

# STUDY ON IMPROVING DURABILITY OF BIALKALI PHOTOCATHODE FOR AN RF-GUN WITH THE CSBR PROTECTIVE LAYER

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## Abstract

At Waseda university, we have been studying for high quality electron beam generation and developing variety of application experiments using 1.6 cells Cs<sub>2</sub>Te photocathode RF-gun. The performance of photocathodes is evaluated mainly in terms of Quantum Efficiency(Q.E.) and the lifetime. Cs<sub>2</sub>Te photocathode used in the RF-Gun at Waseda university is known for high Quantum Efficiency about 10% with UV light and relatively longer lifetime among semiconducting photocathodes.

For increasing the charge of electron beam and simplify the laser system, we started introducing CsK<sub>2</sub>Sb photocathode in the RF-gun which has light sensitivity in UV and visible range, and high Q.E. with green light. However, CsK<sub>2</sub>Sb photocathode has a difficulty in durability and we observed that it was not enough for long-term operation in the RF-gun. Then we plan to improve lifetime and durability of CsK<sub>2</sub>Sb photocathode by coating the cathode surface with CsBr thin film. In this conference, we report the result of lifetime measurement of CsK<sub>2</sub>Sb photocathode with CsBr thin film and future prospects.

## INTRODUCTION

CsKSb photocathode which we consider introducing in the RF gun is known for excellent characters such as high Quantum Efficiency in visible range, short pulse, and low emittance, and is expected to be used for the next generation radiation light source such as FEL and ERL[1,2]. This is why many research institutions around the world have been studying for CsKSb photocathode. This photocathode is less durable than Cs-Te photocathode which we have used in the RF-gun at Waseda University and metal photocathode, for instance Cu and Mg. This means that CsKSb needs for an extreme high vacuum condition. Other research institution has reported using CsKSb photocathode in RF electric field[3], but it is not clear how stable CsKSb is in strong RF electric field such as 100MV/m.

At Waseda university, we have been studying for high quality beam generation and developing application experiments using 1.6 cell photocathode RF-gun such as Laser Compton Scattering[4], coherent-Thz radiation[5] and pulse-radiolysis. We use the evaporation chamber for developing photocathodes in ultra-high vacuum. For improving the durability and lifetime of CsKSb photocathode, we have used CsBr for coating CsKSb photocathodes, which is more chemically stable in air pressure than CsKSb and lattice matching with CsKSb[6]. However, there is a problem that Q.E. decrease sharply during CsBr coating. We considered this is because we develop CsKSb without heating the substrate, and KSb which remains without reaction

during Caesium evaporation deteriorate the degree of lattice matching between CsBr and CsKSb[7]. For fabricating high crystallinity CsKSb, we evaporate Cesium and Potassium simultaneously after Antimony evaporation, and make CsKSb directly without making KSb. In addition, we coat CsKSb surface just after co-evaporation and compare the durability with coated CsKSb which is developed by sequential evaporation process.

## EXPERIMENTAL DETAILS

### Evaporation Chamber

Figure 1 shows the external appearance of evaporation chamber at Waseda university, which is used to fabricate photocathodes. In the evaporation chamber, each material to fabricate CsKSb and coat photocathode surface, namely Cesium, Potassium, Antimony and CsBr is set on evaporation source holder. By electrical heating, we can evaporate each element to Mo substrate. The evaporation source holder (Fig. 2) is placed between quartz crystal microbalance and Mo substrate during evaporation, so we can evaporate with monitoring the thickness of each evaporation material, but we can't measure the thickness of Cesium and Potassium at the same time during Co-evaporation.

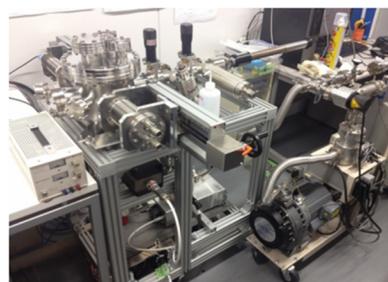


Figure 1: Evaporation chamber.

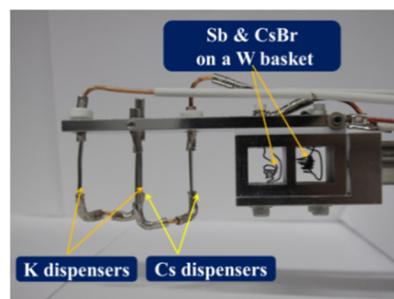


Figure 2: Evaporation source holder.

The evaporation chamber is evacuated by a scroll pump, two turbo molecular pump, ion pump and NEG pump, and internal pressure can be maintained  $10^{-7}$  Pa  $\sim$   $10^{-6}$  Pa dur-

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ing evaporation. Using Xe flash lamp and a monochrometer, 523nm or 532nm probe light incident to photocathodes and we can measure Q.E.

### Evaporation Method & Coating

In the following procedure, we fabricated CsKSb by a co-evaporation method and CsBr coating. First Antimony is evaporated to Mo substrate around 20nm thick, and then Potassium and Cesium is evaporated simultaneously at constant evaporation rate respectively. Co evaporation continues until Quantum Efficiency reaches peak value. Just after CsKSb evaporation, CsBr is evaporated and we measured Quantum Efficiency of coated CsKSb as a function of CsBr thickness, but a W basket shields from the probe light during CsBr evaporation, so measuring Q.E. and CsBr evaporation is done alternately. We evaporated CsBr at evaporation rate  $0.1\text{\AA}/\text{s} \sim 0.3\text{\AA}/\text{s}$ . After coating, we continued measuring Q.E. and took 1/e lifetime, and compared with the result of CsKSb fabricated by sequential evaporation process. Substrate temperature is maintained at room temperature during evaporation and lifetime measurement.

## RESULTS AND DISCUSSIONS

### Co-Evaporation

First, we researched the relationship between Q.E. and the composition ratio of Cesium and Potassium. We consider that the composition ratio (the number of atoms ratio) is in proportion to the deposition rate ratio of Caesium and Potassium during co-evaporation, so we tried to optimize a co-evaporation method by fabricating CsKSb repeatedly while changing the deposition rate ratio. Figure 3 shows the relationship between the composition ratio of Caesium and Potassium, and Quantum Efficiency measured at 523nm.

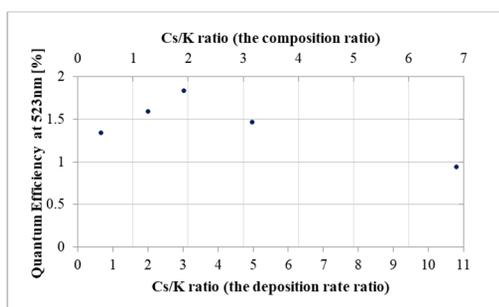


Figure 3: The relationship between Cs/K ratio and Q.E.

Figure 3 shows that Q.E. is the peak value 1.9% at the composition ratio of Cesium and Potassium of 2 : 1. (1.6% measured at 532nm) Actually, the distance of a Potassium dispenser and Mo substrate and that of a Cesium dispenser and Mo substrate are different, so real deposited thickness of Cesium and Potassium to the substrate isn't known. Thus, the value of each composition ratio of Fig. 3 is relative value. Table 1 shows the result of comparison Q.E. of CsKSb evaporated in sequential evaporation method with that in co-evaporation method.

Table 1: Comparison of Q.E. Between CsKSb Fabricated by Sequential Evaporation and Co-evaporation

Evaporation Method	Q.E. measured at 532nm [%]	Q.E. measured at 523nm [%]
Sequential Evaporation (substrate heated)	No data	2.9
Sequential Evaporation (substrate not heated)	1.9	2.3
Co evaporation (substrate heated)	1.8	1.9
Co evaporation (substrate not heated)	1.6	1.8

### CsBr Coating After Co-evaporation

Figure 4 shows the transient Q.E. of CsKSb during coating measured at 532nm after co-evaporation. The plots show relative Q.E. when Q.E. before coating set to be 1.

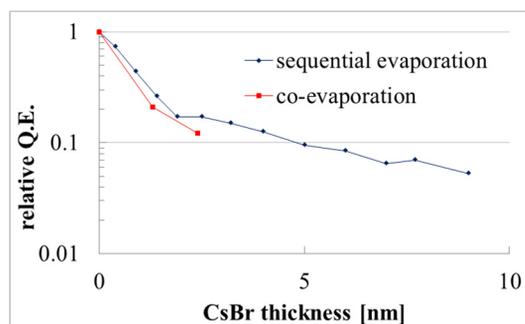


Figure 4: Quantum Efficiency of coated CsKSb as a function of CsBr thickness measured at 532nm.

Table 2: Comparison of Quantum Efficiency Before and After CsBr Coating Between CsKSb Fabricated by Sequential Evaporation and by Co-evaporation

Evaporation Method	Q.E. before coating [%]	CsBr thickness [nm]	Q.E. after coating [%]
Sequential evaporation	2.00	9.0	0.11
Co-evaporation	0.72	2.4	0.09

There was almost no difference of the Q.E. transition between CsKSb fabricated by sequential evaporation and co-evaporation, while coating. We considered this result shows that the composition of CsKSb made by a co-evaporation method isn't optimized like CsKSb fabricated by sequential evaporation, having excess Caesium around the surface. For that reason, it's necessary to establish the optimum evaporation procedure including Antimony thickness.

Figure 5 shows the result of the lifetime measurement of CsKSb just after CsBr coating. The 1/e lifetime of this cathode was 140 hours, and we confirmed before the 1/e

lifetime of coated CsKSb fabricated by a sequential evaporation method was 90 hours without heating and 970 hours with heating. These results indicate that there is not much difference of the cathode lifetime between both evaporation methods without heating the substrate, and we judged that the crystallinity of CsKSb didn't have much difference between both evaporation methods. We considered two reasons. First, BNL reported that heating substrate during deposition affects the CsKSb crystallinity, and it has better crystallinity when evaporated with heating the substrate[7]. Second, we have confirmed that CsKSb evaporated with heating the substrate and coated CsBr thin film has longer  $1/e$  lifetime than that of without heating[8]. Thus, we consider that there is the relationship between the crystallinity of photocathodes and  $1/e$  lifetime after coating. It is necessary to optimize some parameters such as the evaporation rate ratio during co-evaporation and fabricate CsKSb having better crystallinity, higher Quantum Efficiency and longer  $1/e$  lifetime. The lifetime of CsKSb can be improved by increasing CsBr thickness.

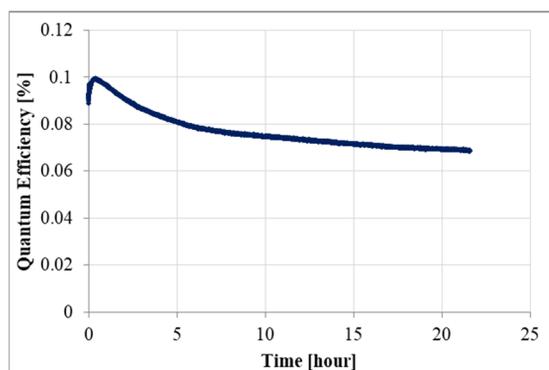


Figure 5: The lifetime measurement of coated CsKSb, fabricated by co-evaporation.

## CONCLUSION

For improving crystallinity of the photocathode, we tried to fabricate CsKSb by co-evaporation of Cesium and Potassium. We evaporated CsKSb repeatedly while changing the evaporation rate ratio of Cesium and Potassium. Resulting photocathode achieved Q.E. of 1.9% measured at 523nm, but less Q.E. value compared with that of fabricated by a sequential evaporation process. There was not much difference between the result of lifetime measurement in sequential evaporation method and that in co-evaporation method. We considered that the crystallinity of CsKSb was not enough with the co-evaporation method. As mentioned above, it is necessary to optimize the co-evaporation procedure including Antimony thickness, and we considering undertaking triple element co-evaporation.

We are going to test the coated CsKSb in an RF-gun after the optimizations were successfully done in order to confirm the usefulness of CsBr thin film coating.

## REFERENCE

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