

STUDY OF Cs-Te PHOTOCATHODE FOR RF ELECTRON GUN*

Shuri Matsuzaki, Mariko Nishida, Kazuyuki Sakaue, Masakazu Washio,
Waseda University, Tokyo, Japan
Hokuto Iijima, Tokyo University of Science, Tokyo, Japan

Abstract

At Waseda University, we have been studying high quality electron beam with an rf electron gun. In recent accelerator study and application researches, high quality electron beam are strongly required. Photocathode is a key component to generate higher quality electron beam, thus we started to develop a Cs-Te photocathode as an electron source since 2007. Cs-Te photocathode shows high quantum efficiency (Q.E.) (~10 %) and has long life time (~several months). From 2013, we built a photocathode evaporation chamber and started photocathode study. In this study, our purpose is to clarify their property and to establish an ideal evaporation recipe. We succeeded in producing high quality Cs-Te photocathode, and electron beam generated by our Cs-Te photocathode shows high charge (4.6 nC/bunch) and high Q.E. (1.74 %) in our rf electron gun. Furthermore, we found a Q.E. recovery after Cs deposition process and it causes higher Q.E. than usual due to, we believe, Cs deposition quantity or Cs deposition speed. Thus we are now surveying the optimum Cs evaporation parameters. In this conference, we will report a detail of our photocathode development system, the latest progress of optimization study of Cs-Te photocathode and future plans.

INTRODUCTION

At Waseda University, we have been studying high quality electron beam generation with photocathode rf gun and it was applied for several experiments, such as laser Compton scattering (LCS) [1] and pulse radiolysis [2]. In recent accelerator study and application researches, high quality and high charge electron beam are strongly required. Photocathode is a key component to generate high charge electron beam, thus we started to use a Cs-Te photocathode as an electron source since 2007 and built a photocathode evaporation chamber in 2013. Cs-Te photocathode is widely used because of its property of high quantum efficiency (Q.E.) (~10 %) with UV light and long life time (~several months). In this study, our purpose is to clarify their property and to establish an ideal evaporation recipe. We found a Q.E. recovery after Cs deposition process and started to research its mechanisms because it caused higher Q.E.. In our past study, we have already clarified that Te deposition seemed

to not have relationship with it. Carrying out further study, we developed two new devices. The first device is a newly-designed evaporation source holder which enables us to measure Cs deposition quantity and Cs deposition rate. The second device is a substrate heating system. In this paper, we describe our results of optimization study of Cs-Te photocathode preparation by means of substrate temperature in the Cs deposition.

EXPERIMENTAL EQUIPMENTS

Photocathode Evaporation Chamber

We built a photocathode evaporation chamber in 2013. Figure 1 shows the appearance of the chamber. It is required ultrahigh vacuum for preparing Cs-Te photocathode, therefore, the chamber is equipped several vacuum pumps. Its vacuum level can reach 6×10^{-8} Pa after chamber baking (~200 °C, 24 h). Since the chamber is independent from our rf gun, we adopted a load-lock system to transfer a photocathode without air exposure.

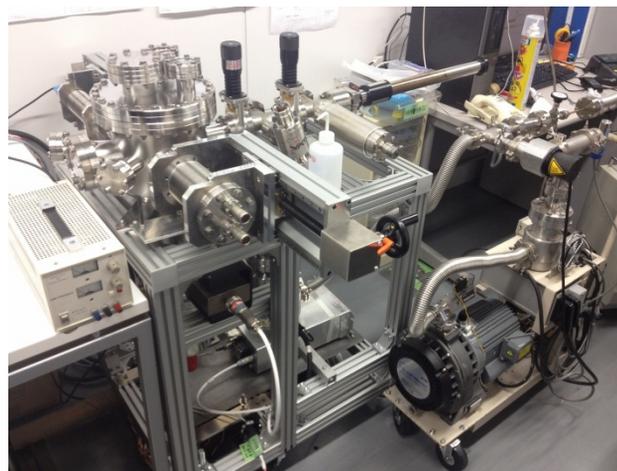


Figure 1: The appearance of the photocathode evaporation chamber.

Evaporation Source Holder

In order to make it possible to measure Cs deposition quantity and Cs deposition rate, we developed a newly-designed evaporation source holder shown in Fig. 2. It can be mounted four kinds of evaporation source (tellurium, antimony, cesium and potassium). Sb and K are in preparation for multi-alkali photocathode study in near future. As shown in Fig. 2, this Evaporation source holder is equipped two Cs dispensers. These dispensers

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#matsuzaki@akane.waseda.jp

are connected in series and face in opposite directions, so that we can deposit Cs on a substrate and measure the thickness by a sensor, respectively.

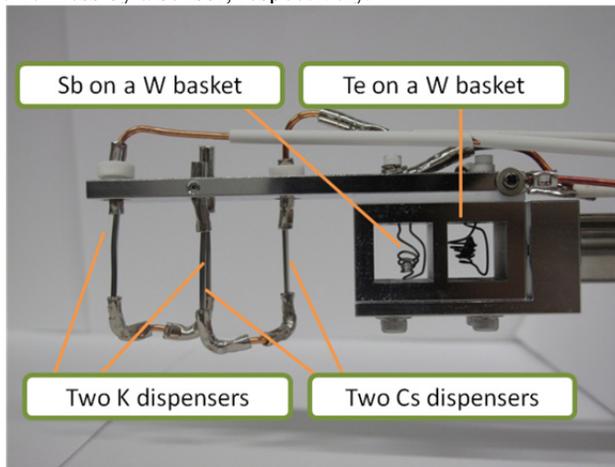


Figure 2: New-designed evaporation source holder.

Substrate Heating System

We developed a substrate heating system in order to study relationships between properties of Cs-Te photocathode and substrate temperature. We can also carry out substrate cleaning by heat with this system. As shown in Fig. 3, a k-type thermocouple and a ceramic heater, which can reach 1000 °C, are equipped on the back from a deposited side.

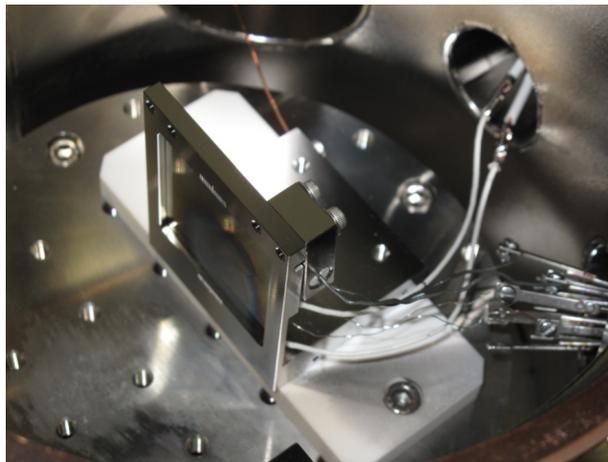


Figure 3: A substrate heating system.

RESULTS AND DISCUSSION

Cs-Te Photocathodes Preparation

We used a molybdenum substrate ($50 \times 50 \times 0.3$ mm) in this study. The substrate was heated 600 °C for 1 hour for cleaning up the surface before every Cs-Te preparation. After the process, we waited until cooling down the substrate to room temperature, and then started 20 nm thick Te deposition as monitoring deposition quantity and rate with a QCM (Quartz Crystal Microbalance). We carried out Cs deposition at different three substrate temperature ranges:

- **Room temperature** 20~30 °C
- **Middle temperature** 60 °C
- **High temperature** 140 °C

We prepared two Cs-Te photocathodes in each condition and carried out Q.E. measurement with UV light ($\lambda=262$ nm) during Cs deposition. Currents supplied to Cs dispensers were increased gradually and stopped when it passed a few minutes since Q.E. plot showed a peak. Maximum deposition rate of Cs depositions were kept to be within 1.0~1.8 Å/s. Although we started Cs depositions after substrate temperature had been stable at each temperature, it became approximately 20 °C higher than the beginning due to heat from Cs dispensers.

Q.E. Measurement during Cs Deposition

Figure 4 shows the results of Q.E. measurements during Cs deposition at three temperature ranges. All Q.E. are summarized in Table 1. We observed the lower both peak and stable Q.E. as the substrate temperature higher.

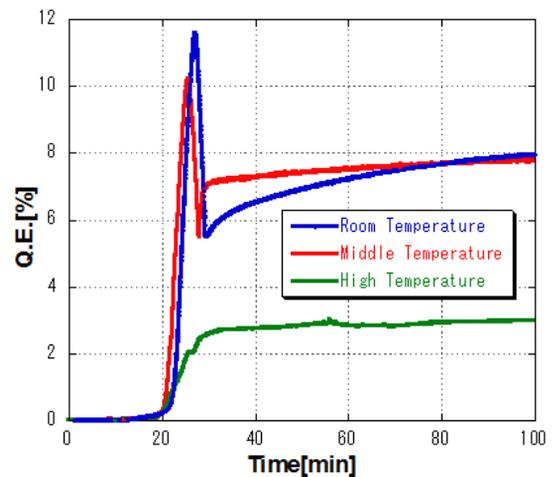


Figure 4: Q.E. measurement during Cs deposition.

Table 1: Results of Q.E. Measurement

Substrate Temperature	Peak Q.E. [%]	Stable Q.E. [%]
Room#1	13.4	11.5
Room#2	11.6	8.4
Middle#1	10.2	8.3
Middle#2	8.5	6.6
High#1	2.7	3.2
High#2	2.9	3.4

* Peak Q.E. at high temperature is defined as the level part after Q.E. sharp rise.

We observed Q.E. recoveries at room and middle temperature. Time required for saturation of Q.E. recovery was shorter at middle. From these differences, we inferred that heat promoted a reaction of Cs with Te. Q.E. transition at high temperature had no peaks; this point is completely different from the others. In order to

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confirm that the difference in each condition was not caused by changes in a Te layer due to heat a substrate, we prepared an additional Cs-Te photocathode with the following deposition recipe:

- 20 nm thickness of Te deposition
- Heating substrate to 140 °C
- Wait until it returns to room temperature
- Carrying out Cs deposition

This Cs-Te photocathode showed 12.1 % of Q.E. and had the same characteristic of Q.E. transition at room temperature, so it is obvious that substrate temperature during Cs deposition, i.e. reaction between Cs and Te strongly influenced Q.E..

Q.E. Measurement During Substrate Heat Cleaning

During substrate heat cleaning process, we measured substrate temperature, vacuum level and Q.E.. Figure 5 shows the results of the process which cleaned up Cs-Te photocathode prepared at room temperature.

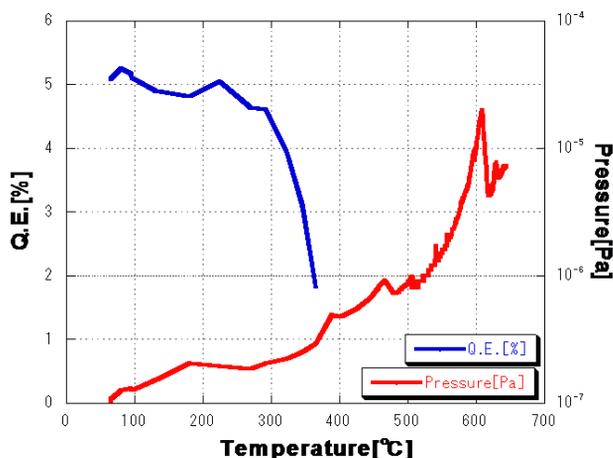


Figure 5: Results of substrate heat cleaning.

The measured Q.E. was fluctuated after substrate temperature had reached approximately 400 °C so that we stopped measurement around 400 °C. We confirmed that Q.E. became 0 % after this cleaning. Both Q.E. decrease and a pressure rise started after substrate temperature had reached approximate 300 °C. It suggested that desorption of Cs-Te started at around 300 °C, that is, Q.E. fluctuations during Cs depositions at 30~140 °C were not mainly caused by desorption of Cs-Te. From these results, we inferred that changes of Q.E. transition at 30~140 °C, which shown in Fig. 4, were caused by compositional changes of Cs-Te or reactions of Cs-Te with residual gasses. We carried out spectral response measurement in order to confirm the hypothesis, but there were no significant differences in Q.E. in each preparation condition. Further studies are needed so as to clarify relationships between properties of Cs-Te and substrate temperature.

CONCLUSIONS AND PROSPECTS

We studied on relationships between properties of Cs-Te photocathode and substrate temperature with our new devices. We prepared Cs-Te photocathodes at different three substrate temperature in order to clarify the relationships between Q.E. and substrate temperature during Cs deposition. We confirmed that Q.E. of Cs-Te photocathode had relationships with substrate temperature and became higher when it prepared at lower temperature. From this study, we inferred that heat promoted a reaction of Cs with Te and changes of Q.E. transition at 30~140 °C were caused by compositional changes of Cs-Te or reactions of Cs-Te with residual gasses. We are going to carry out further studies to clarify relationships between properties of Cs-Te and substrate temperature. We prepared Cs-Te photocathode on the substrate heating system in this study, so we should confirm whether these results will be appeared when we prepared it on a plug which is installed in our rf gun. We also keep on studying on optimization of Cs-Te preparation recipe by researching relationships between Q.E. and other factors, e.g. Te deposition, Cs deposition and vacuum and so on. We also plan to study about alkali antimony photocathodes for rf electron gun.

REFERENCES

- [1] K. Sakaue, et al., Radiation. Phys. Chem. 77. 1136 – 1141 (2008).
- [2] Y. Hosaka, et al., Radiation. Phys. Chem. 84, 10(2013).