Cs-K-Te ヘテロ接合によるGaAsカソードの高耐久化

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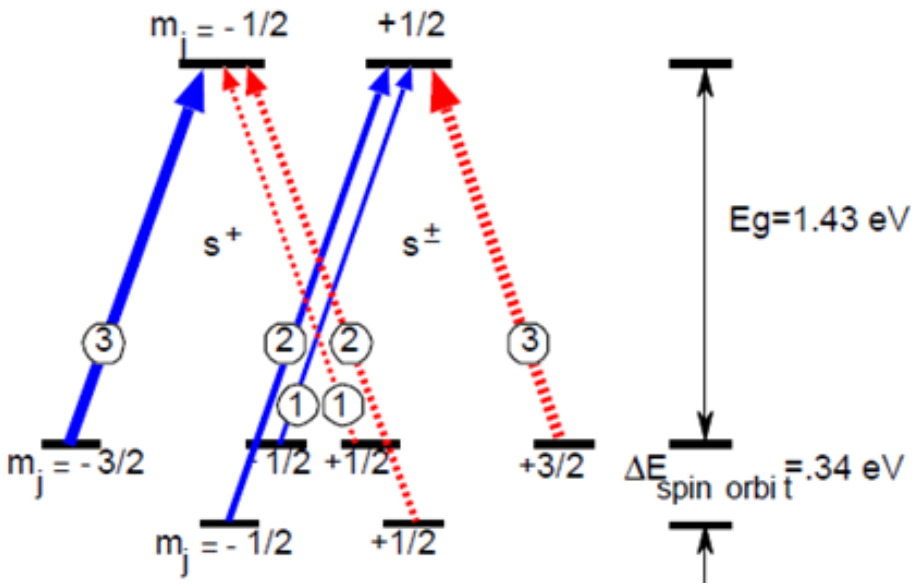
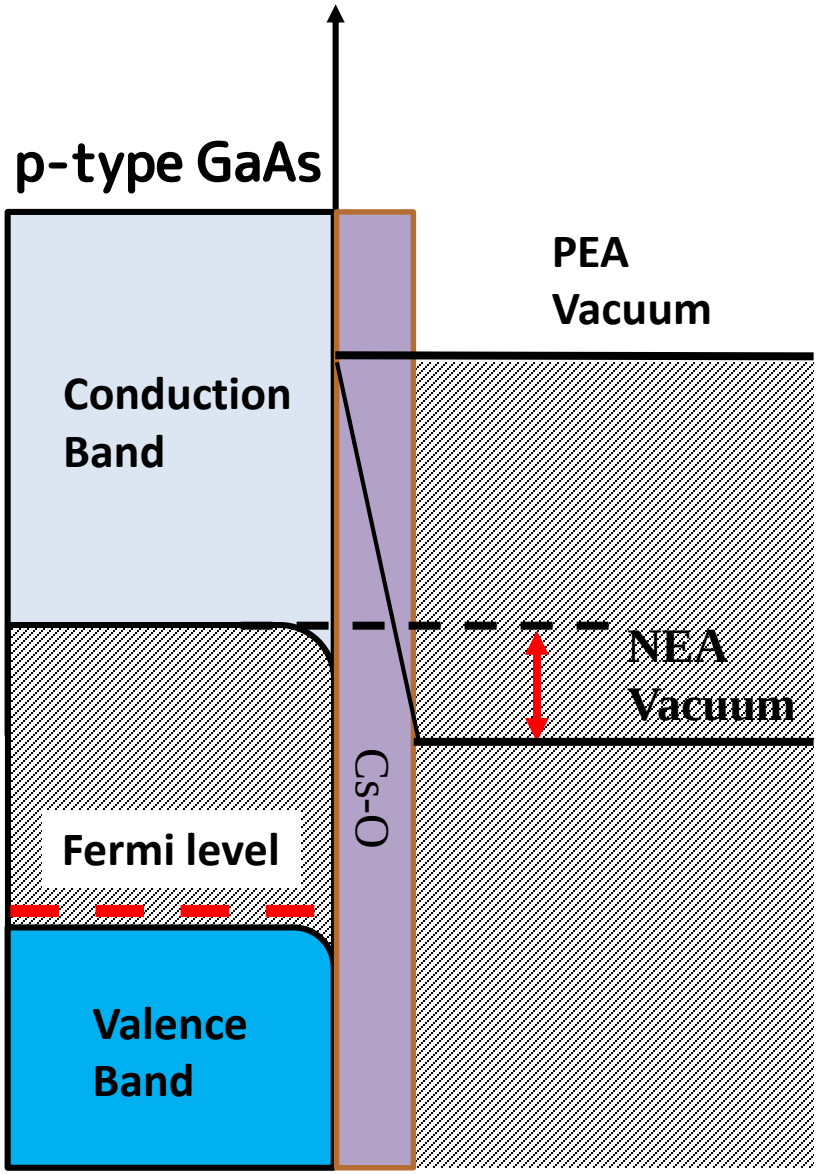
Contents

- Introduction,
- NEA Activation with Cs-K-Te
- Summary.

Introduction

Cs-O NEA-GaAs Photo-cathode

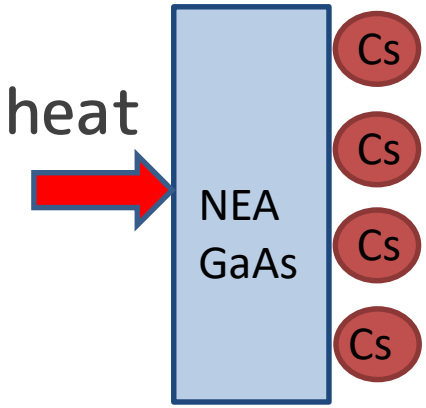




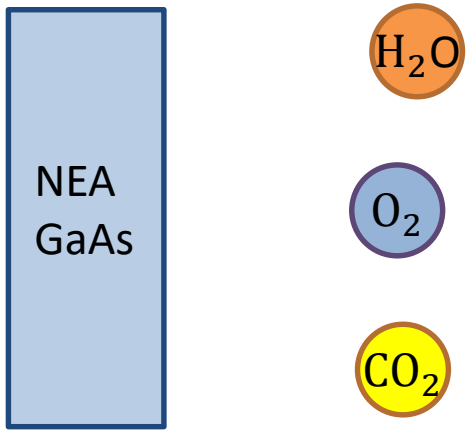
- Electron excited by circularly polarized laser is spin polarized.
- The polarized electron can be extracted to vacuum by NEA surface.

Degradation of Cs-O NEA surface

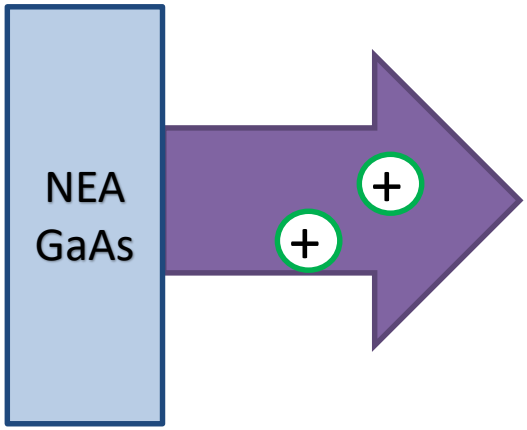
Thermal desorption

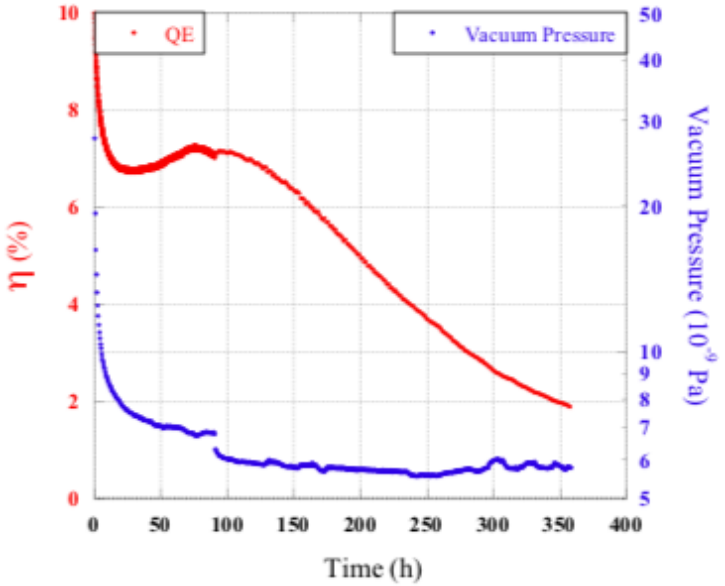


Gas adsorption



Ion Feedback





1/e lifetime
3.0 – 4.0 x 10^{-4} Pa.sec

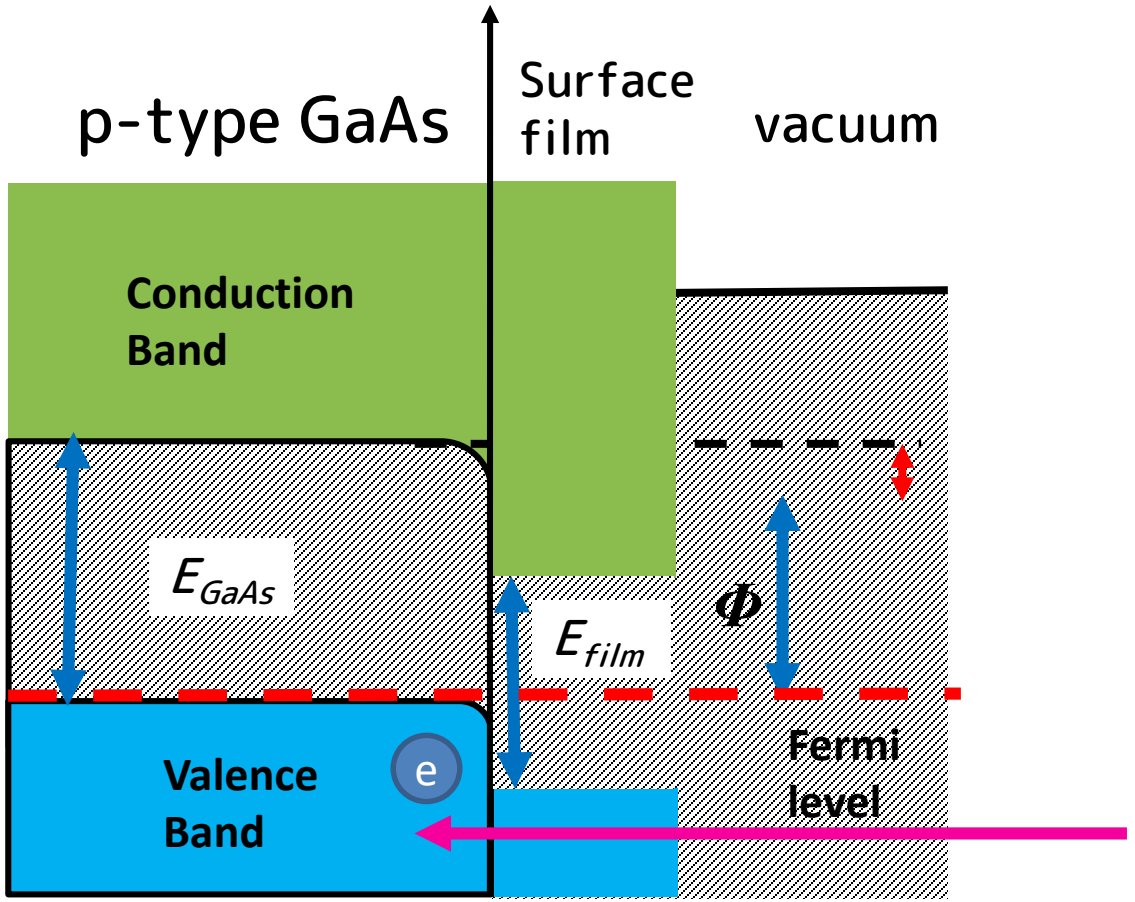
C. Shonaka, Master thesis, Hiroshima U. (2009)

Robust NEA GaAs cathode

- Cs-O NEA GaAs has a limited robustness.
  - Requires UHV (<1.0e-9 Pa).
  - Only compatible with DC biased electron gun, ~5 MV/m.
  - Limited bunch intensity, long bunch, large emittance.
- If a robust NEA surface on GaAs is developed,
  - Less requirement on vacuum.
  - Compatible with RF electron gun, ~ 100 MV/m.
  - High bunch intensity, short bunch, small emittance.

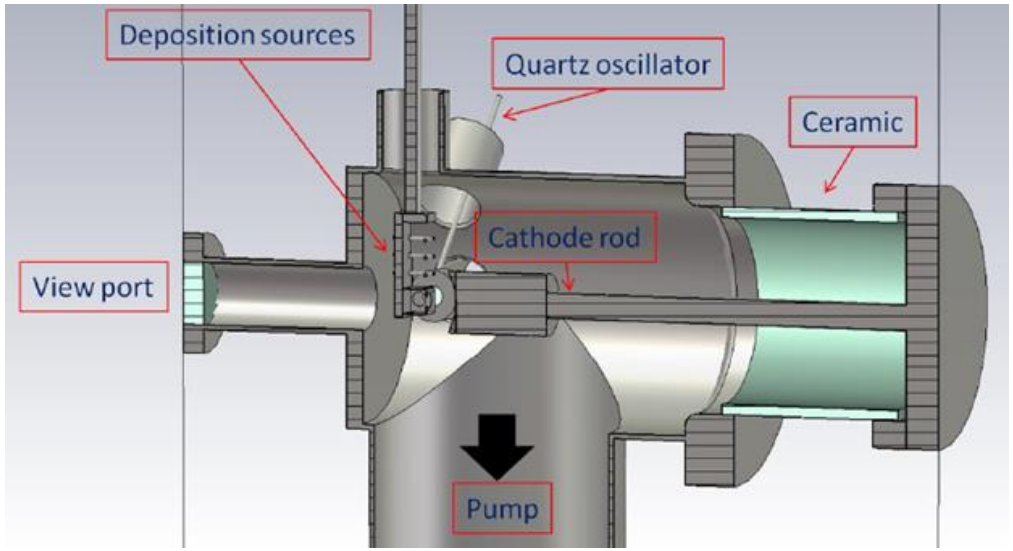
NEA Activation with Cs-K-Te

NEA surface with Hetero Junction

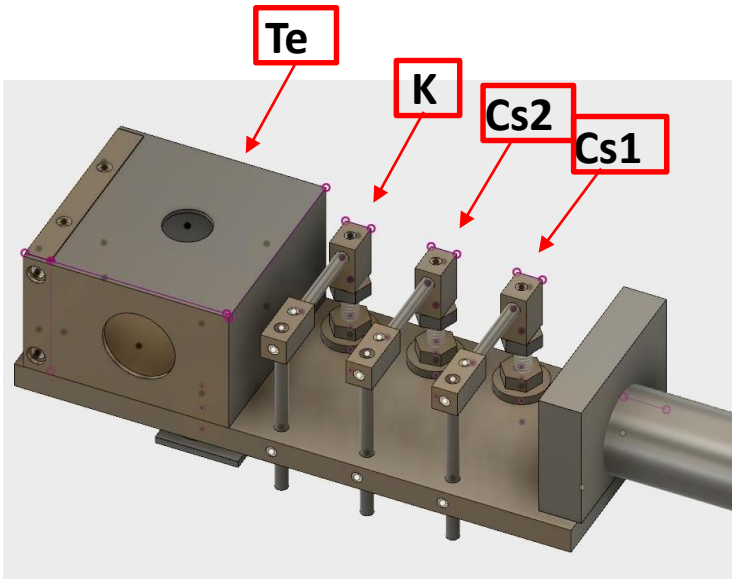


- $E_{GaAs} > \varphi$ for NEA state.
- $E_{film} > E_{GaAs}$ for transparency.

Apparatus



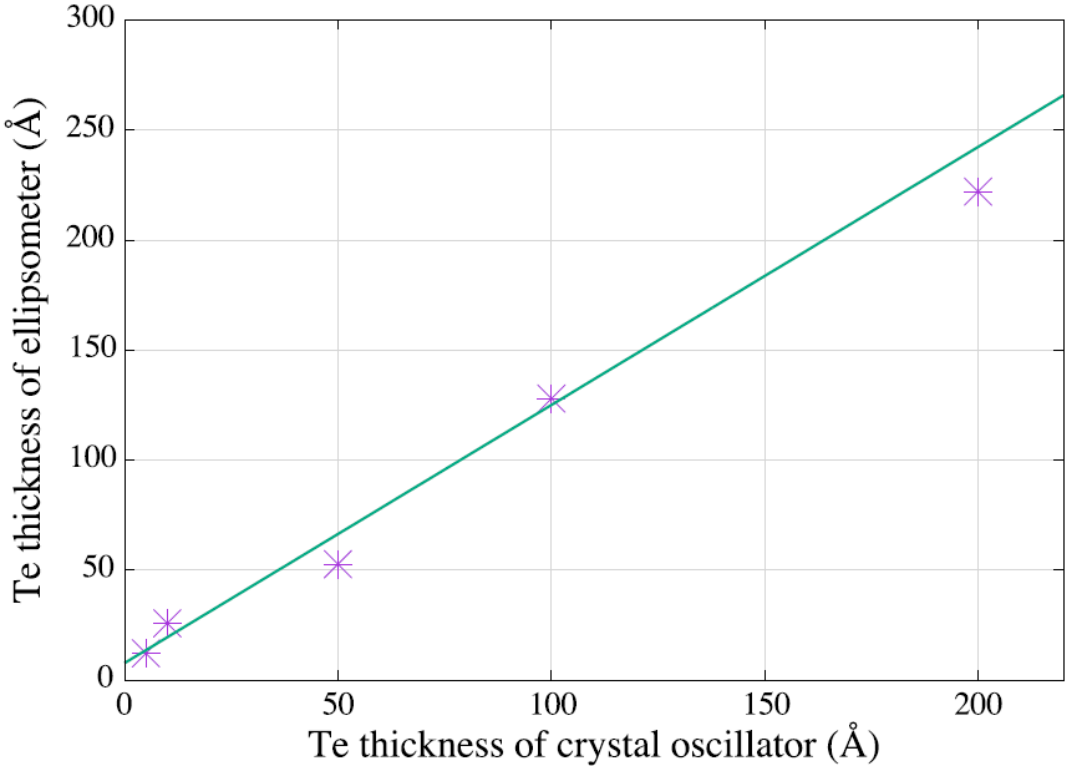
Chamber



Evaporation head

- Chemically polished SUS chamber with NEA and Ion pumps. Typical vacuum pressure is1.5e-8 Pa.
- Cs, K, and Te evaporation.
- Heater for cleaning.
- Quartz thickness monitor.
- Quantum efficiency measurement with Xe lump.

Calibration of Te thickness



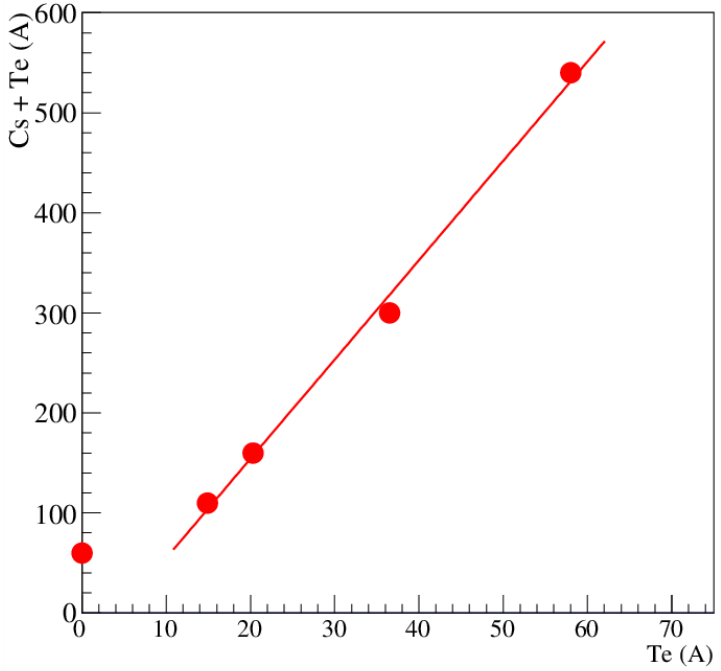
Several samples of Te evaporated on GaAs substrate.

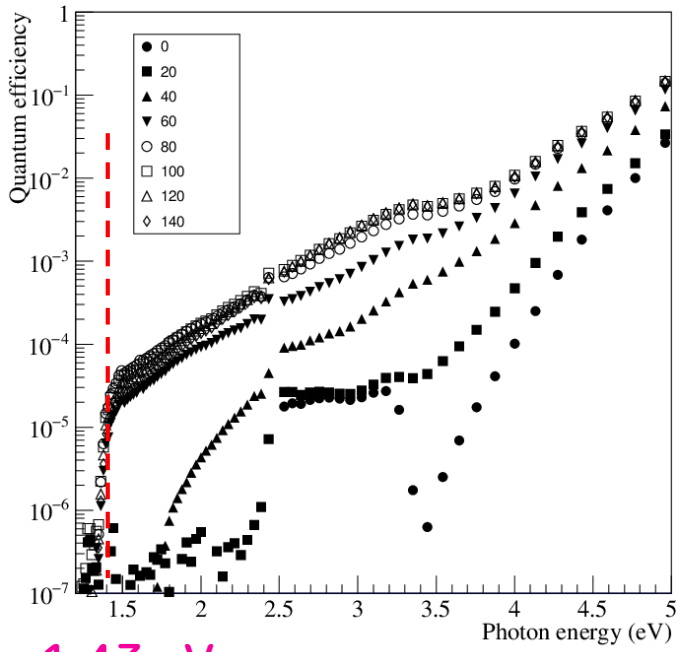
Calibrated with Ellipsometry measurement.

Use the thickness with the ellipsometry for further analysis.

Experiment

- Evaporate Te until the decided thickness.
- Evaporate K and Cs repeatedly.
- Measure the QE spectrum after each K and Cs evaporation.
- The optimum thickness of Cs and K is defined as that giving the maximum QE at 4.9 eV.

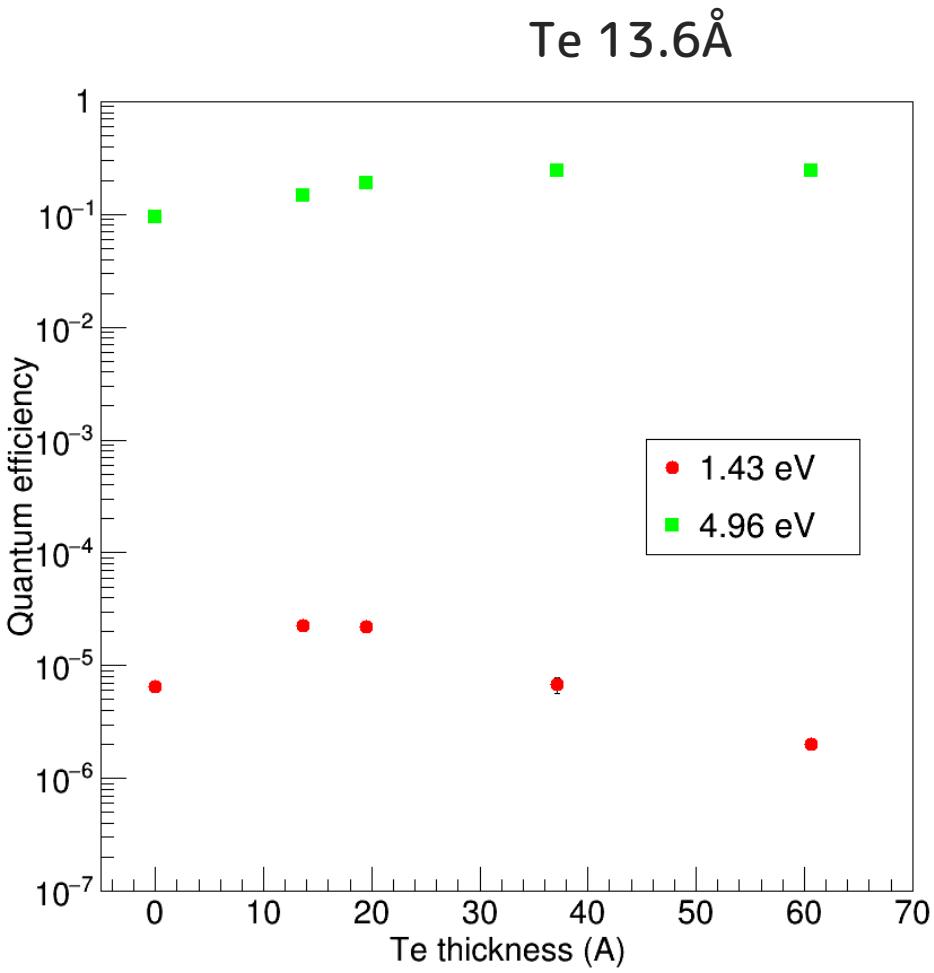




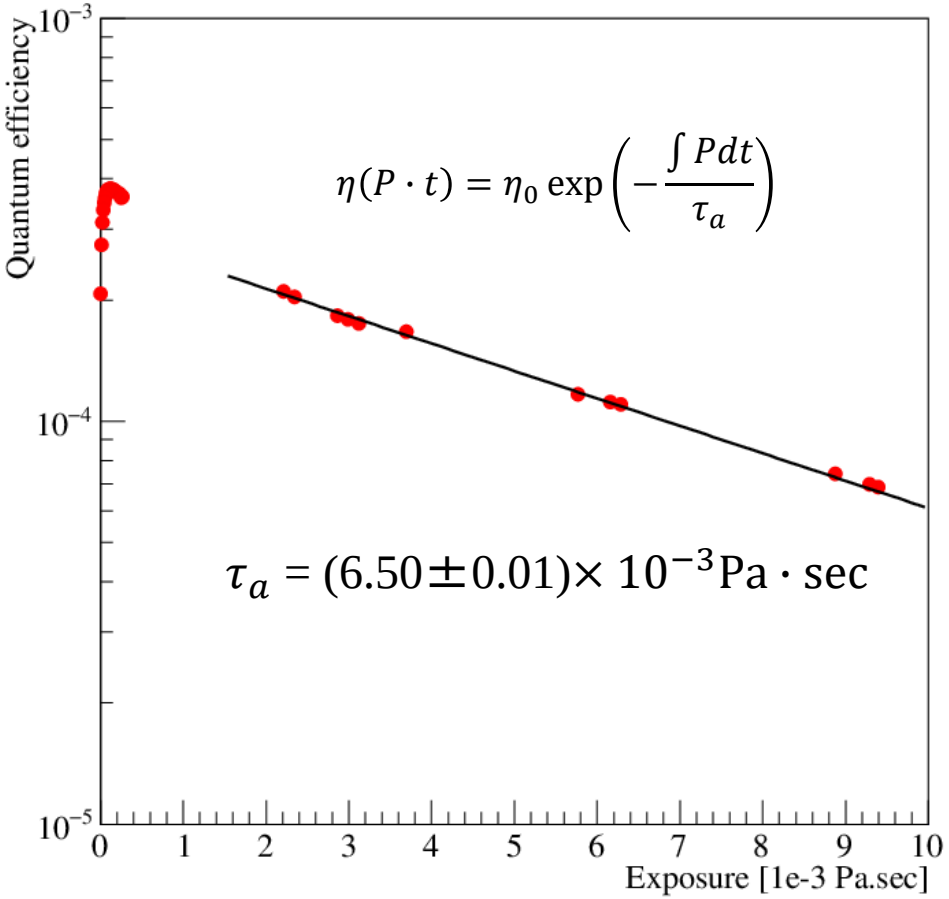
1.43 eV

Thickness VS. QE

- QE at 4.96 eV is saturated with more Cs-K and Te.
- QE at 1.43 eV is peaked at some Te and Cs-K thickness.
- These results are consistent that electron emissions with 4.96 and 1.43 eV photon are from CsKTe and GaAs, respectively.



Lifetime of CsKTe NEA GaAs



Cathodes	Lifetime τ_a [10^{-3}Pa · sec]
CsKTe/GaAs	6.50±0.01
Cs-O/GaAs	0.29±0.03 [1]
Cs-O/GaAs	0.40±0.02 [2]

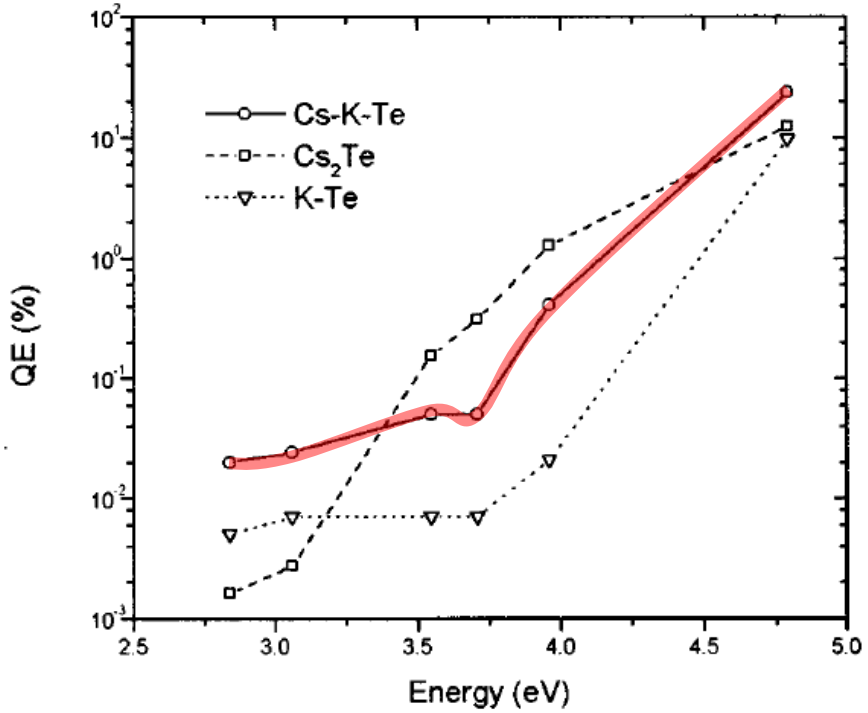
[1]K. Miyoshi, M. Thesis, Hiroshima U. (2013)
[2]G. Lei, M. Thesis, Hiroshima U. (2014)

E-Gun	Pressure[Pa]	Life[h]
DC-gun	5.0×10^{-10}	1535.6
RF-gun	1.0×10^{-7}	7.7

Summary

- We found that GaAs is activated with CsKTe.
- QE was 2.0~3.0e-4 with 15-20 Å Te thickness.
- Thicker Te gave less QE.
- We found that the CsKTe GaAs has a longer lifetime (darklife) than that of Cs-O GaAs cathode.
- It is operable in RF gun, even a frequent cathode activation is needed.

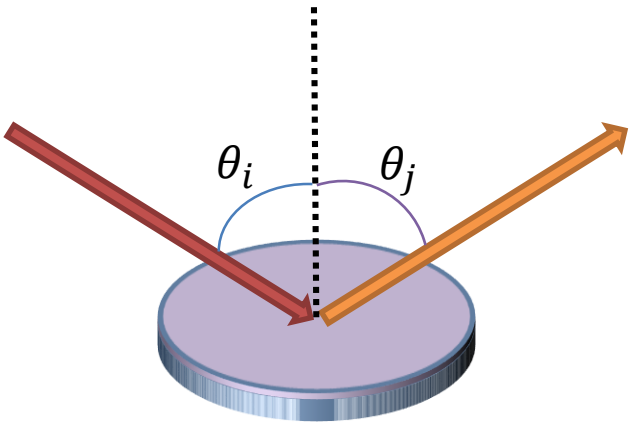
NEA Activation with CsKTe



- Thin film photo-cathode by evaporation.
- High quantum efficiency at 4.75 ~ 3.0 eV.
- Work function and band gap?

Fig : Quantum effiency of Cs-K-Te, Cs_2Te, K-Te : Appl. Phys. Lett. **70**, 1491 (1997)
D. Bisero and B. M. van Oerle et al., "High efficiency photoemission from Cs–K–Te")

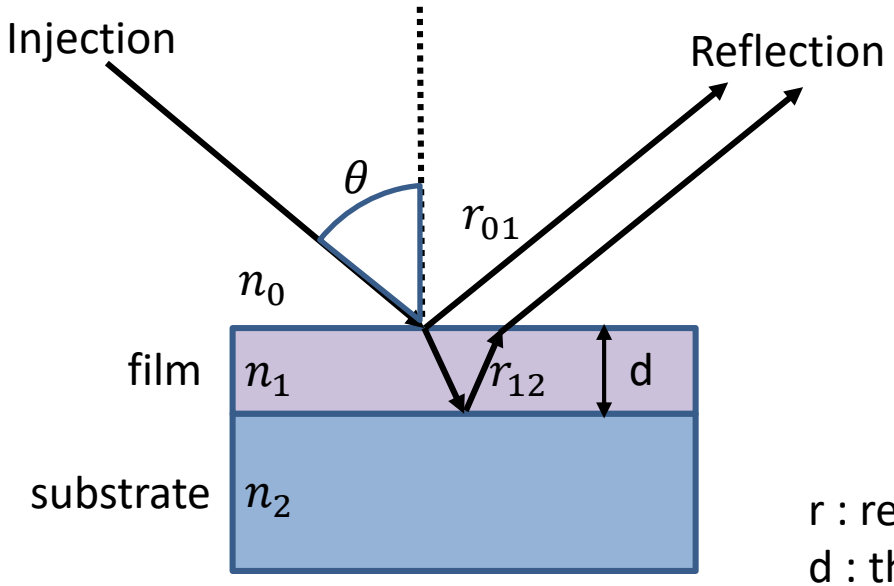
Ellipsometry



Reflectivity and phase difference for S and P polarization is measured.

$$\rho = \tan(\psi)e^{i\Delta}$$

$$\psi = \frac{r_p}{r_s} \qquad \Delta = \varphi_p - \varphi_s$$



$$\rho = \frac{\dfrac{r_{p01} + r_{p12}e^{-i2\beta}}{1 + r_{p01}r_{p12}e^{-i2\beta}}}{\dfrac{r_{s01} + r_{s12}e^{-i2\beta}}{1 + r_{s01}r_{s12}e^{-i2\beta}}}$$

r : reflectivity
d : thickness

$$\beta = 2\pi\frac{d}{\lambda}n_1 cos\theta_1$$