CsK_2Sb PHOTOCATHODE DEVELOPMENT FOR bERLinPro*

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Abstract

In order to generate high brightness and high-current electron beams for bERLinPro, an SRF photoinjector is being developed at HZB. Normal conducting CsK_2Sb cathodes will be used due to their high quantum efficiency (QE) at visible wavelengths and fast response time. We report on the commissioning of a preparation and analysis system that allows investigation of the surface and near-surface chemical composition of the cathodes using XPS and ion scattering. In addition, the design of an UHV transport system for cathodes is presented.

INTRODUCTION

The ERL concept imposes strong demands on the injector. For bERLinPro [1], we intend to operate an SRF photoinjector in CW mode with high bunch charge in order to achieve an average current of 100 mA [2]. The use of CsK_2Sb photocathodes with high QE in the visible allows to drive the injector with a laser wavelength of 532 nm and average power of only 10s of Watts, thus relaxing the requirements on the cryogenic and drive laser system. The preparation of the cathodes will be performed in a dedicated growth chamber, where the cathode material is deposited on a plug that will be inserted in the back wall of the photoinjector cavity. The cathodes must be transferred between the two systems in ultra high vacuum conditions of $\leq 10^{-10}$ mbar.

Alkali antimonides have been used in phototubes and light-sensitive devices for decades and a number of empirically optimized deposition recipes are available. However, many aspects of their growth, like the diffusion of alkalis in the material and the crystallization as well as correlations between composition, crystal structure, and electronic structure and emission properties have yet to be understood. The demand from accelerator physics for highest QEs, reproducible growth, smooth surfaces, and stable operation (as desired by future user facilities) calls for dedicated investigations of these topics.

Using in-situ surface analysis with the system described below it is intended to study the influence of growth parameters on the composition of the material and find correlations with electronic structure and emission properties.

COMMISSIONING OF THE PREPARATION SYSTEM

The preparation and analysis system was commissioned at BNL and is now back in Berlin. It consists of a preparation chamber and a surface analysis chamber which are connected via a sample manipulator. Evaporation can be performed from a thermal evaporation cell for Sb and two ports for Alkali deposition from SAES dispensers. The analysis chamber is equipped with a X-Ray source (Al and Mg anodes), an ion source and a SPECS Phoibos 100 hemispherical analyzer. Both chambers have a base pressure below $3 \cdot 10^{-10}$ mbar.

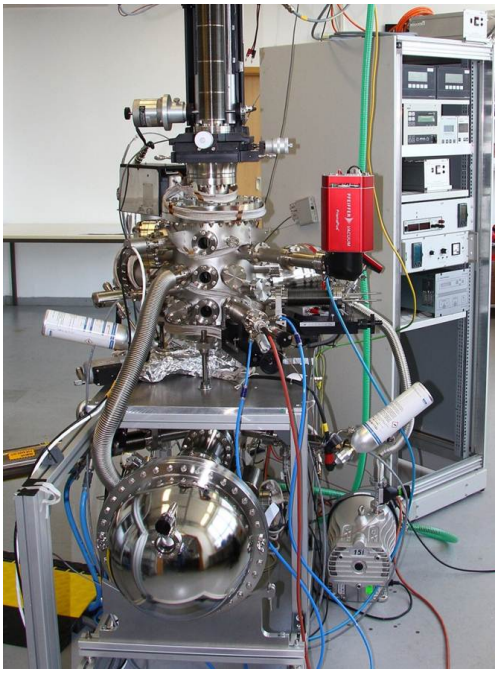

Figure 1: Photograph of the photocathode preparation and analysis (PPA) system.

PHOTOCATHODE CHARACTERIZATION

The photocurrent of a sample is collected by a biased anode and measured with a picoamperemeter. Currently, the sample is excited by a 532 nm solid state laser with 1 mW optical power. It is planned to set up a Xe-arc lamp with monochromator which would allow to resolve the spectral sensitivity of a sample. The spectral intensity of commercial tunable light sources is about 10 μW per nm bandwidth, which would allow us to measure QEs down to 10^{-5}.

A first cathode sample was prepared in April 2015 on a Mo foil (Sigma Aldrich, 99.9%). The substrate was cleaned by heating it to 450°C for 1 h and Ar^+ sputter cleaning at 3 keV for 30 min. After the cleaning procedure, only small O and C contaminations were still present. An Sb layer was deposited at a deposition rate of 0.5 Å/s, which corresponds to $1 \cdot 10^{-7}$ mbar vapour pressure. During deposition, the partial pressure of H_2O was $2 \cdot 10^{-9}$ mbar, O_2 and CO_2 were below $1 \cdot 10^{-10}$ mbar. The film proved to be very clean and no contaminations were found in the XPS spectrum.

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Following a sequential growth procedure, K and Cs were subsequently deposited. For both alkalis, the vapour pressure was very low and could hardly be resolved in the mass spectrometer (<10^{-13} mbar). During the K deposition the partial pressure of H_2O was $2 \cdot 10^{-9}$ mbar, O_2 and CO_2 were below $1 \cdot 10^{-10}$ mbar. The Cs dispenser had to be heated above its specified current to obtain a reading on the quartz microbalance. A too high temperature of the dispenser led to high background pressure of atomic O and N in the 10^{-9} mbar range. An XPS spectrum was taken after the deposition of both Alkalis where traces of Cr and O are discernible. All three spectra can be compared in fig. 2.

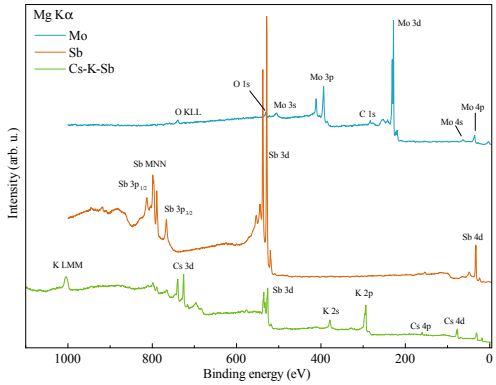

Figure 2: XPS survey spectra of three steps of a cathode preparation. The Mo substrate after cleaning (see text), after Sb deposition and after K and Cs deposition is shown.

SUBSTRATE PREPARATION AND CATHODE TRANSFER

The preparation system is located in a laboratory room apart from the injector, thus the cathodes must be transported in a movable vacuum vessel and transferred into the injector cryomodule using a load-lock. The transfer system is based on a setup that is in use at HZDR.

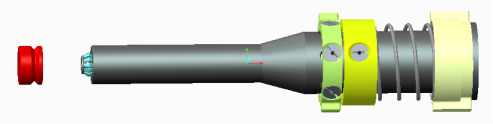

Figure 3: Drawing of the pug holder that will fit into the back wall of the gun cavity. The small CuBe spring that holds the plug is locked tightly and can be opened by a mechanism inside the holder rod.

The cathode puck (red cap in fig. 3) can be made of copper or molybdenum. Copper plugs will be used for the commissioning of the injector with low bunch charge and molybdenum plugs will be used as substrates for the CsK_2Sb cathodes. In order to maintain the low surface resistivity of copper, but exploit the better substrate behavior of refractory metals, the use of a Cu plug with Ta or Mo evaporated on the surface as a barrier substrate layer will be investigated. Here, field emission properties need to be considered [3].

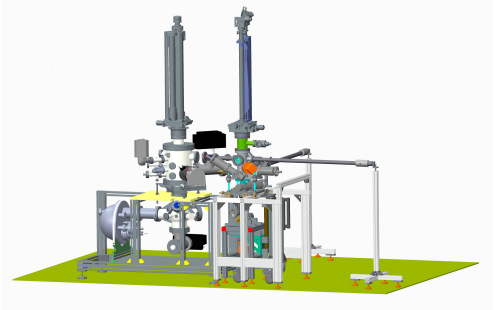

Figure 4: Drawing of the transfer system at the PPA system, as-planned.

In the preparation system and during transport the plugs will be mounted on omicron style sample holders. The transfer system (fig 4) at the injector allows to take the plugs off their sample holders and mount them on a cathode stalk shown in fig. 3. Both transfer systems can handle a tray of four sample holders which can be inserted to the vacuum suitcase (fig. 5) through a load-lock.

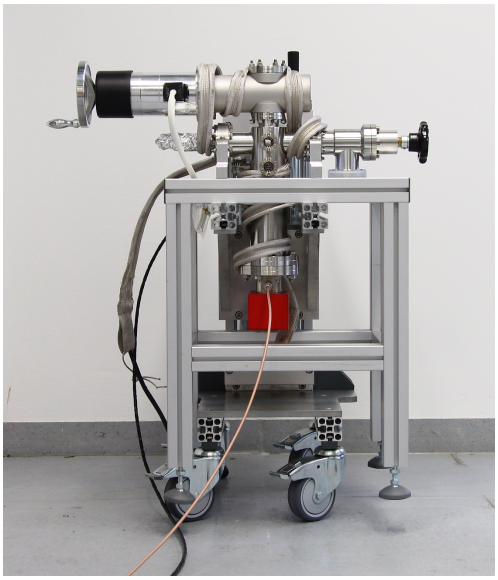

Figure 5: Photograph of the vacuum suitcase with 4 cathode positions, as recently commissioned. Base pressures in the low 10^{-11} mbar range can be maintained.

Ongoing work will be focused on studying the QE dependence on the composition, optimization of growth procedures, photocathode life time studies and the development of a reproducible growth procedure of CsK_2Sb photocathodes with a smooth surface and high QE. A prototype of the photoinjector and a diagnostics beamline will be available in spring 2016 [4], where in-gun experiments and post-operation analysis will be performed.

ACKNOWLEDGMENT

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