and photoemission performance measurements for caesium telluride photocathodes synthesized at CERN. The photocathodes were transported under ultra-high vacuum (UHV) and analysed at the STFC Daresbury Laboratory using ASTeC's Multiprobe (SAPI) for surface characterisation via XPS and STM, and the unique Transverse Energy Spread Spectrometer (TESS)* for Mean Transverse Energy (MTE) measurements. The MTE measurements were made at both room and cryogenic temperatures. We discuss the evident correlations between the measured surface characteristics and the MTE values under a range of photocathode illumination wavelengths.

- B.L. Militsyn, 4-th EuCARD2 WP12.5 meeting, Warsaw, 14-15 March 2017

** L.B. Jones et al., Proc. FEL '13, TUPPS033, 290-293; <https://accelconf.web.cern.ch/FEL2013/papers/tupso33.pdf>

Presenter: Dr JONES, Lee (STFC)

Session Classification: Semiconductor Photocathode

Contribution ID: 10

Type: **Presentation**

Operation of Cs₂Te in SRF gun for THz user shifts

Wednesday, September 21, 2022 3:00 PM (20 minutes)

Presenter: Dr XIANG, Rong (HZDR)

Session Classification: Semiconductor Photocathode

Contribution ID: 11

Type: **Presentation**

Ultrafast sub-threshold one-photon photoemission

Thursday, September 22, 2022 10:00 AM (20 minutes)

Presenter: SCHROEDER, Andreas (Uni Illinois)

Session Classification: Theory

Contribution ID: 12

Type: **Presentation**

Molecular beam epitaxy of Cs-Sb thin films: structure-oriented growth of high efficiency photocathodes

Thursday, September 22, 2022 12:20 PM (20 minutes)

Presenter: Dr GALDI, Alice (Universita' degli Studi di Salerno)

Session Classification: Advanced Photocathode Characterization

Contribution ID: 13

Type: **Presentation**

Stoichiometry control and automated growth of alkali antimonide photocathode films by molecular beam deposition

Thursday, September 22, 2022 12:40 PM (20 minutes)

Presenter: Dr PAVLENKO, Vitaly (LANL)

Session Classification: Advanced Photocathode Characterization

Contribution ID: 14

Type: **Presentation**

Exploring cesium–tellurium phase space via high-throughput calculations beyond semi-local density-functional theory

Thursday, September 22, 2022 9:40 AM (20 minutes)

Presenter: SASSNICK, Holger-Dietrich (Uni Oldenburg)

Session Classification: Theory

Contribution ID: 15

Type: **Presentation**

JLAB DC gun developments

Tuesday, September 20, 2022 4:00 PM (20 minutes)

Presenter: Dr GARCIA, Carlos Hernandez (JLAB)

Session Classification: Photocathode Performance in Accelerator Applications

Contribution ID: 16

Type: **Presentation**

Performance of bialkali photocathode in DC-SRF photoinjector

Tuesday, September 20, 2022 5:20 PM (20 minutes)

Presenter: Dr XIE, Haumu (Peking University)

Session Classification: Photocathode Performance in Accelerator Applications

Contribution ID: 17

Type: **Presentation**

High crystalline cesium telluride photocathode on atomically thin graphene with co-deposition

Thursday, September 22, 2022 12:00 PM (20 minutes)

Presenter: Dr GAOWEI, Mengjia (BNL)

Session Classification: Advanced Photocathode Characterization

Contribution ID: 18

Type: **Presentation**

Monte Carlo simulations of electron photoemission from plasmon-enhanced alkali photocathode

Thursday, September 22, 2022 9:20 AM (20 minutes)

Presenter: Dr JIANG, Zenggong (SINAP)

Session Classification: Theory

Contribution ID: **19**

Type: **Presentation**

Copper cathode

Wednesday, September 21, 2022 11:30 AM (20 minutes)

Presenter: Dr NOAKES, Tim (STFC)

Session Classification: Metallic Photocathodes

Contribution ID: 20

Type: **Presentation**

AI/ML-selection of air-stable photocathodes

Wednesday, September 21, 2022 10:20 AM (20 minutes)

Presenter: Dr ANTONIUK, Evan (Stanford)

Session Classification: New Photocathode Ideas

Contribution ID: 21

Type: **Presentation**

ASU Photocathode Research Lab

Thursday, September 22, 2022 11:00 AM (20 minutes)

Presenter: Dr KARKARE, Siddartha (Uni Arizona)

Session Classification: Advanced Photocathode Characterization

Contribution ID: 22

Type: **Presentation**

Resolving surface chemical states of p-GaN:Cs photocathodes by XPS analysis

Thursday, September 22, 2022 11:40 AM (20 minutes)

Presenter: SCHABER, Jana (HZDR)

Session Classification: Advanced Photocathode Characterization

Contribution ID: 23

Type: **Presentation**

Cs₂TE\KCsSb in gun operation at PITZ

Wednesday, September 21, 2022 2:40 PM (20 minutes)

Presenter: Dr MOHANTY, Sandeep (DESY/INFN)

Session Classification: Semiconductor Photocathode

Contribution ID: 24

Type: **Presentation**

Photocathode response time measurement

Thursday, September 22, 2022 11:20 AM (20 minutes)

Presenter: Dr LOISCH, Gregor (DESY Zeuthen)

Session Classification: Advanced Photocathode Characterization

Contribution ID: 25

Type: **Presentation**

Ultra-thin MgO films on metal photocathodes to enhance QE

Wednesday, September 21, 2022 9:00 AM (20 minutes)

Metal photocathodes are widely utilised for their ease of use, high durability and fast response time. However, the high work function (WF) and low quantum efficiency (QE) typically observed in metals necessitates the use of high power deep UV lasers. Metal oxide films on metals have been shown to produce a surface with a lower WF and improved QE* whilst maintaining photocathode durability.

We present an overview of experimental work conducted to apply ultra-thin MgO films on copper and silver photocathodes, and a study of their performance as candidates for future photocathode applications. We show their the surface properties and photoemissive characteristics, including surface composition and roughness, WF, QE and mean transverse energy (MTE) as a function of illumination wavelength.

*V. Chang, T. C. Q. Noakes, and N. M. Harrison. "Work function and quantum efficiency study of metal oxide thin films on Ag(100)". In: Physical Review B 97 (15 Apr. 2018), doi: 10.1103/PhysRevB.97.155436.

Presenter: Dr BENJAMIN, Christopher (Uni Warwick and STFC)

Session Classification: New Photocathode Ideas

Contribution ID: 26

Type: **Presentation**

CsK2Sb-photocathodes for application in an industrial accelerator

Tuesday, September 20, 2022 4:20 PM (20 minutes)

The LightHouse project is a novel industrial application of an electron accelerator for the production of medical isotopes (^{99}Mo) as an alternative to nuclear reactors.

In the framework of the SMART project of the company Institut National des Radioéléments (IRE), RI is responsible for the superconducting electron accelerator which includes the DC photoinjector, the SRF modules and the entire beamline for a 75MeV, 40mA, 3 MW cw beam to the target.

One subproject is the production and supply of the photocathodes for the photoinjector. Therefore, RI built up a beam test facility which includes the injector, a deposition chamber, and an automated transfer line to bring the photocathodes from the deposition chamber to the gun keeping the cathodes in a common ultra-high vacuum system.

The photocathodes are based on typical sequential deposition recipes of CsK2Sb-cathodes [1-3] on Mo and SS substrate. An advantage of the deposition chamber is the use of thermal effusion cells which can be filled with a few grams of alkali metals. The alkali metals are alloyed into indium in order to increase the evaporation temperature. This allows the production of more than 20 photocathodes without the need to refill the evaporators.

First results show that photocathodes with a QE > 4% can be produced reliably and can be transported from the deposition chamber into the gun without a measurable degradation.

[1] Schmeißer, M. "Photocathodes for high brightness, high average current photoelectron injectors." Dissertation Humboldt-Universität zu Berlin (2019)

[2] Wang, E., et al. "Long lifetime of bialkali photocathodes operating in high gradient superconducting radio frequency gun." Scientific Reports 11.1 (2021): 1-9.

[3] Bazarov, I., et al. "Chapter 7: "Semiconductor photocathodes for unpolarized electron beams." An Engineering Guide to Photoinjectors, T. Rao and D. H. Dowell, Eds. (2013): 184-217

Presenter: KUEMPER, Verena (Research Instruments)

Session Classification: Photocathode Performance in Accelerator Applications

Contribution ID: 27

Type: **Presentation**

Monte Carlo transverse emittance and quantum efficiency study on Cs₂Te

Thursday, September 22, 2022 9:00 AM (20 minutes)

Monte Carlo simulation study of Cs₂Te

Gowri Adhikari^{1,7}, Houjun Qian^{1,2}, Peng-Wei Huang³, Mikhail Krasilnikov¹, Matthias Gross¹, Frank Stephan¹, Sven Lederer⁶, Pavel Juarez⁶, Caterina Cocchi⁴, Holger-Dietrich Sassnick⁴, Daniele Sertore⁵, and Laura Monaco⁵

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⁵ Istituto Nazionale di Fisica Nucleare - LASA, Segrate, Italy

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⁷ SLAC National Accelerator Laboratory, Menlo Park, CA 94025, USA

The semiconductor photocathodes are very attractive because of their high quantum yield. The semiconductors that have a relatively large band gap (E_g) and a comparatively low electronic affinity (E_a) are considered good photo emitters [1]. Cs₂Te is considered a robust high current photo emitter for FEL and particle accelerator applications [2]. In this contribution, a theoretical formulation of a three-step model [3] is developed, using the Density Functional Theory (DFT) and the Monte Carlo simulation [4]. The simulation includes the density of states (DOS) of the valence bands, the electron transport mechanisms, the direction changes after each scattering event, the Schottky effect, band bending effects, and the transverse momentum conservation. The model agrees well with measured results for thermal emittance, quantum efficiency, and response time data of Cs₂Te.

1. Spicer W.E. "Photo emissive, photoconductive, and optical absorption studies of alkali-antimony compounds" *Phys. Rev* 112 114 (1958).
2. Kong S. H., Kinross-Wright J. and Nguyen D. C. "Cesium Telluride photocathodes" *J. Appl. Phys.* 77 6031 (1995).
3. Dowell D and Schmerge J "Quantum efficiency and thermal emittance of metal photocathodes" *Phys. Rev. Spec. Top. Accel. Beams* 12 074201 (2009).
4. Ferrini G., Michelato P. and Parmigiani F. "A Monte Carlo simulation of low energy photoelectron scattering in Cs₂Te" *Solid State Communications* 106-1 21-26 (1998).

Presenter: ADHIKARI, Gowri (SLAC)

Session Classification: Theory

Contribution ID: 28

Type: **Poster**

Stability and electronic properties of CsK₂Sb surface facets

Tuesday, September 20, 2022 6:00 PM (5 minutes)

Multi-alkali antimonides have been proposed as a promising class of photocathode materials for particle accelerators. First-principles results have recently complemented the experimental efforts in the characterization of these systems [1]. However, most of the existing studies focus on bulk crystals and still little is known about their surface properties. We fill this gap with an ab initio study based on density-functional theory of the energetic and electronic properties of 7 CsK₂Sb surface facets of low Miller index [2]. We analyze the structural optimization of the atomic layers at the interface with vacuum and investigate formation energies as a function of chemical potential to quantify the stability of these systems at varying concentration of the alkali species. We find that the (111)-surfaces terminated with K on top of Sb are generally the most stable ones. The considered surfaces exhibit either semiconducting or metallic character. With a band gap of 1.3 eV for the most stable semiconducting surface and work functions around 2.5 eV for the metallic ones, the computed results are in good agreement with experimental values.

[1] C. Cocchi and H-D. Sassnick, *Micromachines* 12, 1002 (2021).

[2] R. Schier, H-D. Sassnick, and C. Cocchi, submitted (2022); arXiv:2208.05843.

Presenter: Dr SCHIER, Richard (UNI-Oldenburg)

Session Classification: Poster

Contribution ID: 29

Type: **Poster**

Superconducting photocathode quantum efficiency enhancement with UV plasmonics

Tuesday, September 20, 2022 6:05 PM (5 minutes)

A surface modification technique is described that significantly enhances the photoelectric quantum efficiency (QE) of Nb at 248 nm by more than two orders of magnitude, thereby making this material suitable potentially as a cathode for superconducting radiofrequency (SRF) photoinjectors. The approach uses ultra-thin-film metallic coatings that exploit proximity coupled superconductivity, as well as plasmonic resonances in the deep UV, to enhance QE while at the same time allowing exposure of the Nb cathode to air. The first step is the in-situ deposition of a 10 nm layer of Mg onto a clean Nb surface prepared by a high temperature UHV anneal. Earlier proximity effect studies of similarly processed Nb/Mg bilayers reveal the superconducting gap of Nb on the surface indicating the induced superconductivity in the Mg layer should maintain the low RF losses of Nb. Deposition of ultra-thin islands of In (4 nm thickness) on top of air exposed samples (Nb/Mg/Mg-oxide) leads to reproducible overall enhancements of QE by a factor of greater than 400. This strong enhancement is attributed to the deep UV plasmon resonances of the In islands observed in the optical reflectance of the coated Nb sample and found in COMSOL simulations. This proof-of-principle experiment opens the door to lithographically tailored surface plasmonic nano structures to create fully superconducting photocathodes based on Nb, or other higher T_c superconductors, that are robust in air and have acceptable QE values in the UV.

Presenter: Dr SPENTZOURIS, Linda (Illinois Tech (IIT))

Session Classification: Poster

Contribution ID: **30**

Type: **Presentation**

Copper photocathode experience at FERMI

Wednesday, September 21, 2022 11:50 AM (20 minutes)

Presenter: TROVÒ, Mauro (ELETTRA)

Session Classification: Metallic Photocathodes

Contribution ID: 31

Type: **Presentation**

Photocathode activities at DESY

Tuesday, September 20, 2022 5:00 PM (20 minutes)

Presenter: Dr JUAREZ LOPEZ, David Pavel (DESY)

Session Classification: Photocathode Performance in Accelerator Applications

Contribution ID: 32

Type: **Presentation**

Protective layers on bi-alkali photocathodes

Wednesday, September 21, 2022 10:00 AM (20 minutes)

Presenter: Dr MOODY, Nathan (LANL)

Session Classification: New Photocathode Ideas

Contribution ID: 33

Type: **Presentation**

CERN Photocathode Activities

Wednesday, September 21, 2022 9:40 AM (20 minutes)

Presenter: Dr CALDERON, Miguel Martinez (CERN)

Session Classification: New Photocathode Ideas

Contribution ID: 34

Type: **Presentation**

Technology aspects in preparation at NCBJ of Nb_Pb sc photocathodes for XFEL-type RF e- gun.

Wednesday, September 21, 2022 12:10 PM (20 minutes)

A photocathode composed of a Pb layer deposited on Nb substrate is an attractive solution proposed for fully superconducting, radio-frequency electron gun to be used in the linear accelerator of the European X-ray free electron laser (Eu-XFEL) operating at Deutsches Elektronen Synchrotron (DESY) and in other, similar devices. Much effort has been put in development of deposition and post-processing of Pb films as superconducting photoemitters. These works led to a satisfactory solution based on lead deposition in a cathodic-arc followed by ex-situ smoothing of the obtained film through its re-melting with a pulsed plasma ion beam. Pb layers obtained by different procedures have been tested for their morphology, microstructure, dark current emission, quantum efficiency and impact on SRF e- gun performance. Preliminary results are presented of recent Pb coatings on Nb aimed at further improvement of the film smoothness.

Presenter: Dr LORKIEWICZ, Jerzy (NCBJ)

Session Classification: Metallic Photocathodes

Contribution ID: 35

Type: **Presentation**

ERL Roadmap for Europe

Wednesday, September 21, 2022 3:20 PM (20 minutes)

Presenter: MILITSYN, Boris

Session Classification: ERL Roadmap for Europe

Contribution ID: 36

Type: **Poster**

**THE ALKALI METAL PHOTOCATHODE
PREPARATION FACILITY AT DARESBURY
LABORATORY: FIRST CAESIUM TELLURIDE
DEPOSITION RESULTS**

Tuesday, September 20, 2022 6:10 PM (5 minutes)

Presenter: CHURN, H. M. (ASTeC)

Session Classification: Poster