BROOKHAVEN NATIONAL LABORATORY

Photocathode Physics for Photoinjectors (P3) 2016:

Synthesis and x-ray characterization of Bi-alklai antimonide photocathodes

Presented by

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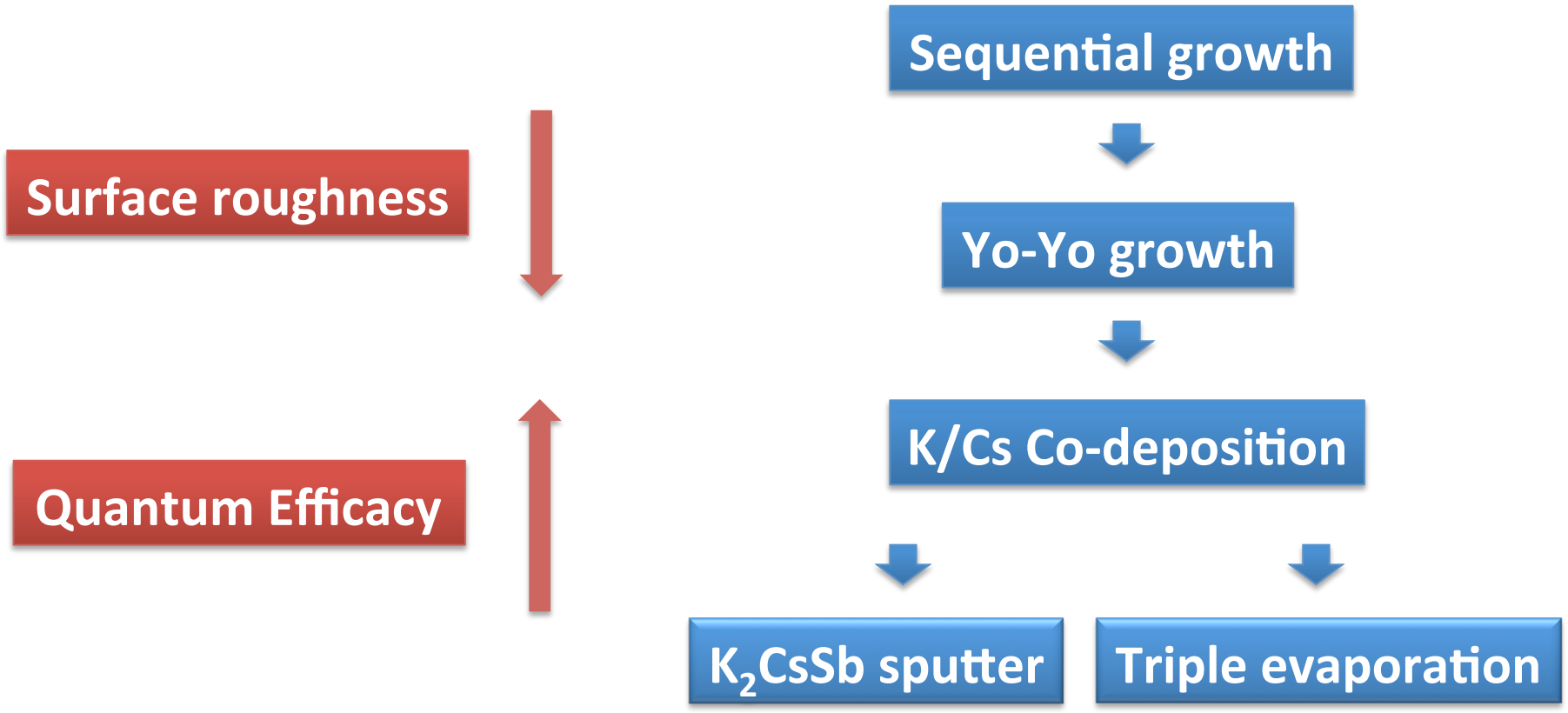
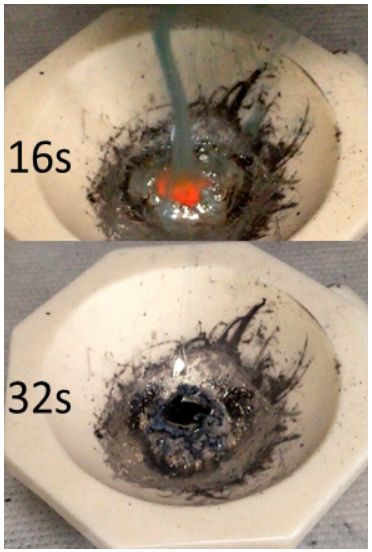
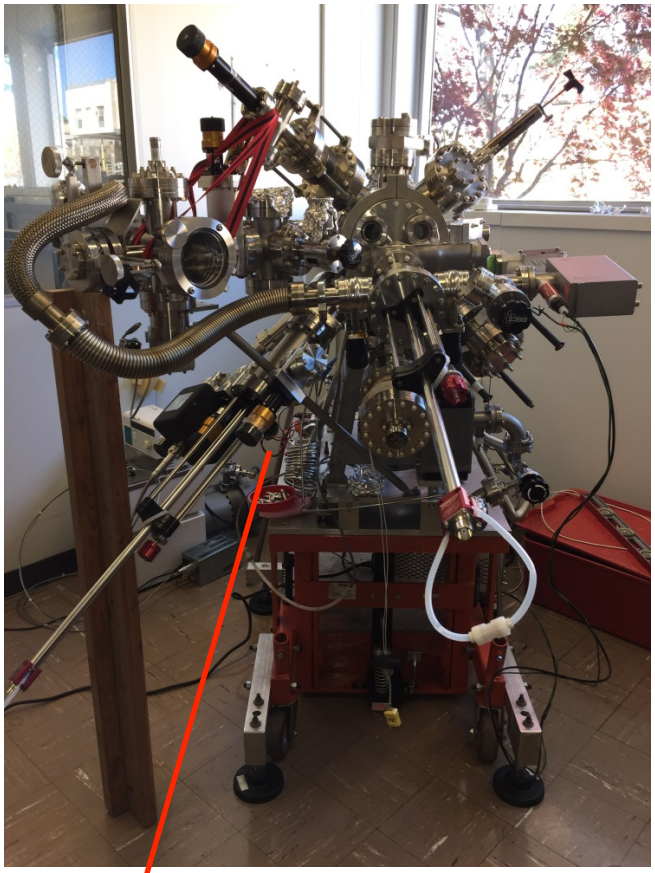
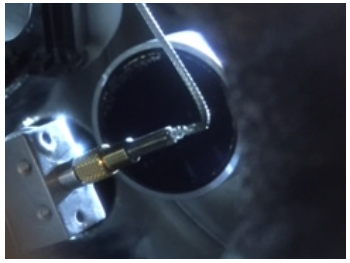
Oct 17th , 2016


Surface roughness
Quantum Efficacy
Sequential growth
Yo-Yo growth
K/Cs Co-deposition
K_2CsSb sputter
Triple evaporation

Sputter growth of Bi-alkali photocathode







Before

Sputtering

Sputter target and sputter gun was product of RMD. Inc. Photos of sputter target prep are contributed by H. Bhandari

Sputter growth of Bi-alkali photocathode

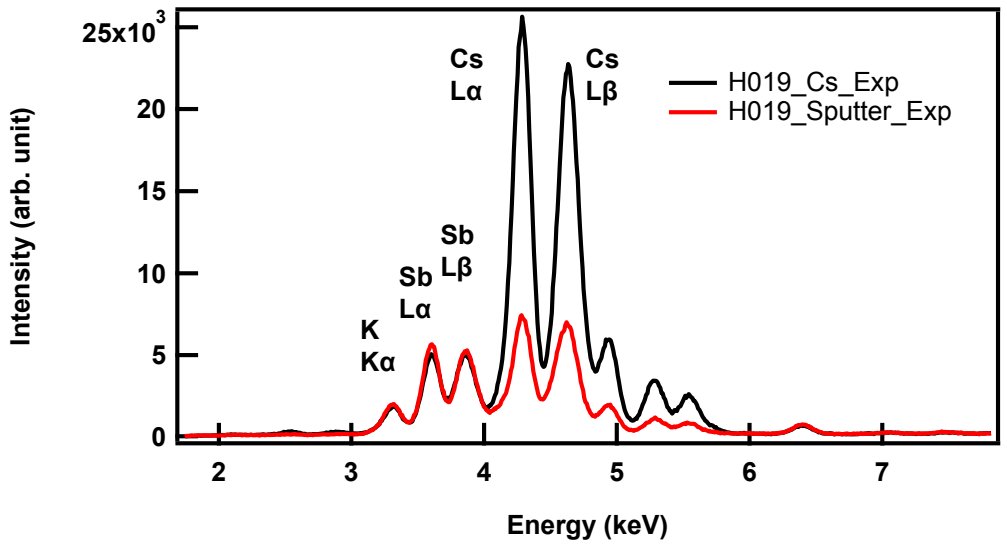
Si / MgO substrate @ 90C

↓

K_2CsSb sputter

↓

Cs deposition @ 60 ~ 70 C

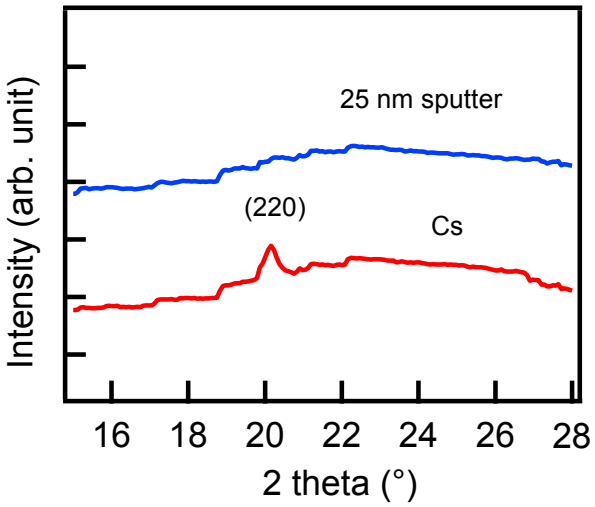


layer	K (+/-0.1)	Sb (+/-0.05)	Cs (+/-0.05)	K/Cs
K_2CsSb sputter	0.83	1.00	0.41	2.02
Cs	0.84	1.00	1.75	0.48

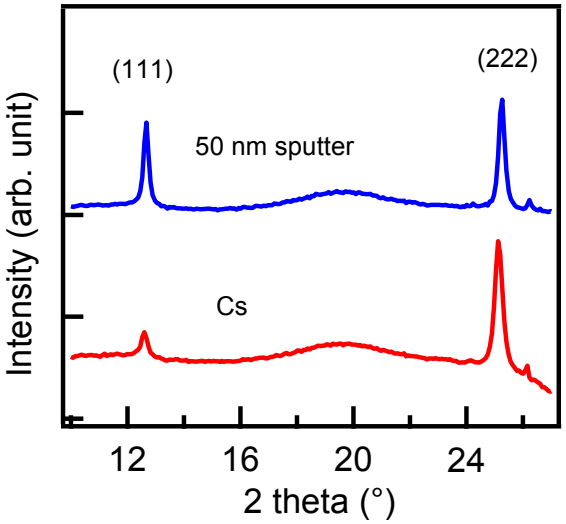
- Sputtered layers are deficient in Alkali
- Is maintaining a good K/Cs ratio

Structure of sputtered cathodes

- 25 nm sputtered layer + Cs



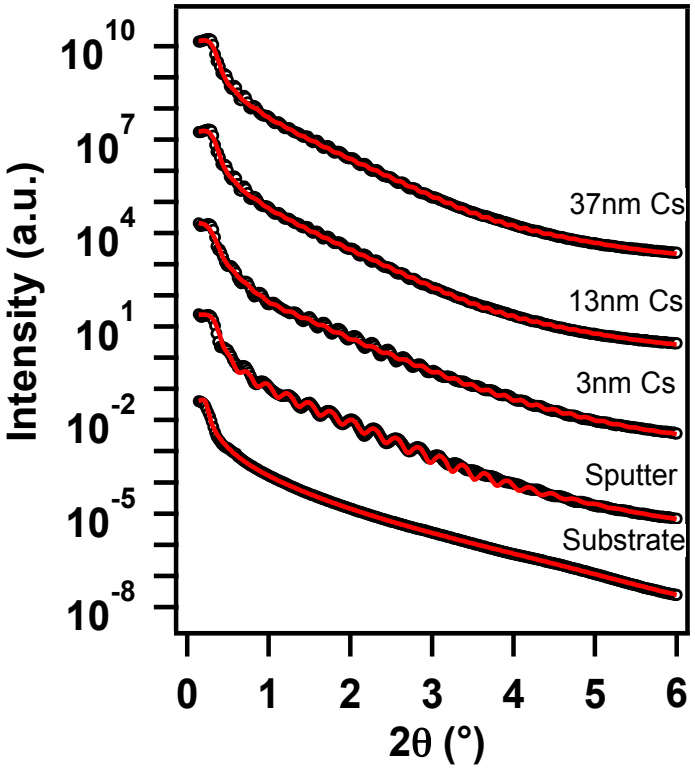
- 50 nm sputtered layer + Cs



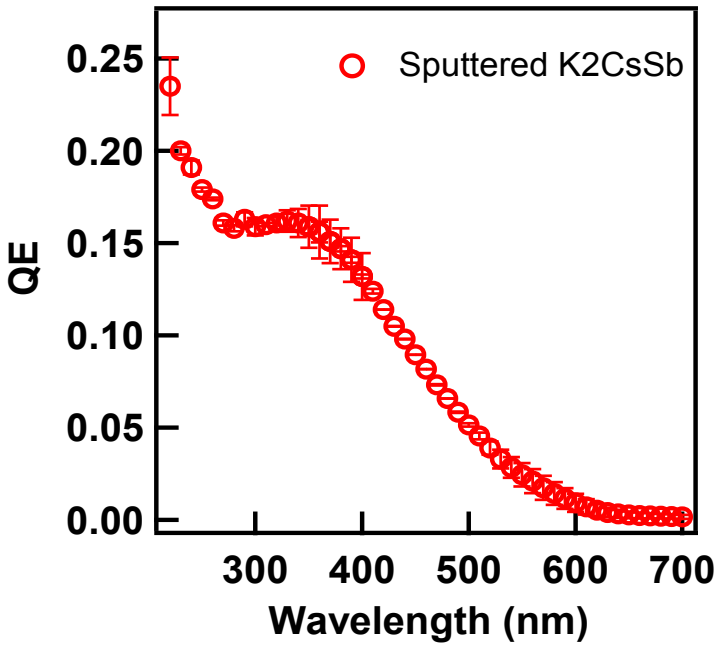
HKL	Theo.K2CsSb	Theo.KCs2Sb	Sample1 (after Cs)	Sample2 (sputter)	Sample2 (after Cs)
111	12.67			12.67	12.6
220	20.76	20.12	20.16		
222	25.46	24.71		25.27	25.12

- Sputtered layer is initially amorphous and will weakly crystalize as film thickness increase.
- Adding Cs will increase crystallinity, might change cathode from K_2CsSb to KCs_2Sb

Surface roughness & QE of sputtered photocathodes



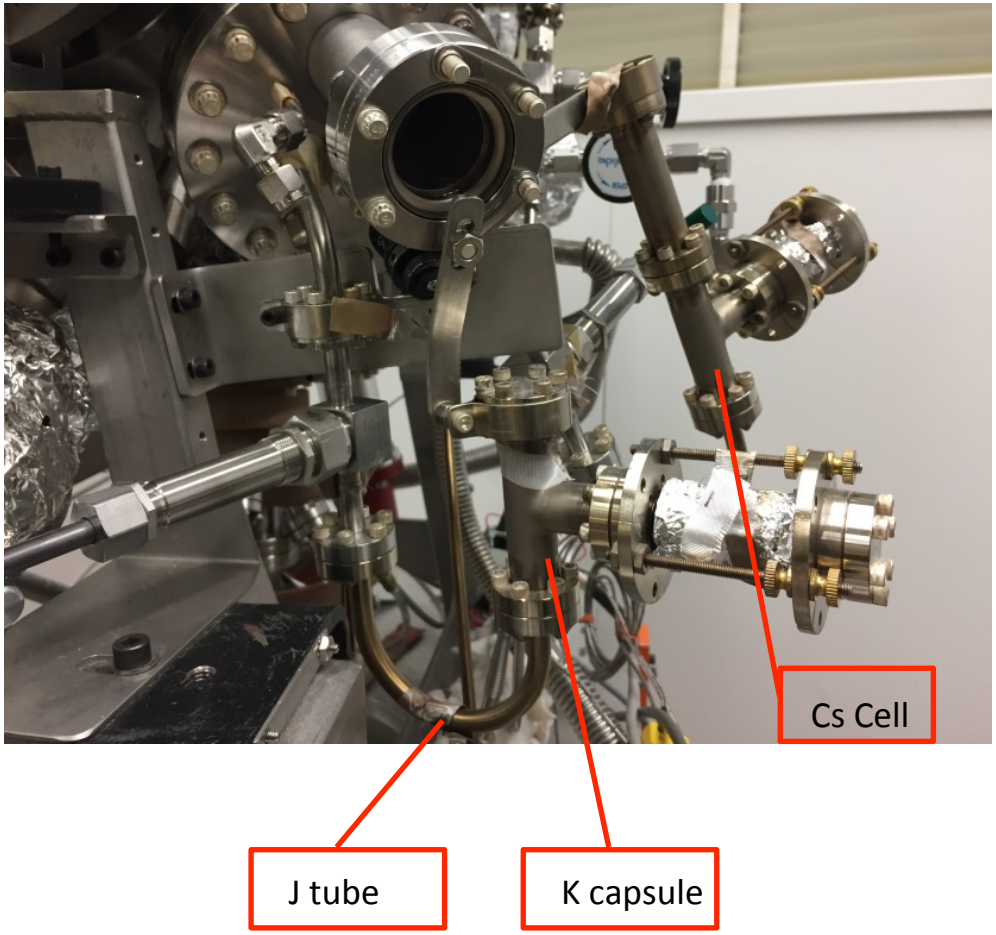
	Thickness (Å)	Roughness (Å)
Substrate (Si)		3.75
SiO_2	10.24	3.27
Sputtered layer	234.2	5.17
1st Cs	249.5	4.91
2nd Cs	341.3	4.94
3rd Cs	416.0	5.67

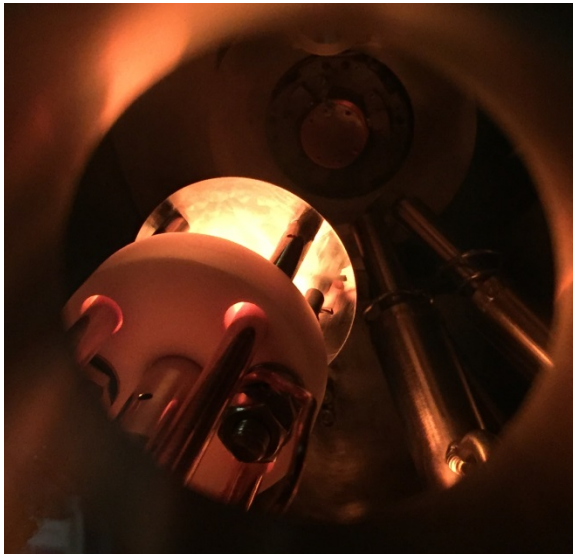


- Peak QE > 20%
- Green QE: 4.3%

Triple evaporation cathode growth with effusion cell

Simultaneously evaporate from Sb evaporator and K,Cs effusion cells





In situ, In operado XRR, XRF, XRD & Quantum efficiency (QE) measurement

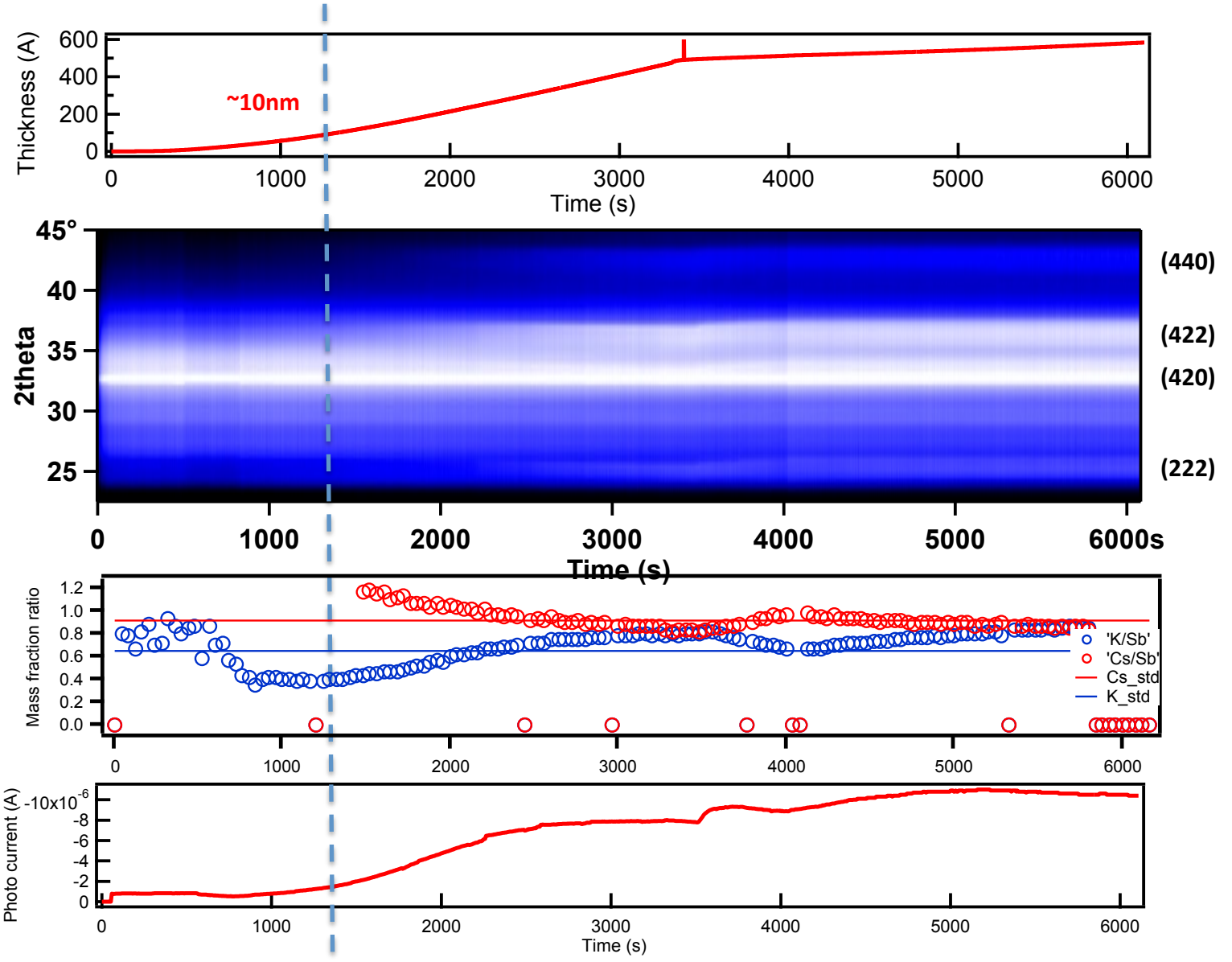
- Growth rate are controlled by J tube temperature, valve and shutter

Thickness

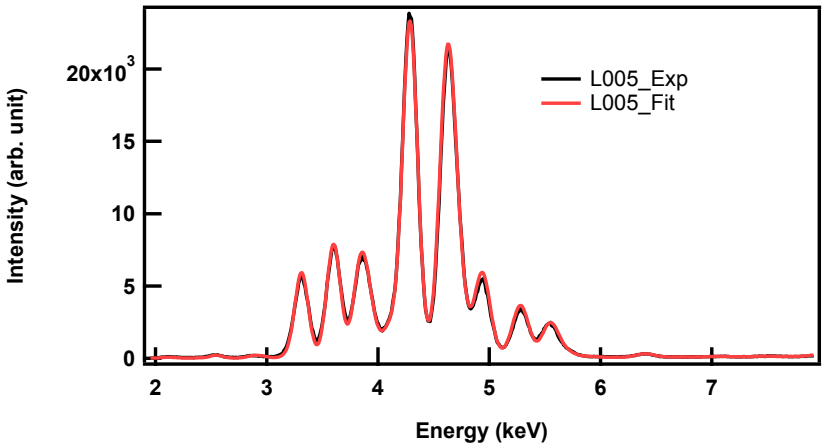
Real time XRD

Real time Fluorescence

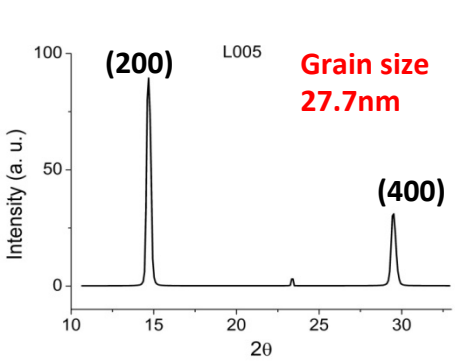
QE

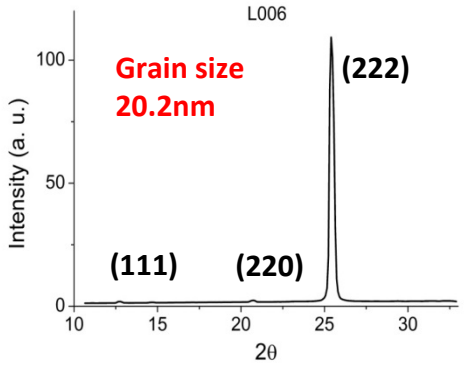


Stoichiometry & Structural Analysis

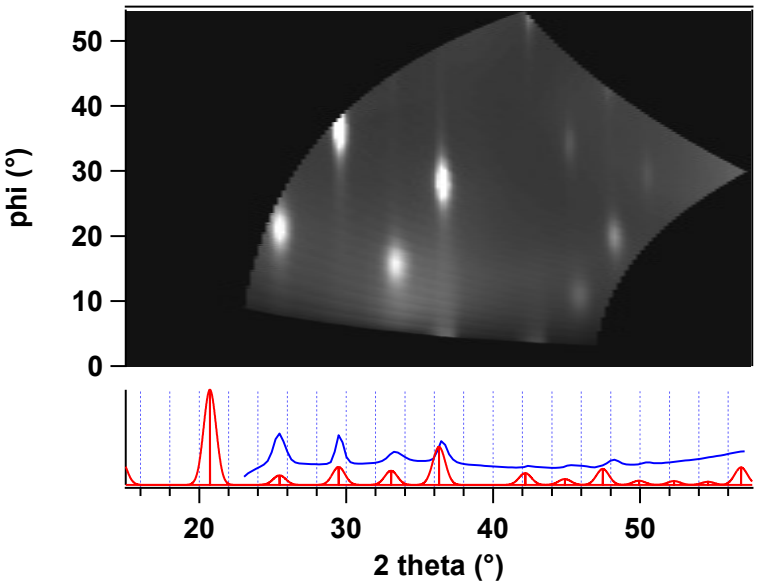


Camera 1





Camera 2

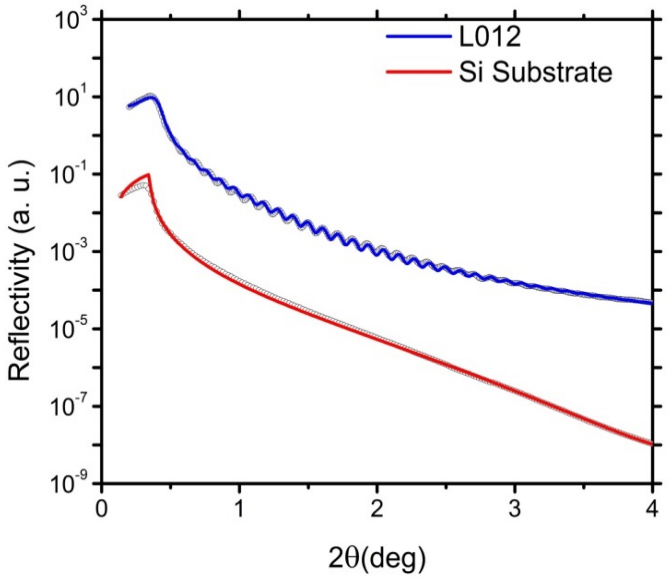


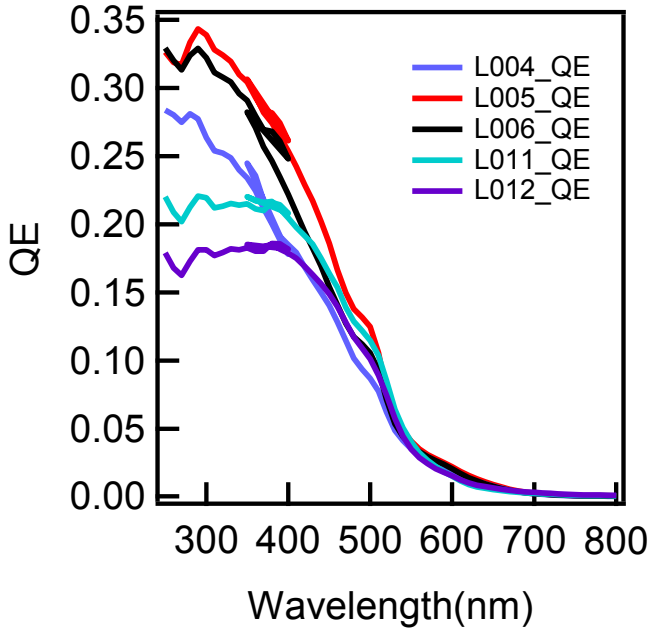
	K	Sb	Cs
L004 Si	2.50	1.00	1.16
L005 Si	2.37	1.00	0.91
L006 Si	2.21	1.00	0.95
L011 Si	2.07	1.00	0.94
L012 MgO	1.98	1.00	0.88

Good K/Cs/Sb ratio!

Highly textured K_2CsSb phase!

Surface roughness & QE





	QE@532nm (%)	Roughness(A)	Thickness (A)	Grain size (A)
L004 Si	4.9	3.5	234	155
L005 Si	5.8	11.5	815.3	277
L006 Si	5.4	13.8	757.5	202
L011 Si (Higher substrate T)	6.4	79.0	905.2	208
L012 MgO	5.7	8.6	566.4	193

Summary

- Both sputter and effusion cell are very promising method in cathode growth.
- Sputtering will create amorphous cathodes with the best roughness and high QE. This method is highly reproducible and can grow over large area.
- Effusion cell is an endless source for growth. Can achieve growing very thick cathodes.
- Cathodes grown by triple evaporation using effusion cell will create large grains that reduces grain boundary scattering. It will have very smooth surface and higher green QE.

Thanks for your attention!

- Thanks to Z. Ding, J. Sinsheimer, S. Schubert, J. Kuhn, H. Bhandari, M. Marshall, V. Nagarkar, E. M. Muller, J. Xie, J. Walsh, K. Attenkofer, H. Padmore, H. Frisch, J. Smedley
- J Lab crew: Matt Poelker, Fay Hannon, Md. Abdhulla Mamun, and more
- Staff @ CHESS and beamline G3
- DOE Office of Science – Basic Energy Science and High-Energy Physics