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STUDY ON IMPROVING DURABILITY OF Cs-Te PHOTOCATHODE FOR AN RF-GUN

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Abstract

At Waseda University, we have been studying for high quality electron beam generation using 1.6 cell Cs-Te photocathode rf-gun. We use photocathode as the electron source, which can generate high- quality electron beam such as low emittance, and short bunch. The performance of photocathode is evaluated mainly in terms of quantum efficiency (Q.E.) and lifetime. Cs-Te photocathode used in the rf-gun is known for high Q.E. about 10% with UV light and relatively longer lifetime among semiconductor photocathodes.

Since it is a hard environment for photocathode inside the gun, it is necessary to replace the photocathode every several months. In other words, in order to achieve long-term operation of rf-gun, it is necessary to find highly durable photocathode recipe. It has been reported that the Cs-Te photocathode by co-evaporation can produce a photocathode having a longer lifetime as compared with the sequential evaporation. Moreover, we have done studies to improve lifetime and durability of Cs-Te photocathode by coating the cathode surface with CsBr thin film. In this conference, we report the evaluation results of Cs-Te photocathode by co-evaporation, CsBr coating and future prospects.

INTRODUCTION

In recent years, the demand for high brightness electron beam is rising for practical applications such as the free electron laser (FEL) and the energy recovery linac (ERL)[1-5]. Photocathodes are useful electron sources for generating high brightness and low-emittance beam. Semiconductor photocathodes, which have higher Q.E. compared with metal photocathodes, [6, 7] are especially expected to be the candidates for an electron source that requires high brightness and high current beam. However, there is an issue that semiconductor photocathodes generally have a shorter lifetime and require ultra-high vacuum or an even better vacuum environment [8].

Though, photocathodes are used in both DC guns and rf-guns [9], the requirements of characteristics for the photocathodes are different in each electron gun. At present, we are using the photocathode rf-gun for the generation of high brightness electron beam. In the rf-gun cavity, it is difficult to achieve both extreme high vacuum and high efficiency (i.e. high Q.E.). Deterioration of vacuum degree inside the cavity due to Joule heat and discharge is to be caused by the rf electric field. The rf electric field itself directly causes deterioration of the cathode. Cs-Te photocathode, which has relatively long lifetime, is often used in rf-guns [10,11]. In our case, it is necessary to exchange the photocathode every several months due to decrease of Q.E[12].

The purpose of this research is to make the Cs-Te photocathode withstand longer-term rf-gun operation even under the above-mentioned environmental conditions. It has been reported that Cs-Te photocathode by co-evaporation tends to have a longer lifetime as compared to that by sequential evaporation process [13].

At Waseda University, we have been studying an S-band rf electron gun [14,15] and the application of high quality electron beams to laser Compton scattering experiments [16], pulse radiolysis [17] and so on [18]. We usually use Cs-Te photocathode as an electron source and maintain high Q.E. by exchanging the cathode every six months. Thus, we have been investigating the effectiveness of Cs-Te photocathode by co-evaporation in order to reduce the number of the cathode exchange.

EXPERIMENTAL DETAILS

Evaporation Chamber

Figure 1 shows the appearance of evaporation chamber at Waseda University, which is used to fabricate photocathode. In the evaporation chamber, each material to fabricate Cs-Te and coated photocathode surface, namely Cesium, Tellurium and CsBr are set on evaporation source holder. We can evaporate each element to Mo substrate by applying the electrical heating. The evaporation source holder is placed between quartz crystal microbalance and Mo substrate during the evaporation, so we can evaporate under the monitoring of the thickness for each evaporation material. However, we cannot measure the thickness of Cesium and Tellurium at the same time during co-evaporation. The photocathode evaporation chamber is shown in Fig. 2 and the evaporation source holder is shown in Fig. 3.

Figure 1: Evaporation Chamber.

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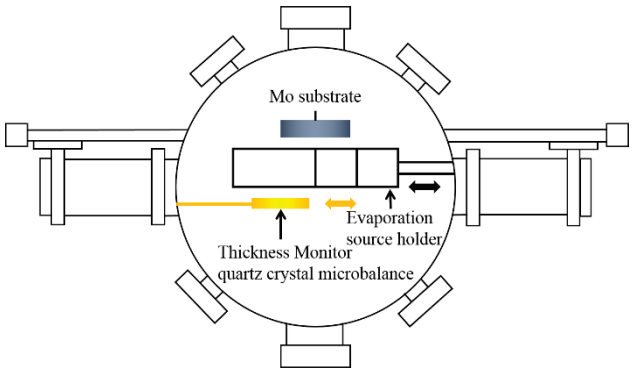

Figure 2: Schematic of the photocathode evaporation system.

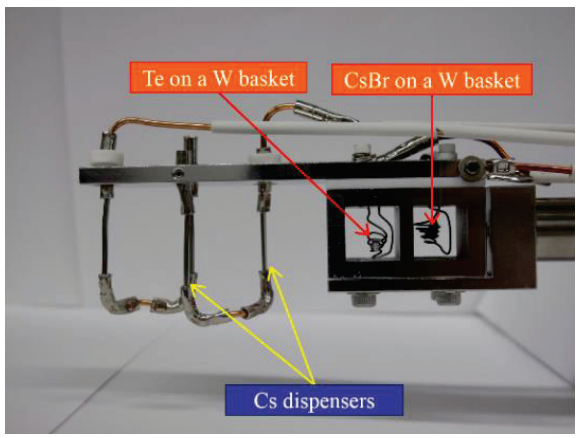

Figure 3: Evaporation source holder.

The evaporation chamber is evacuated by a scroll pump, two turbo molecular pumps, ion pump and NEG pump, and the internal pressure can be maintained 10^{-7} Pa and 10^{-6} Pa during the evaporation. Using Xe flash lamp and a monochromator, 262nm probe light can be incident to photocathodes so that we can measure the Q.E. On the other hand, 265nm light of UV LED is guided from top of the evaporation chamber, because incident light is blocked by quartz crystal microbalance and Tellurium on a tungsten basket during co-evaporation.

Evaporation Process & Coating

In the following procedure, we had fabricated Cs-Te photocathode by the co-evaporation process with CsBr coating. Co-evaporation is processed until the Q.E. reaches a peak value. Just after the Cs-Te evaporation, CsBr is evaporated and we measured Q.E. of coated Cs-Te as a function of CsBr thickness. Since the tungsten basket interfere with the Xe probe light during CsBr evaporation, Q.E. measurement and CsBr evaporation are done alternately. We evaporated CsBr at evaporation rate 0.1Å/s~0.3 Å /s. After the coating we had continued the measurements of Q.E., for evaluating the 1/e lifetime, and compared with the results of those by sequential evaporation processed one. Substrate temperature is maintained at room temperature during the evaporation and the lifetime measurement.

RESULTS AND DISCUSSION

Co-evaporation

First, we have investigated the relationship between Q.E. and the composition ratio of Cesium and Tellurium. We consider that the composition ratio (atomic ratio) is proportional to the deposition rate ratio of Cesium and Tellurium during the co-evaporation, so we had tried to optimize the co-evaporation process by fabricating Cs-Te repeatedly while changing the deposition rate ratio.

Figure 4 shows the relationship between the composition ratio of Cesium and Tellurium, and the Q.E. measured at 262nm and 265nm.

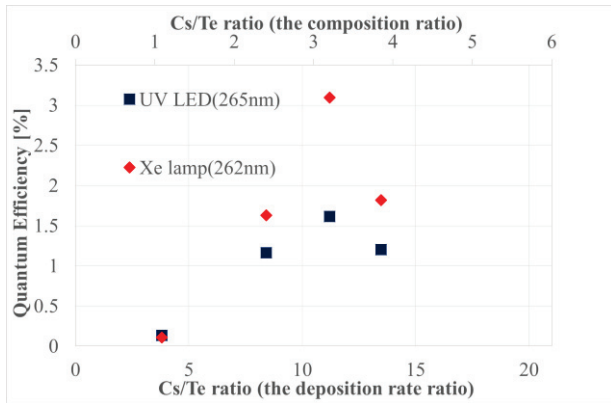

Figure 4: The relationship between Cs/Te ratio and Q.E.

The figure shows that the Q.E. is the highest (3.1%) at the Cesium and Tellurium composition ratio of 3:1. Actually, the distances between the Cesium dispenser and the Mo substrate and that between the Tellurium on the tungsten basket and the Mo substrate are different, so the precise value of deposited thicknesses for Cesium and Tellurium are unknown. Thus, the values of each composition ratio in Fig. 4 should be the relative values. Table 1 shows the results of the measured Q.E. and the 1/e lifetime of Cs-Te with the sequential evaporation process and with co-evaporation process. These results show that co-evaporation process can produce a photocathode with longer lifetime than sequential one.

Table 1: Comparison of Q.E. and Lifetime between Cs-Te Fabricated by Sequential Evaporation and Co-evaporation

Evaporation process	Q.E. measured at 262nm [%]	Q.E. measured at 265nm [%]	1/e lifetime [hour]
Sequential Evaporation	3.76	No-data	869±390
Co Evaporation	3.13	1.62	1818±308

CsBr Coating after Co-evaporation

Figure 5 shows the transient Q.E. for Cs-Te during the coating which are measured at 262nm after the co-evaporation. The plots show relative Q.E. when the Q.E. before

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coating set to be 1. Table 2 shows the measurement results of the Q.E. before and after the coating. As seen in Figure 5, the decrease of the Q.E. in the first few nm is large. Also there was not much difference between the co-evaporation process and the sequential evaporation one in the rate of the Q.E. reduction. We consider that the physical phenomenon (such as the interface problems) occurring at the boundary between Cs-Te and CsBr predominates in the rapid decrease of Q.E. in the initial stage of coating, and another physical phenomenon (such as material migrations) predominates in the subsequent Q.E. decrease.

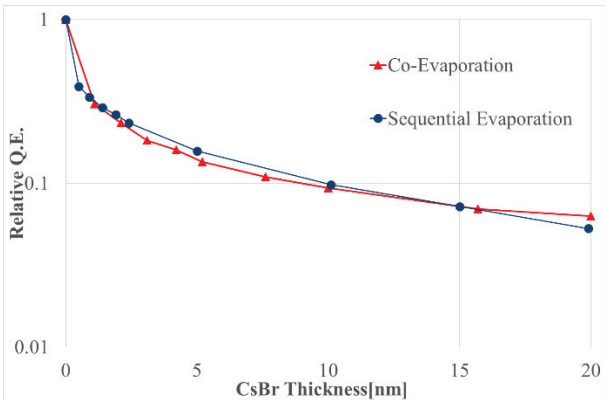

Figure 5: Q.E. of coated Cs-Te as a function of CsBr thickness measured at 262nm.

Table 2: Comparison of Q.E. before and after CsBr Coating between Cs-Te Fabricated by Sequential Evaporation and Co-evaporation

Evaporation Process	Q.E. before coating [%]	CsBr thickness [nm]	Q.E. after coating[%]
Sequential Evaporation	5.7	20.0	0.5
Co Evaporation	3.1	19.8	0.12

CONCLUSION

For improving the stoichiometric conditions of the photocathode, we tried to fabricate Cs-Te by co-evaporation of Cesium and Tellurium. We evaporated Cs-Te repeatedly while changing the evaporation rate ratio of Cesium and Tellurium. The lifetime measurement results show that co-evaporation process can produce the photocathode with longer lifetime than the sequential one. However, resulting photocathode with Q.E. of 3.1% measured at 262nm, had less Q.E. value compared with that of fabricated by a sequential evaporation process. We considered that the stoichiometric conditions of Cs-Te were not high enough. As mentioned above, further study it is necessary to optimize the co-evaporation procedure.

We are going to test the Cs-Te by co-evaporation process in an rf-gun after the optimizations of the process are successfully done.

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