

# NEW ACTIVATION TECHNIQUES FOR HIGHER CHARGE LIFETIME FROM GaAs PHOTOCATHODES \*

O. Rahman<sup>†</sup>, M. Gaowei, W. Liu, E. Wang, Brookhaven National Lab, Upton, USA  
 J. Biswas, Stony Brook University, Stony Brook, USA

## Abstract

GaAs is the choice of photocathode material for polarized electron sources. The well established method of activating GaAs for beam extraction is to use Cs and Oxygen to create a 'Negative Electron Affinity'(NEA) layer. However, this layer is highly sensitive to vacuum and gets damaged due to ion back bombardment in DC guns. In this work, we explore activation methods that used Tellurium in conjunction with the usual Cs and Oxygen. We report our method to activate GaAs and show charge lifetime results for our activation method. Our results show that the use of Te could potentially help with longer charge lifetimes from GaAs cathodes in DC guns.

## INTRODUCTION

GaAs has been used as photocathodes in various DC guns for producing polarized electron beam. An activation layer, usually consisting of Cs and an oxidant (O<sub>2</sub> or NF<sub>3</sub>), is required to achieve "Negative Electron Affinity (NEA)" on the surface [1]. This activation layer degrades during beam extraction due to ion back bombardment and limits the charge lifetime from a photocathode [2]. There has been efforts to develop a more robust activation layer for GaAs activation. Cornell has reported higher charge lifetime by growing a thin CsTe<sub>2</sub> layer on top of the GaAs [3]. Mutli-alkali activation, involving Cs and Li, has shown promises towards more robustness [4]. In this paper, we report results from activation of GaAs with Cs, O<sub>2</sub> and Te.

## EXPERIMENTAL SETUP

We used an existing cathode preparation chamber at BNL for this experiment. The main chamber is a 10 inch sphere with various ports for different equipment. Figure 1 shows a schematic diagram of the main sphere. The system is equipped with a 300 l/s ion pump and two TSP's. After a week of bakeout at 180 celcius, the base pressure of the system was approximately  $5 \times 10^{-11}$  Torr. The stalk heater can heat the cathode up to desired temperature, which was 580 celcius in our case. The laser used was 532 nm laser, with 50  $\mu$ W of power on the cathode surface. The Cs source was a standard SAES getters evaporation source. For the Te source, we used an emptied and cleaned shell from the SAES Cs sources. First the source was emptied using tweezers, then ultrasonic cleaned until there is no particle found under a magnifying glass. Then the emptied shells were filled with small pieces of ultra high purity Te (99.9999%). The

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<sup>†</sup> orahman@bnl.gov

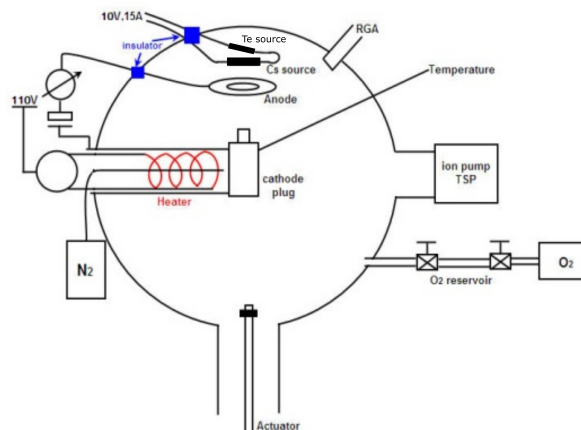


Figure 1: Cathode preparation system.

evaporation rate of these Te sources were calibrated against drive current using a crystal monitor. Such an evaporation rate curve is shown in Figure 2.

## ACTIVATION METHOD

After heat cleaning the cathode at 580 C for an hour, the sample was let to cool down to room temperature. We used co-deposition/saturation technique to activate the cathode with Cs and O<sub>2</sub>. After the QE has reached it's maximum value from Cs-O<sub>2</sub> activation, Te was deposited to a desired thickness. This step showed a decrease in QE. The last step was to deposit Cs on the cathode until the QE recovers to almost to it's original value (right after Cs-O<sub>2</sub>) activation. From then on, charge lifetime measurement continued for 2-5 days.

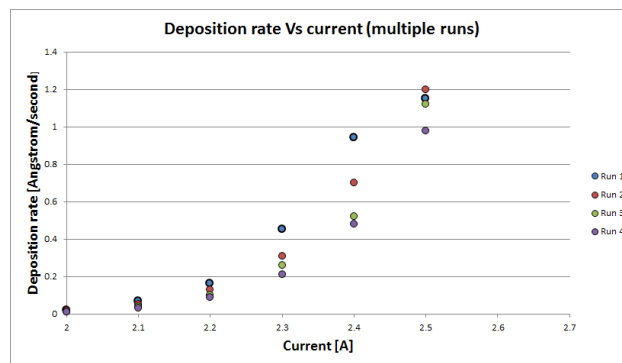


Figure 2: Deposition rate of Te source with respect to current.

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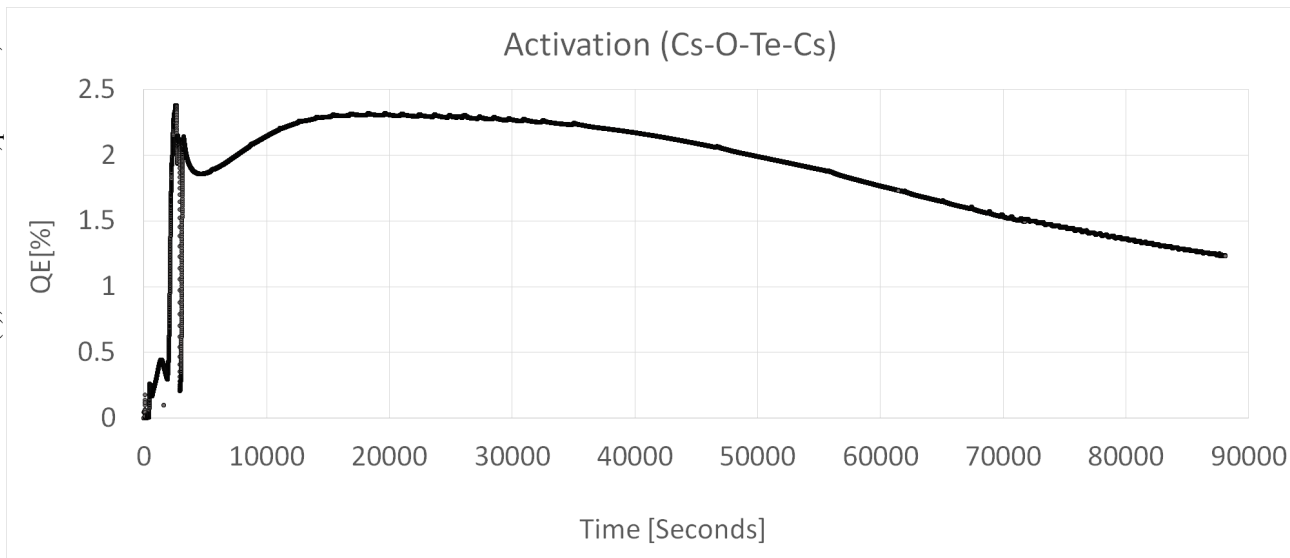


Figure 3: Activation and charge lifetime measurement.

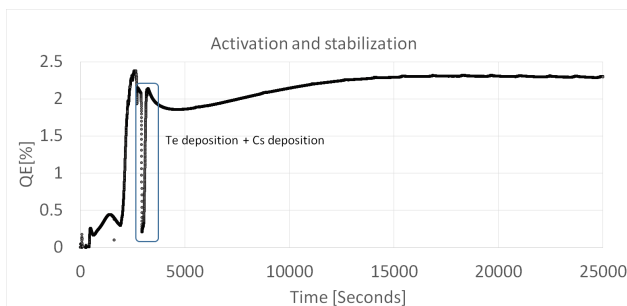


Figure 4: Zoomed in view of the activation and subsequent stabilization of the QE.

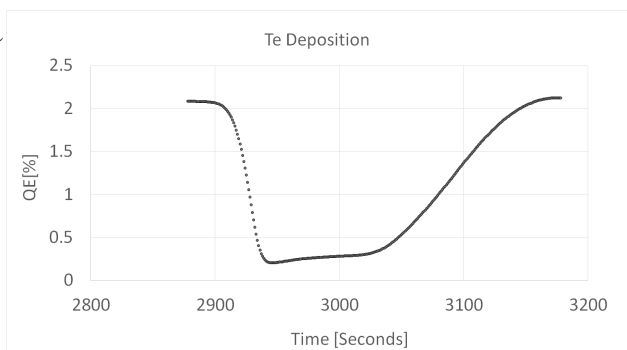


Figure 5: Te deposition and Cs deposition. QE decreases as Te is deposited. Cs deposition restores the QE.

## RESULTS

A sample activation, and subsequent charge lifetime measurement, curve is shown in Figure 3. For this particular activation, Te thickness was approximately 0.7-0.8 nm. A zoomed version of the activation curve is shown in Figure 4 and the Te deposition is shown in Figure 5. The QE after Cs-O<sub>2</sub> activation is 2.5%, which is rather low for 532 nm activation. We suspect that the Cs source got contaminated by the Te source while both the source were degassed during

the bakeout. The sources do not have a buffer in between, which is a definite modification required for the next set of experiments. From Figure 5, the drop of QE is due to Te deposition. The thickness of the Te layer is approximated from the deposition rate at the specific current. After the Te deposition, the rise in QE is due to the final Cs deposition. For Te layer thickness between approximately 0.5-1.2 nm, subsequent Cs deposition can bring the QE back to pre Te deposition value. For Te thickness over 1.5 nm, Cs deposition can only bring the QE back to 10% of it's original value.

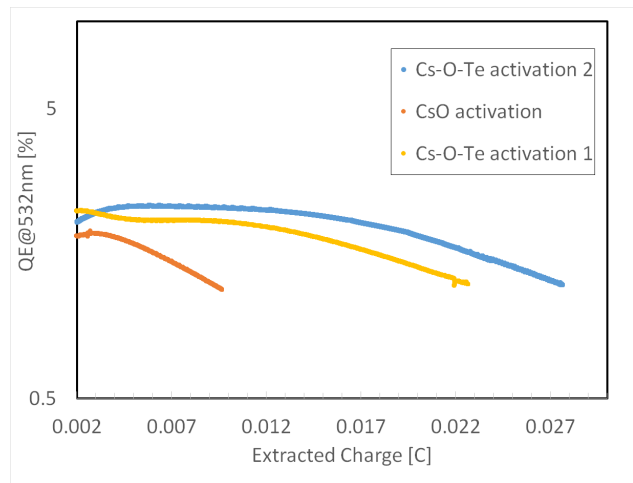


Figure 6: Charge lifetime comparison between Cs-O<sub>2</sub> activation and Cs-O<sub>2</sub>-Te-Cs

From Figure 4, after the Te deposition and subsequent Cs deposition, the QE seems to rise slightly for a while before starting to decrease. This is a feature that was common in all activations with Te thickness between 0.5-1.2 nm. We can speculate that the surface layer is not completely stable

during this period and more experiments to be performed to understand this phenomena better.

Figure 6 shows charge extracted vs QE for Cs-O<sub>2</sub> activation and Cs-O<sub>2</sub>-Te-Cs activations for similar Te thickness. It is clear that the charge lifetime for Cs-O<sub>2</sub>-Te-Cs is approximately 5-6 times higher compared to the conventional Cs-O<sub>2</sub> activation. In all cases the laser power was constant and therefore the current drawn was similar. The charge extracted is much lower compared to the kC charge extracted in DC guns. This is because the bias voltage was only 50 V (compared to 100 kV in DC guns) and ion back bombardment is much more dominant at low voltages.

## CONCLUSION

We activated GaAs using Te in conjunction with Cs and O<sub>2</sub>. First we activated the sample with Cs-O<sub>2</sub> co-deposition, then deposited 0.5-1.2 nm of Te and finally deposited Cs to recover the QE. This method has show to provide higher charge lifetime, at 532 nm laser irradiation, compared to just Cs-O<sub>2</sub> by a factor of 5. We have planned on investigating the usefulness of this recipe for SSL GaAs at 780 nm laser illumination.

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