Cs_2Te photocathode for the TTF Injector II

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Abstract

High quantum efficiency (Q.E.) (10-12 % @ 254 nm) cesium telluride (Cs_2Te) photocathodes has been produced on different substrata. Photoemitter preparation procedure, gas exposition poisoning and rejuvenation effects have been investigated both from the photoemissive properties point of view (e.g. Q.E. vs. λ and vs. gas exposition) and for what is relative to the chemical structure and composition by using electron spectroscopy techniques as AES (Auger Electron Spectroscopy) and XPS (X-ray Electron Spectroscopy). A Cs_2Te preparation system for the TTF injector II is under construction and it will be operative within autumn 1996 at Fermilab, where the gun prototype is being assembled. Moreover we are implementing the apparatus used at Milano for the photocathodes R&D activity with a 250 fs Nd:glass high power laser system and a new UHV analysis chamber: both will be used for optical measurements and low energy electron spectroscopy analysis as angle resolved photoemission.

1 INTRODUCTION

Laser-driven RF guns are nowadays the most promising high brightness electron sources [1]. The primary electron sources of these devices are photocathodes. Therefore it is important to study and understand the parameters that influence the photocathode characteristics (e.g. Q.E., spectral response and operative lifetime). Our activity is devoted to the understanding of the cathode formation processes, the gas pollution effects and the rejuvenation possibility. In these investigation we applied not only Q.E. analysis technique (spectral responses, Q.E. vs. gas pollution) but also AES and XPS. We use these techniques because of the thin thickness (30-40 nm) of our photocatodes.

We think that important informations could also be obtained by an angle resolved energy analysis of the photoemitted electrons. Therefore we are now upgrading our R&D system with a new μ-metal vacuum chamber for time of flight measurements.

Moreover we obtained the responsibility for the TTF Injector II photocathode preparation apparatus. This UHV device is under assembling at Milano. It consists of a preparation chamber and a cathode transfer system. The latter is directly connected to the preparation chamber so no need of a separate transport system is required to move the cathode to the gun.

2 EXPERIMENTAL RESULTS

The photoemissive materials are produced in UHV condition. Tellurium and cesium are evaporated on a Mo substratum. The evaporation of the two elements is obtained and controlled by current flow through the sources and the deposition rate is measured by a quartz microbalance. We use a high pressure Hg lamp with interferential filters to illuminate the cathode. The photocurrent is collected through an anode placed near the cathode, polarizable up to 500 V. The substratum can be heated at more then 500 °C with a stability of 1 °C. Its temperature seems to be an important parameter during the cathode formation. To have a rough idea of the temperature influence we grew some cathodes both on a room temperature substratum ("cold" recipe) and heating it at 120 °C ("warm" recipe). The results we obtained are reported in Figure 1.

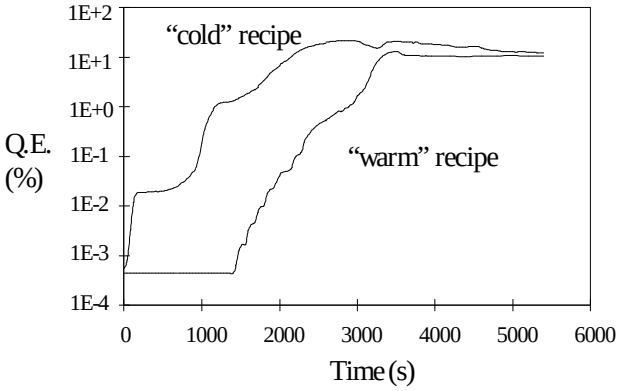

Figure 1. Different effects of substratum temperature on the photocurrent behavior.

The interesting feature is the higher Q.E. value reach with the "cold" recipe. Nevertheless the photocurrent has a rapid decrease and it reaches the value obtained with the "warm" recipe after some hours. The "warm" recipe, indeed, produces a lower but more stable in time Q.E. value. An analysis of the respective spectral response, after some hours, highlights no important differences. The results obtained are reported in Figure 2.

In particular, our data fit the spectral response obtained by Powell [2]. We also obtained the "shoulder" that extend the response of the cathode to energy lower than the Cs_2Te photoelectric threshold of 3.5 eV [3]. For our applications, this shoulder should be reduced in

order to obtain a sharper photoelectric threshold.

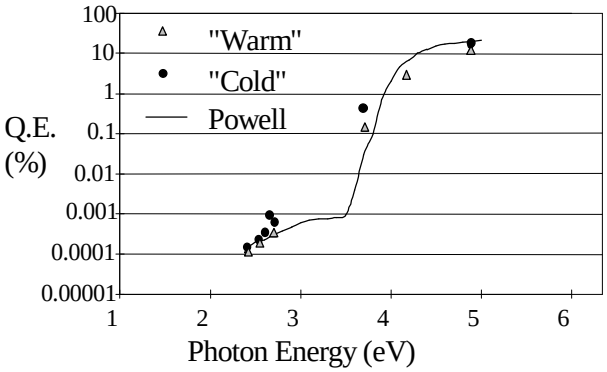

Figure 2. Spectral responses for the "cold" and "warm" recipe.

The use of photocathodes inside a RF gun requires some investigation of the effects of residual gases on the lifetime of the cathode. To estimate the roughness of the cathode to gas exposition, we put the cathode in an oxygen atmosphere (gas pressure $1 \cdot 10^{-9}$ mbar) and continuously measure the photocurrent. We choose oxygen as test-gas because it was the most reactive with alkali photocathode [4, 5]. The photocurrent vs. oxygen exposition is reported in Figure 3.

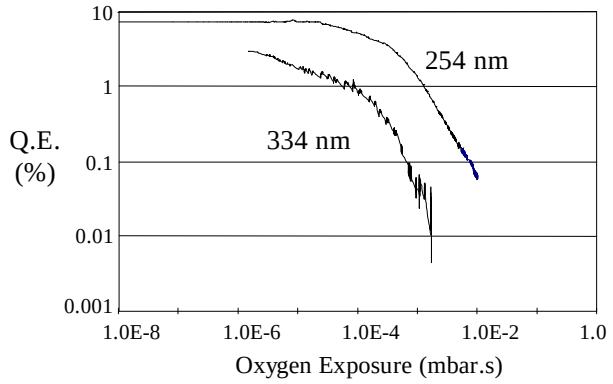

Figure 3. Photocurrent vs. oxygen pollution at two wavelengths.

As shown in Figure 3, we need about 1000 L (1 L= $1 \cdot 10^{-6}$ mbar·s) of oxygen to reduce the Q.E. of Cs_2Te by one order of magnitude. This value must be compared with that (1 L) needed to reduce the Q.E. of K_2CsSb of the same quantity [6].

Another interesting feature of cesium telluride is the possibility to restore the Q.E. after poisoning. This process of rejuvenation of the cathode as been extensively studied by XPS technique. The important feature is that to obtain the rejuvenation both light illumination and cathode heating are necessary. A detail description of the results obtained using the surface techniques described before is reported in an other paper presented at this Conference [7]. In this work, we present a "step by step" analysis of the cathode formation, a study of the reaction of the gas with the cathode elements during the pollution and important results on the rejuvenation effect [8].

3 UPGRADING THE MILANO SYSTEM

The R&D activity till now carried on have improved the understanding of the formation mechanisms of Cs_2Te photocathode, the estimation of the roughness to gas exposition and a preliminary understanding of the rejuvenation effects. The application of the photoemissive materials as electron sources in high brightness laser-driven RF guns, requires also an investigation on the energy and angular distribution of the photoemitted electrons. We are now upgrading the Milano production system to include a new system to accomplish these new measurements.

The new device is a μ-metal chamber connected to the main preparation system so that the photocathode are transported in UHV condition inside the whole system.

The new chamber is provided with a Time Of Flight (TOF) energy spectrometer. This consists of couple of Micro-Channel Plates placed 40 cm from the sample with a μ-metal drift tube. The energy of the emitted electron is measure by their separation in the time of flight from the sample to the detector. The relation between flight time and electron energy is reported in Figure 4.

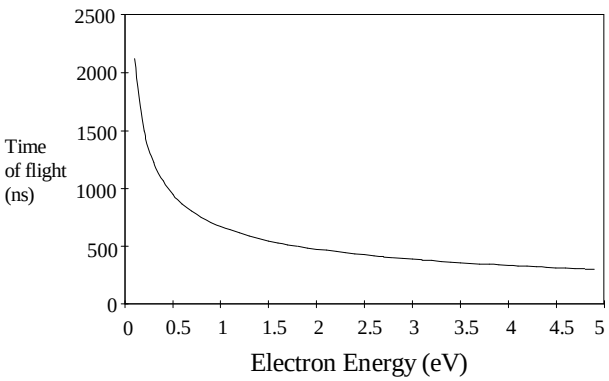

Figure 4. Time of flight vs. Electron energy.

The light source employed in this measurement is a Nd:glass TWINKLE laser. It produces pulses at a repetition rate of 10 Hz in the 4th harmonic (@ 264 nm) of the fundamental. Each pulse is 250 fs long with an energy of at least 100 μJ. When it is employed in measurement with TOF, the pulse energy must be drastically reduced to avoid space charge effects on the electron distribution.

4 THE TTF PHOTOCATHODE PREPARATION CHAMBER

In the context of the TTF collaboration for the Injector II, the Milano group has the responsibility for the realization of the photocathode preparation

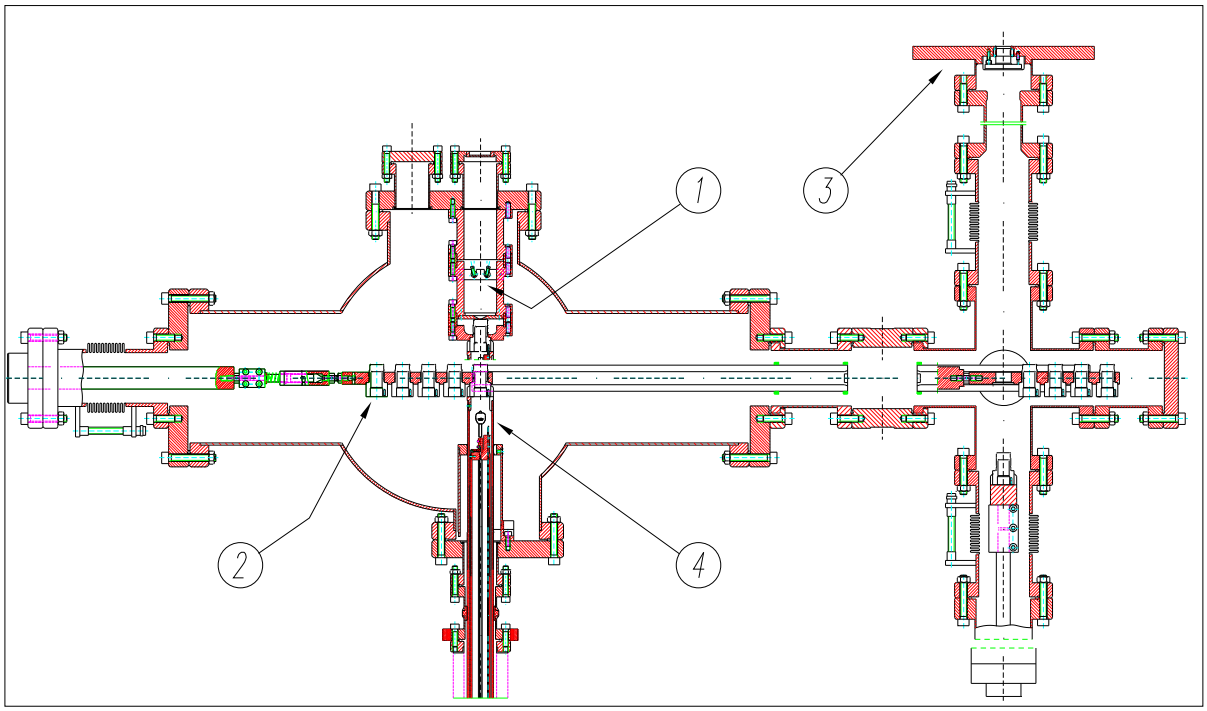

Figure 5. TTF photocathode preparation system. 1) Deposition area with the Te and Cs Sources. 2) Cathode and the five cathode holder. 3) Backside of the gun. 4) Heating and temperature controlling system.

apparatus. In Figure 5, we reported a drawing of the entire assembly. The whole system is UHV compatible and the cathodes are transported directly from the preparation chamber to the gun. A magnetic translator move a five cathodes holder. For the production, a substratum is taken from the holder by a clamp. A linear translator moves the substratum to the deposition area. A second translator moves an halogen lamp and a thermocouple in the back of the substratum. The halogen lamp (12 V, 50 W) allows to heat the substratum up to 600 °C. The temperature is measured by the thermocouple which allows also to maintain a stable value during the production. The deposition area is provided with one Te and one Cs sources, whose deposition rates are measured by a quartz microbalance. The shape of the photoemissive area is determined by a mask placed between the sources and the substratum. After the production the cathode is placed back in the holder which is guided by a rail toward the interchange area. The interchange chamber consists of a modified six-way cross CF 63. The cathode is taken by a clamp mounted on a magnetic translator and moved to the gun.

The whole system is now under assembling. We plan to have the system ready to use at the end of July in Milano. So we think to move it to Fermilab for the autumn 1996.

5 CONCLUSIONS

The results till now obtained by our group have contributed to understand some important processes that characterize Cs_2Te. We have pointed out a more stable Q.E. behavior for the photocathode grown maintaining the substratum at 120 °C. We have highlighted the formation of different compounds during the cathode growth. The roughness of the cathode has been evaluated by oxygen exposition. We have underlined that the Cs_2Te is less sensitive by some order of magnitude to gas pollution if compared to alkali-antimonied and we have some indication on the pollution process. Moreover polluted cesium telluride could be partially rejuvenated by applying heat and UV light.

Our future activity will be devoted to a deeper understanding of the pollution and rejuvenation effects. Moreover the angle resolved electron energy distribution measurements will allow to estimate new properties of these materials.

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