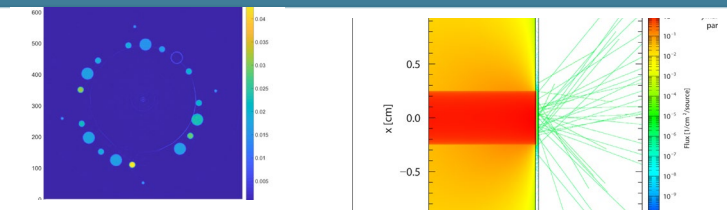
SAND2022-11202C

Sandia National Laboratories

Design and fabrication of multi-metal patterned target anodes for improved quality of hyperspectral X-ray radiography and computed tomography imaging systems



Presented by Courtney L. Hummell

Work by Courtney L Hummell, Noelle M. Collins, Gabriella M. Dalton, Rebecca A. Wheeling, Jeier Yang, Kyle R. Thompson, Ray S. Fuentes, and Edward S. Jimenez

August 22, 2022

SPIE Advances in X-Ray/EUV Optics and Components XVII

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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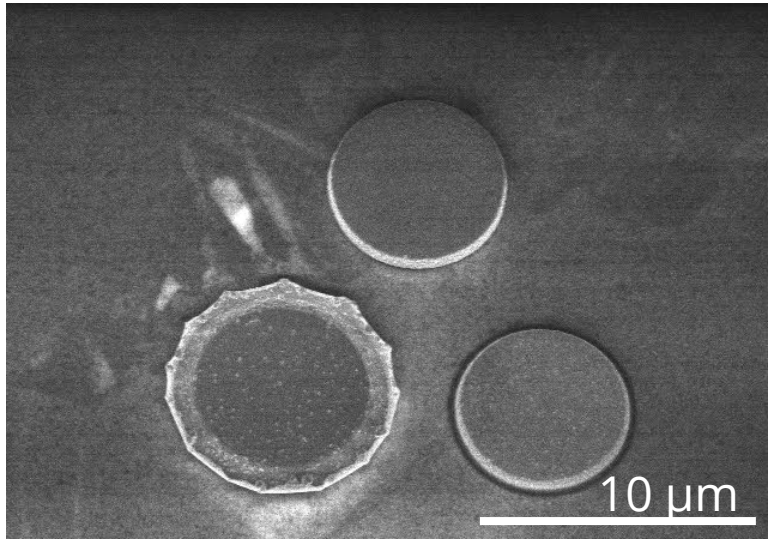
SAND2022-11202 C

Outline

- Overview
- Background
- Design
- Fabrication
- Evaluation
- Results and Discussion
- Conclusion and Future Work



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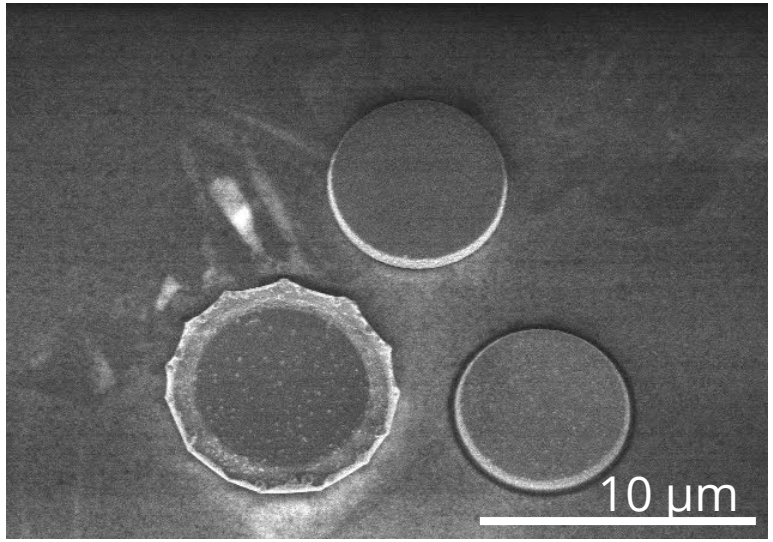

Overview

Goal: Improve SNL's H-CT system's imaging capability.

Approach: Design and fabricate a novel multi-metal patterned transmissive anode for the H-CT system to improve spatial resolution and signal-to-noise ratio (SNR) at energy neighborhoods corresponding to the characteristic peaks of the anode metals.

SNL has developed the ***world's only hyperspectral x-ray computed tomography (H-CT) imaging system*** specifically engineered and designed for industrial and security applications (Jimenez et al.)

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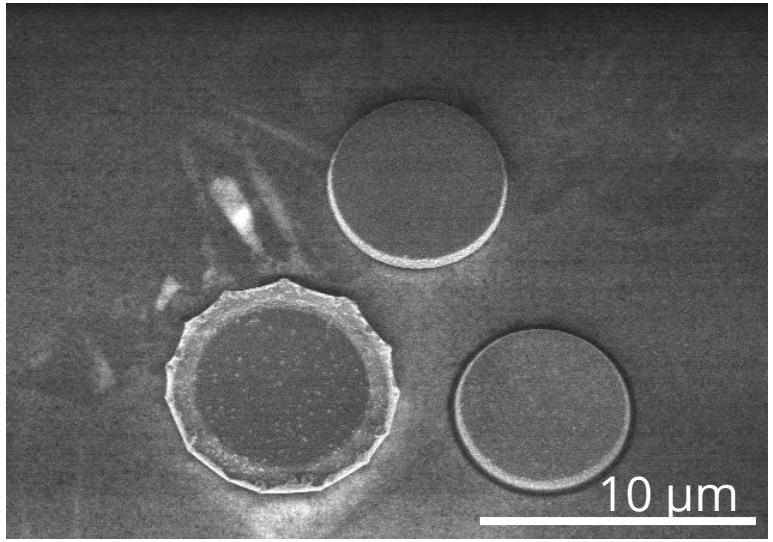


Background - Motivation

Motivation:

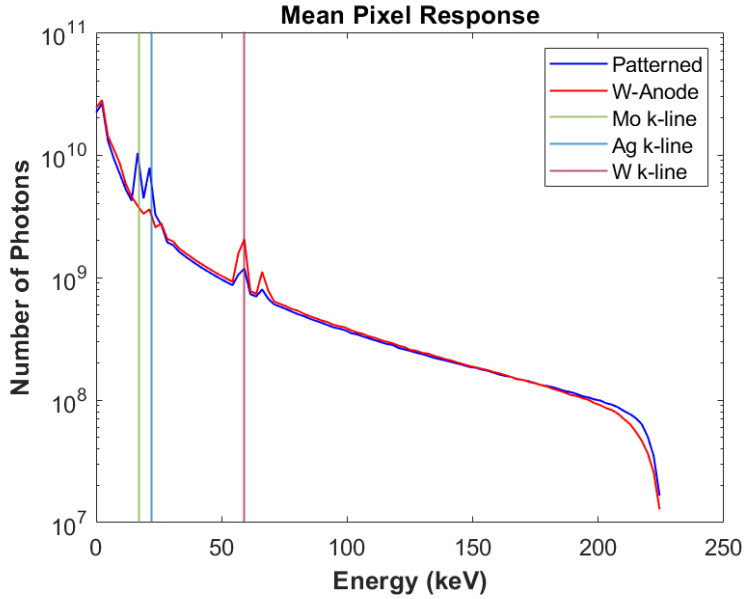
- Design and fabricate **a novel multi-metal patterned anode** for our hyperspectral X-ray computed tomography (H-CT) system **to experimentally validate previous simulation results**

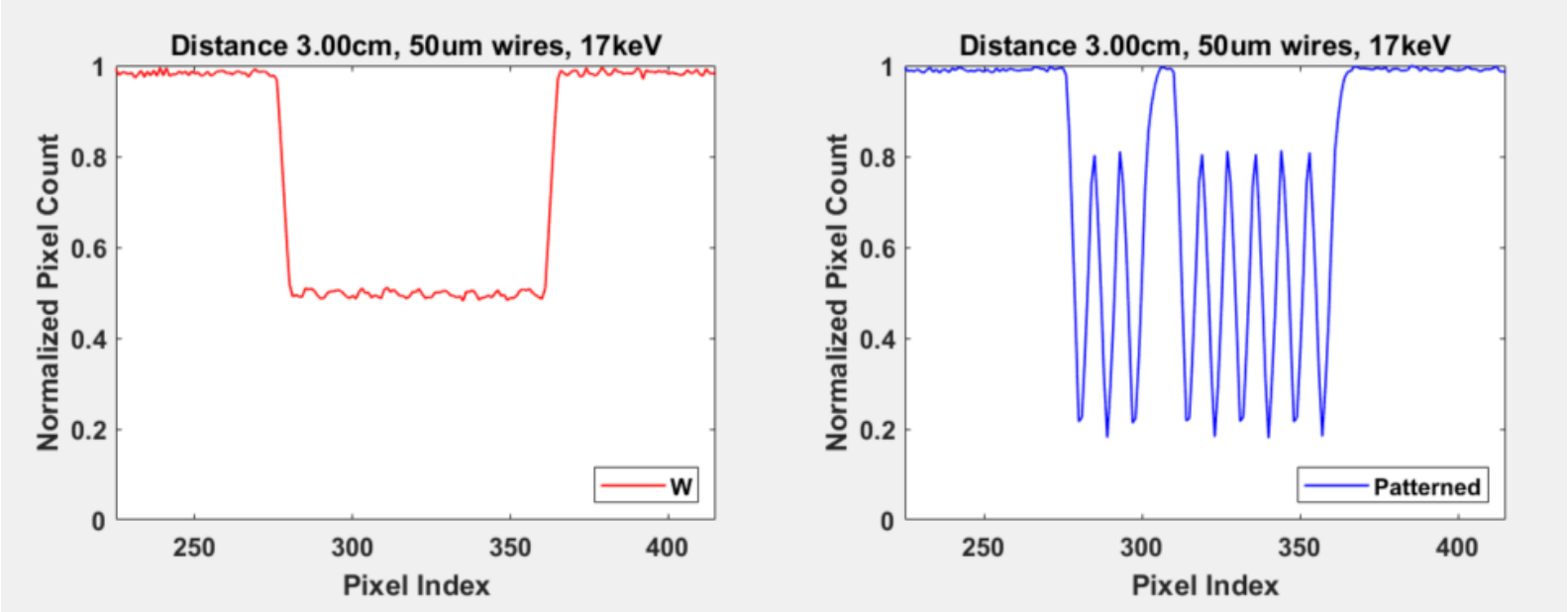
Applications:

- Material identification, counterfeit detection, quality control, nondestructive evaluation

Background:

- Simulations by Dalton et al. 2021
  - **Shrink metal features to reduce focal spot size**
  - **Include additional target materials** to enhance signal in certain spectral regions
  - Simulated that a multi-metal patterned anode combined with an H-CT detector **improves on both spatial resolution and signal-to-noise**

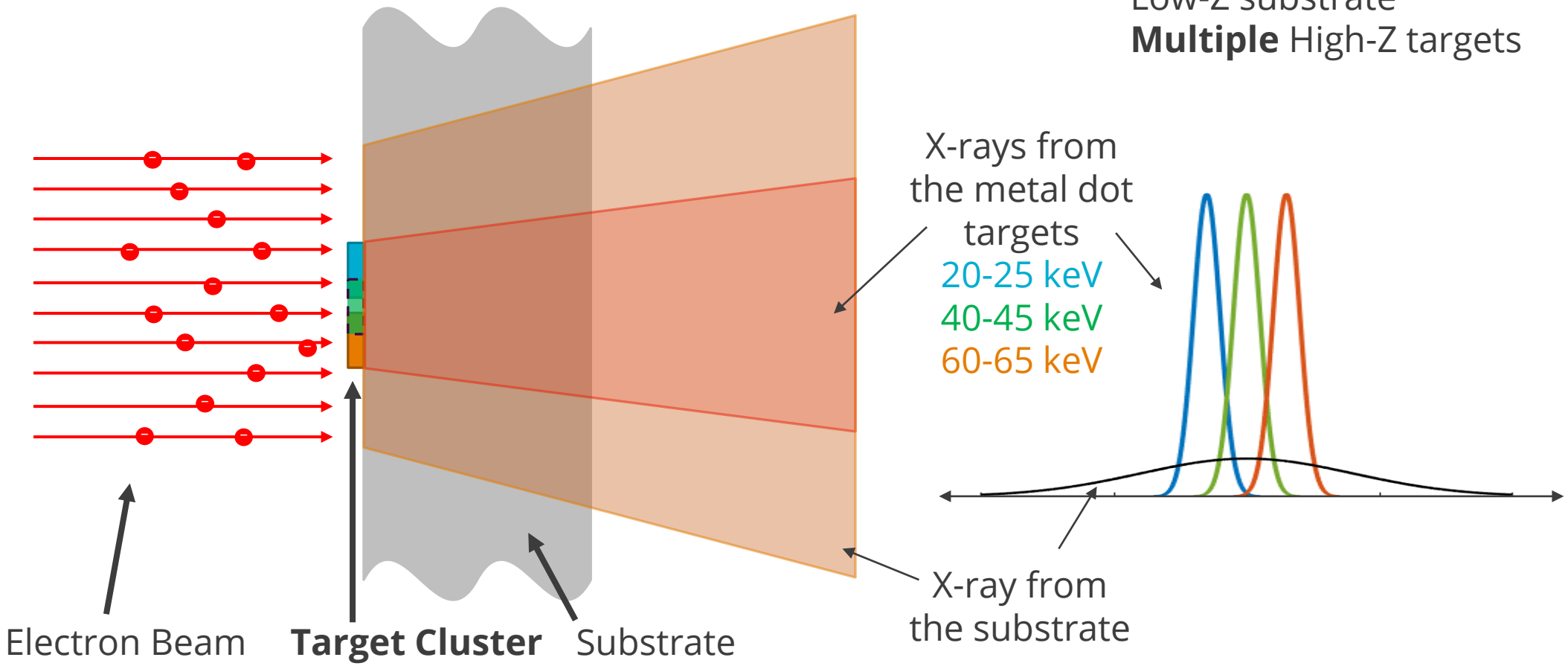




Background – Previous Work, Expanded

Dalton et al. 2021

Low-Z substrate
Multiple High-Z targets



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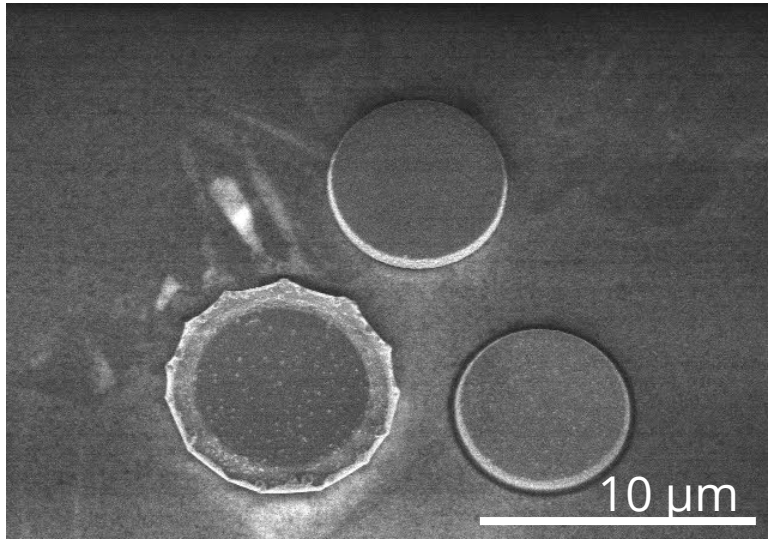


Design: Material Selection

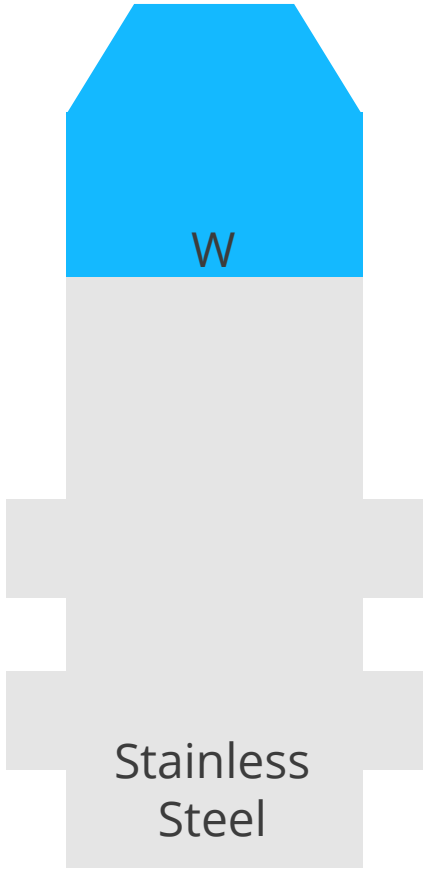
* Simulated by Dalton et al. 2021

Element	Z	Density (g/cm^3)	MP (^{o}C)	$K_{\alpha1}$ (keV)	$K_{\alpha2}$ (keV)	$K_{\beta1}$ (keV)
Ti	22	4.5	1660	4.51	4.50	4.93
Mo*	**42**	**10.22**	**2610**	**17.48**	**17.37**	**19.61**
Ag*	**47**	**10.5**	**962**	**22.16**	**21.99**	**24.94**
Cd	48	8.65	321	23.17	22.98	26.10
Te	52	6.25	452	27.47	27.20	31.00
Sm	**62**	**7.52**	**1072**	**40.12**	**39.52**	**45.41**
Yb	70	6.97	819	52.39	51.35	59.37
W*	**74**	**19.3**	**3410**	**59.32**	**57.98**	**67.24**
Au	**79**	**19.3**	**1064**	**68.80**	**66.99**	**77.98**
U	92	19.10	1132	98.44	94.67	111.30

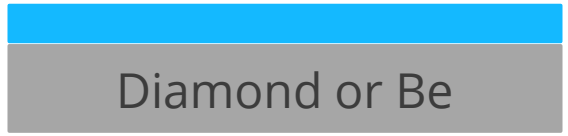
X-ray data from Table 1-2 of the 3rd edition of Lawrence Berkeley National Laboratories' *X-ray Data Booklet*

Design: Existing X-ray Anodes

W
Reflection Anode

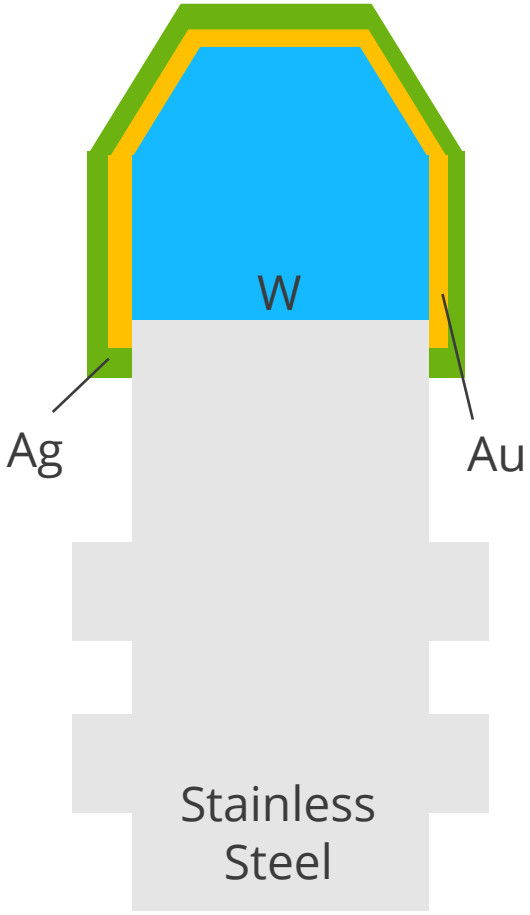


W
Transmission Anode



Design: Custom Multi-Metal X-ray Anodes

Layered Reflection Anode

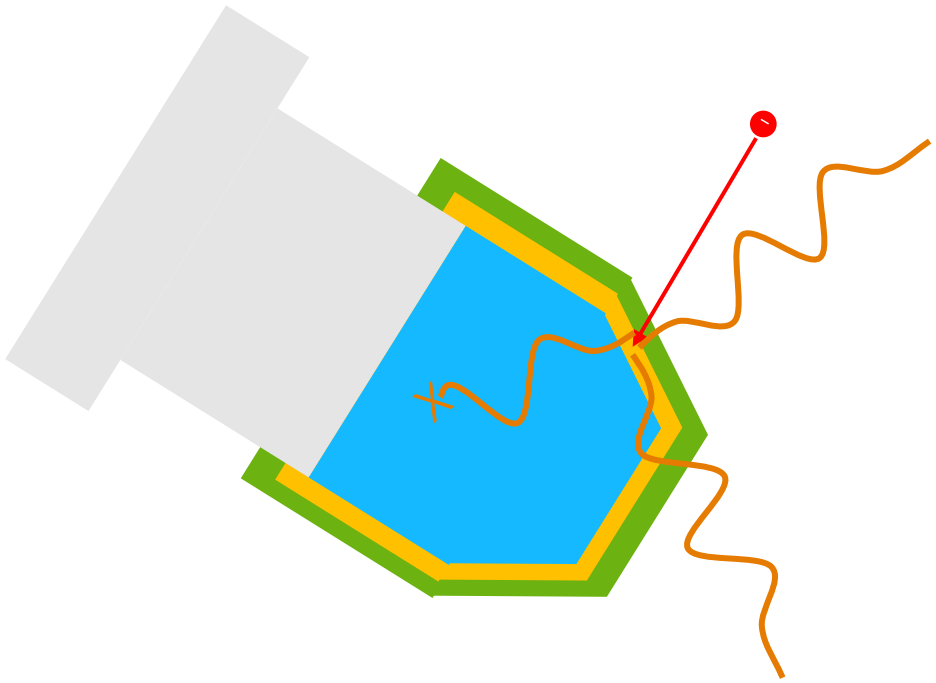


Layered Transmission Anode

Patterned Transmission Anode

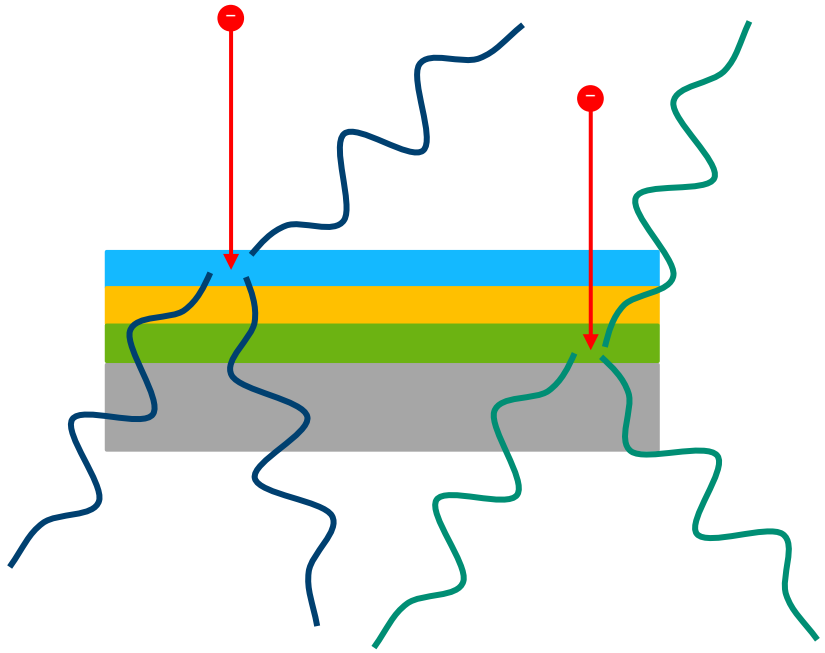
Design: Metal Layering

Layered Reflection Anode



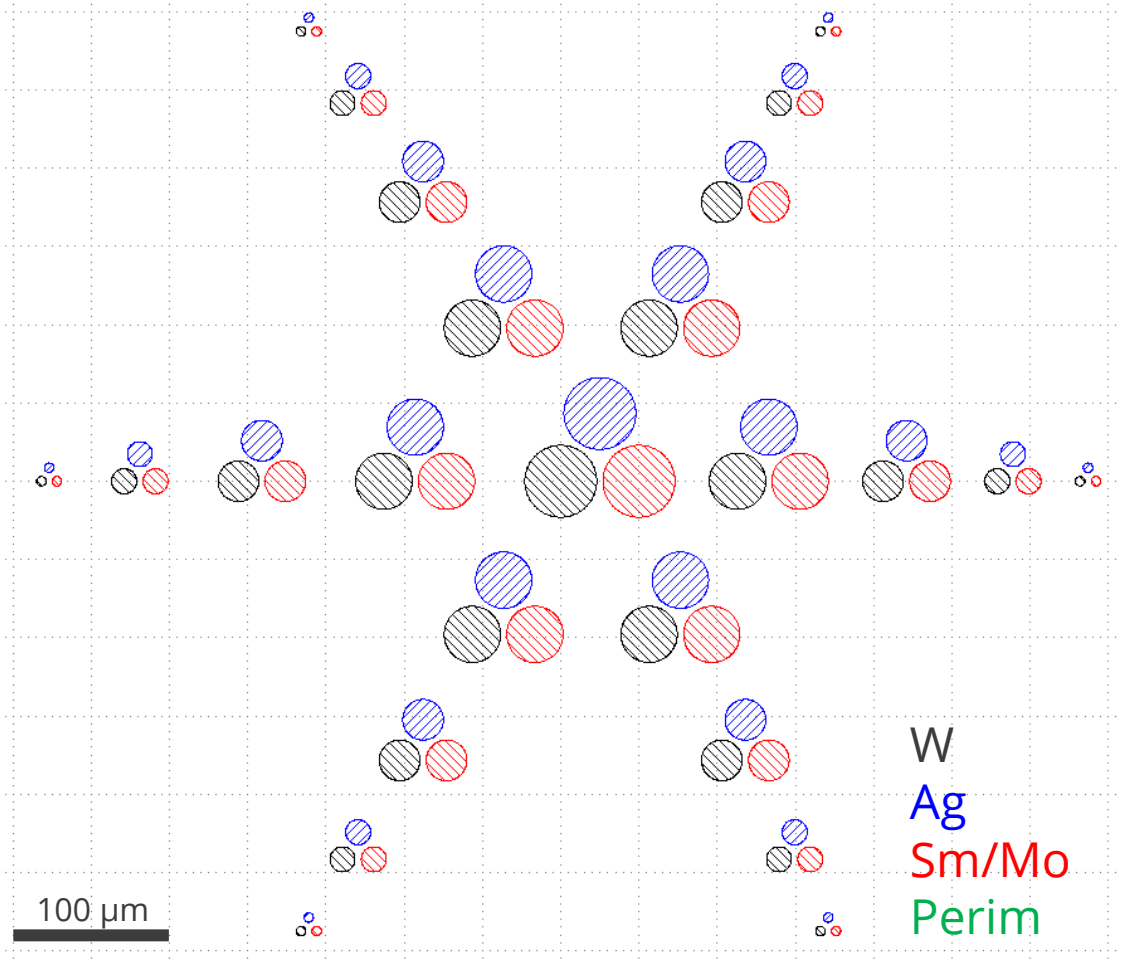
Detector

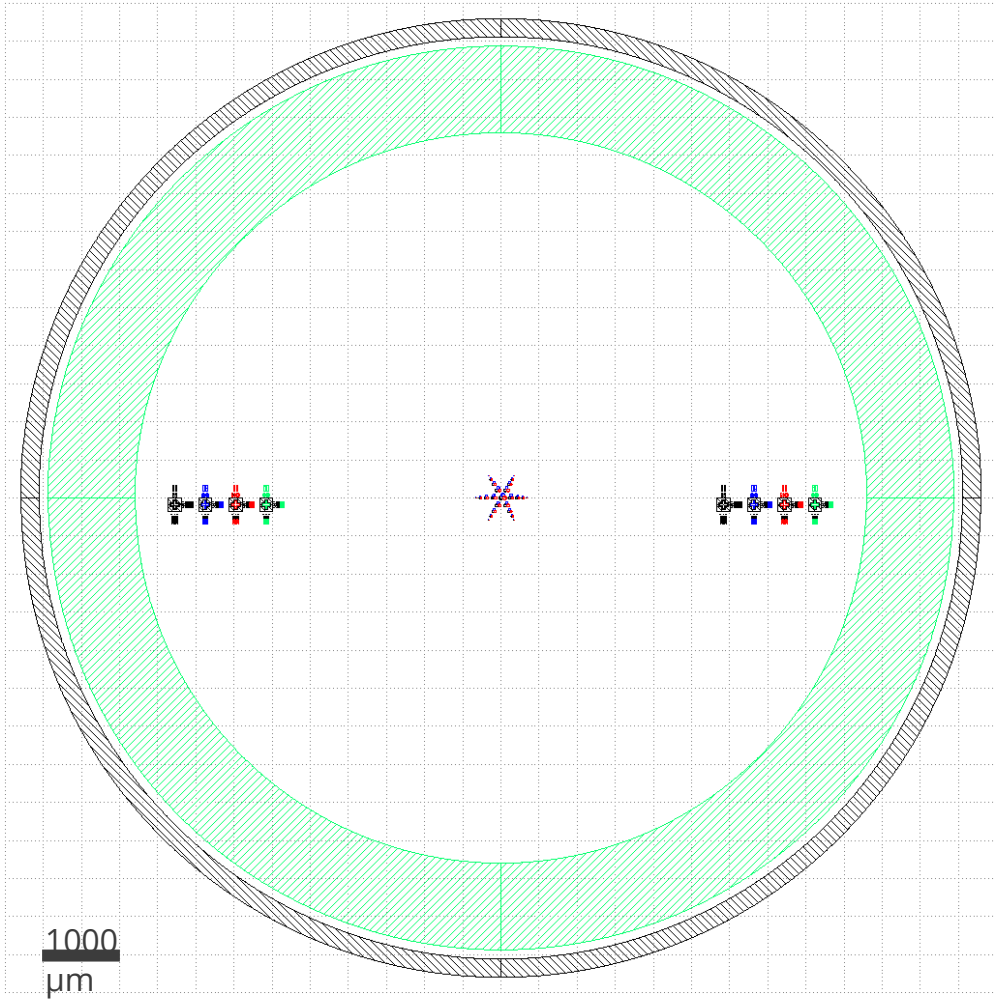
Layered Transmission Anode



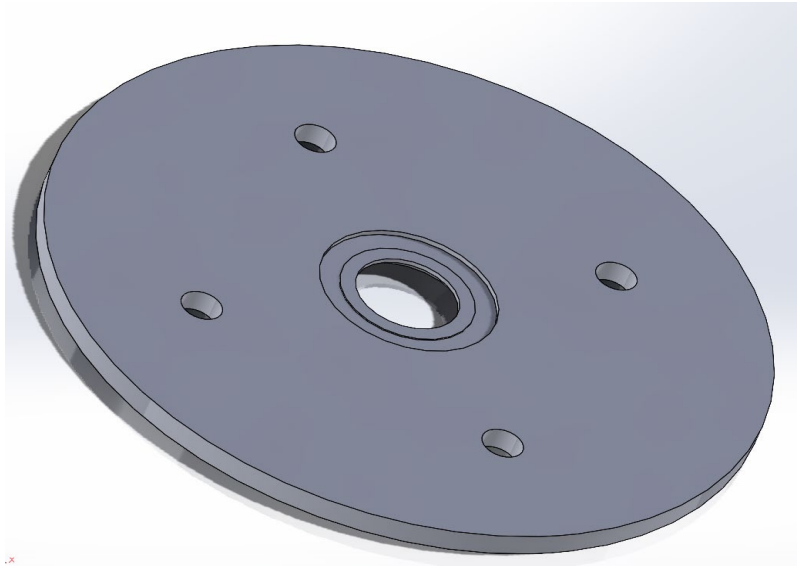
Detector

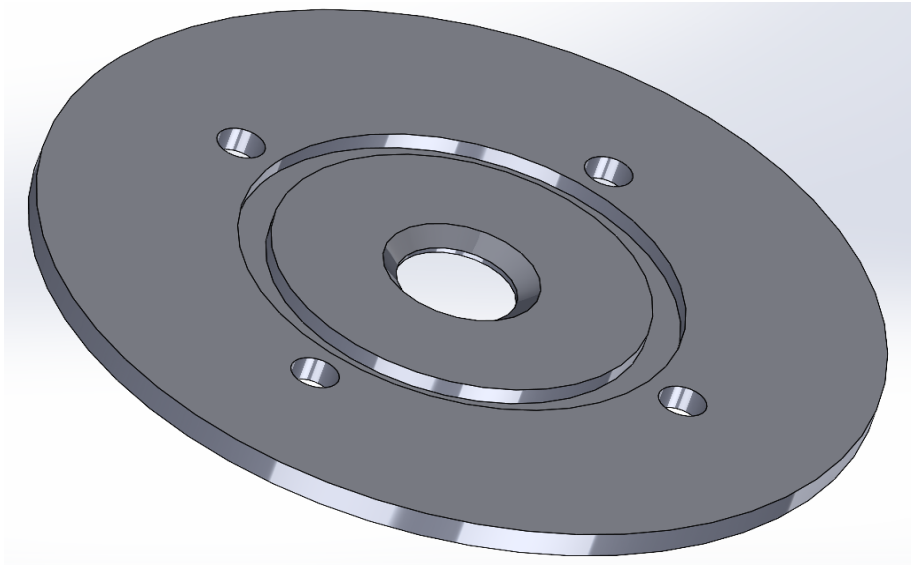
Design: Patterned Multi-Metal X-ray Anodes





Design: Transmissive Anode Packaging





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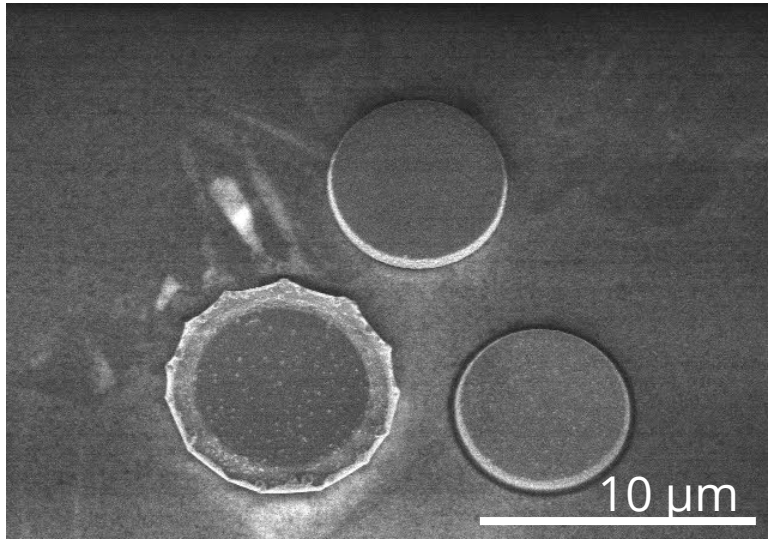
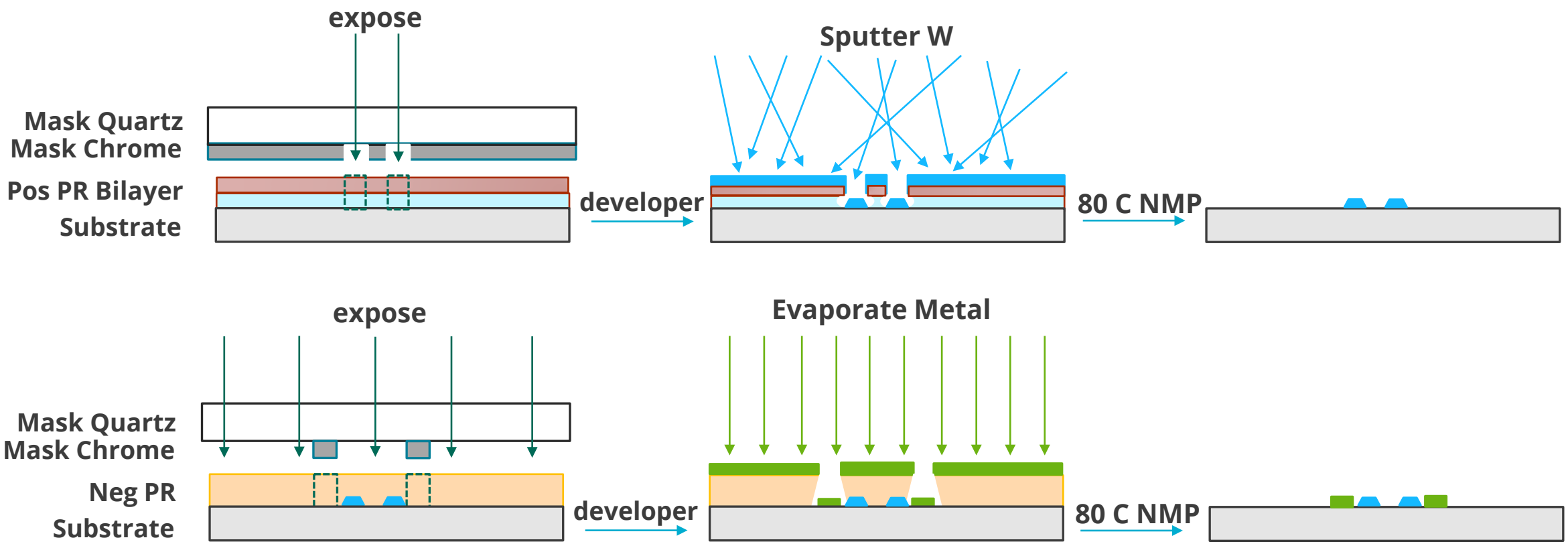
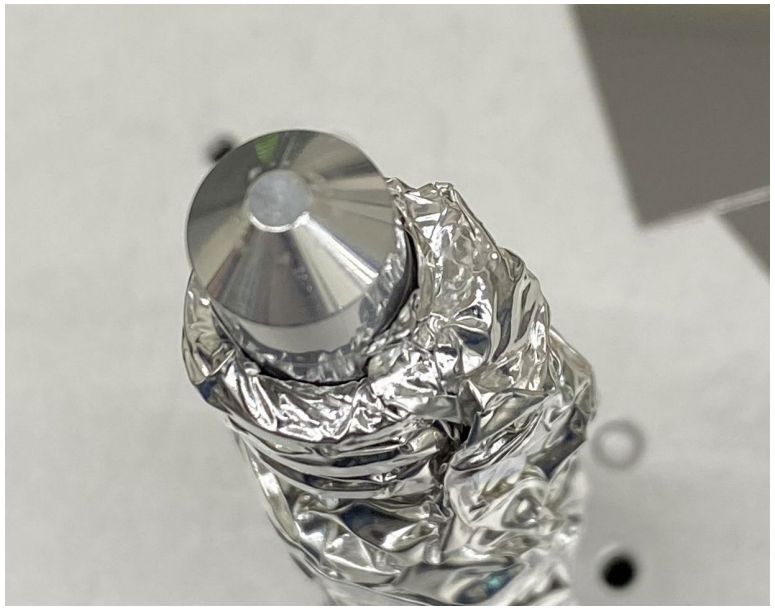
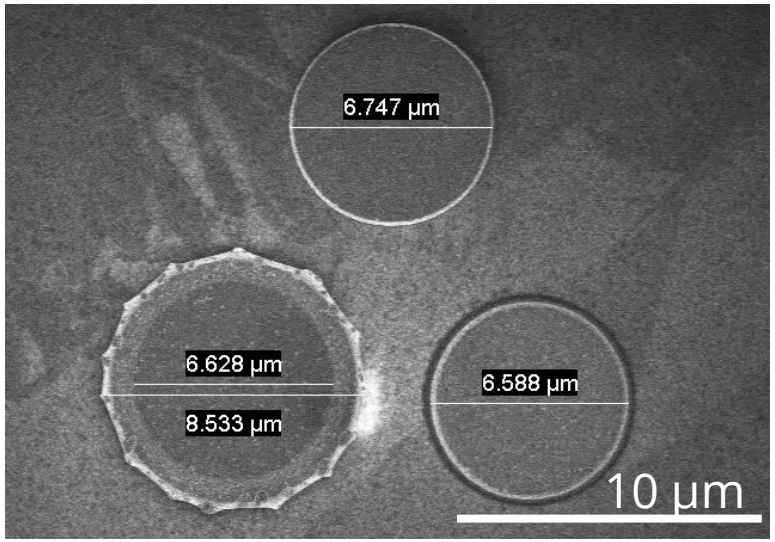


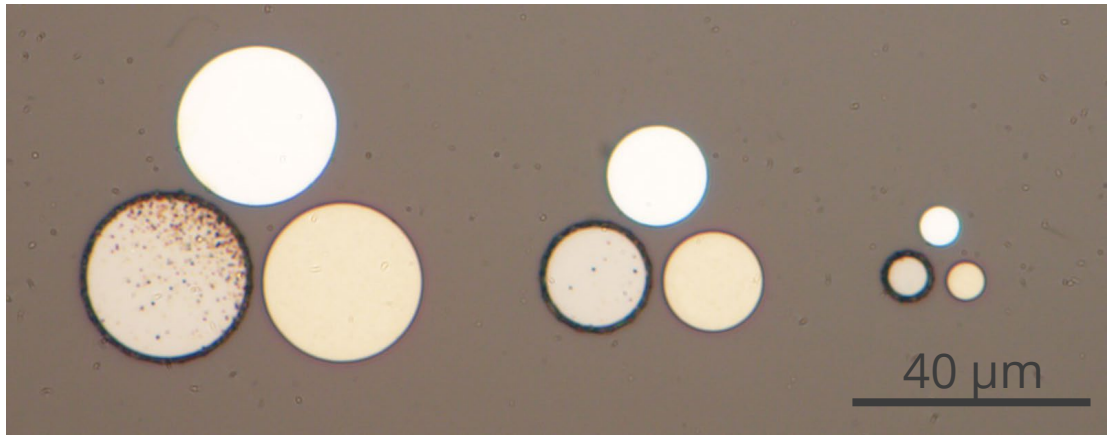
Fabrication: Patterned Multi-Metal X-ray Anodes

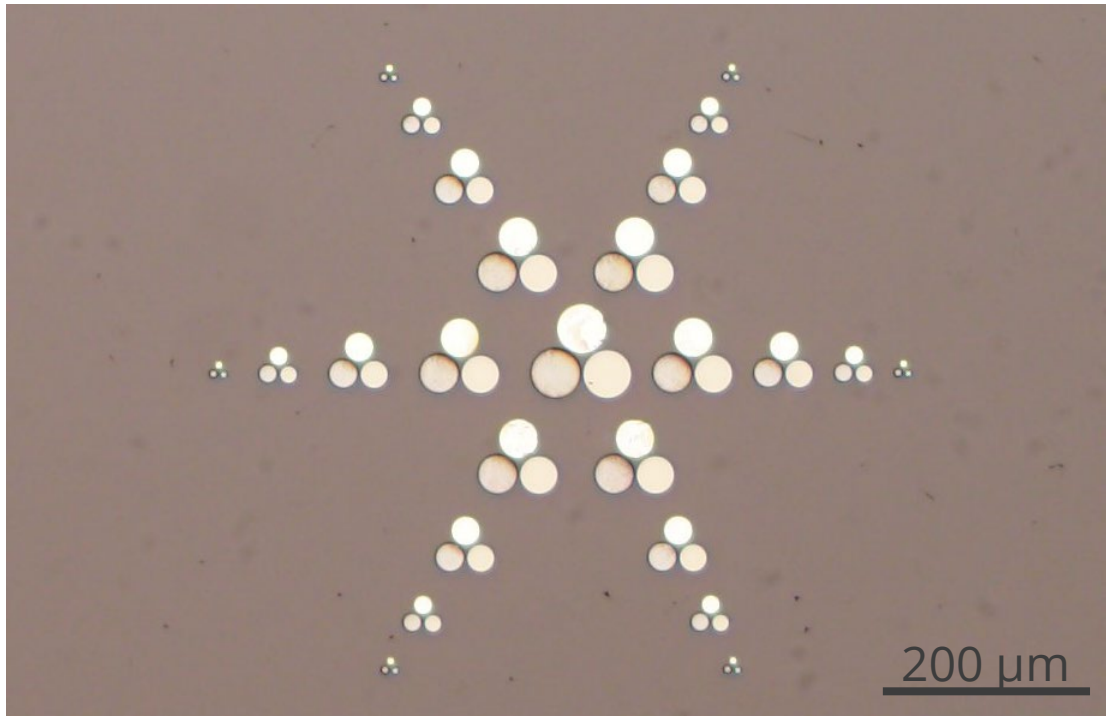


Fabrication: Optical and SEM of Completed Targets

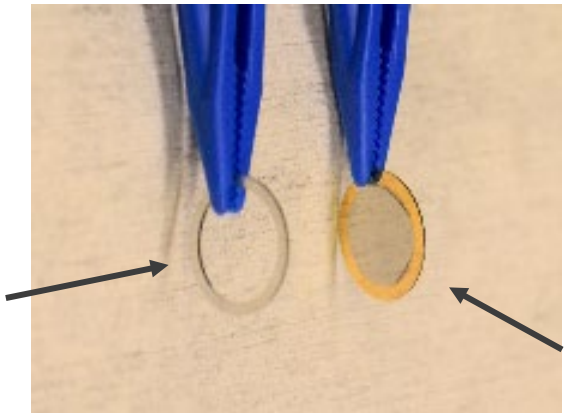






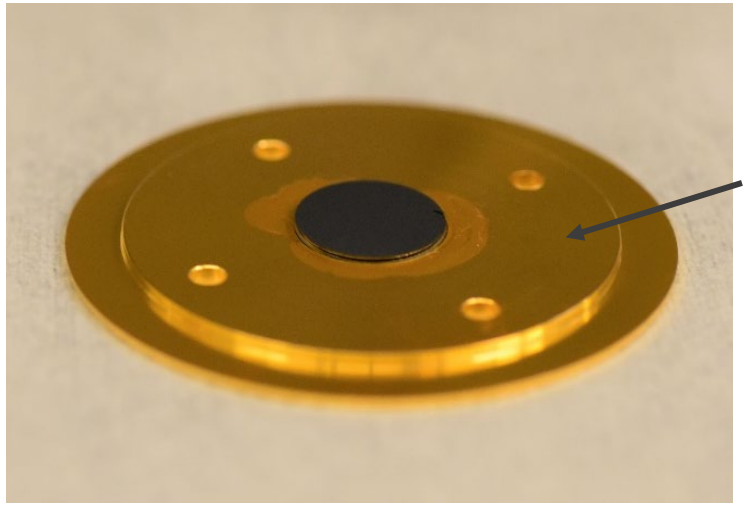


Fabrication: Solder into Packaging

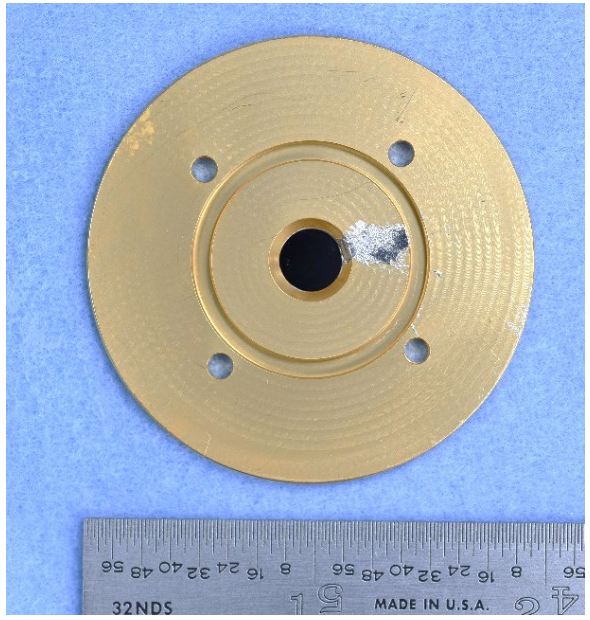


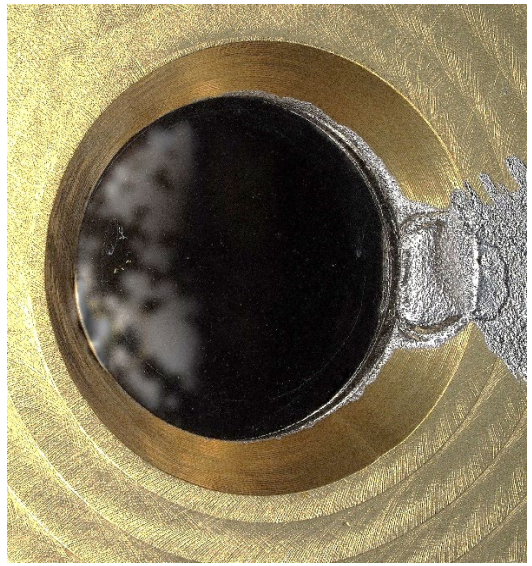
Sn-Pb Solder Preform

Ni-Au Perimeter-Plated Layered Anode



Ni-Au Plated Stainless Steel Holder





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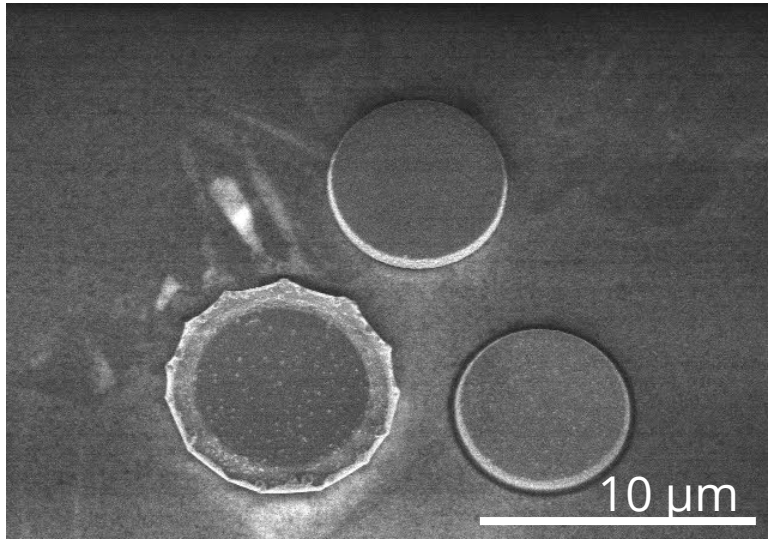

Evaluation

- **X-ray System**
  - X-RAY WorX XWT-225-SE (reflection anode types only)
  - Amptek 1-2-3 Cd-Te X-ray and Gamma Ray Spectrometer, set to 1024 channels
- **Bulk W Reflection Anode vs Layered Multi-Metal Reflection Anode**
  - **Emission spectra** measurements were taken from 25 keV to 150 keV with increments of 25 keV
  - **Longevity** measurements, collected at 125 keV accelerating voltage and 10 μA for 60s every 15min over 5 hours of continuous operation
  - Note, all **data normalized by live-time**: dividing the # of counts in each channel by live-time of the detector for each measurement

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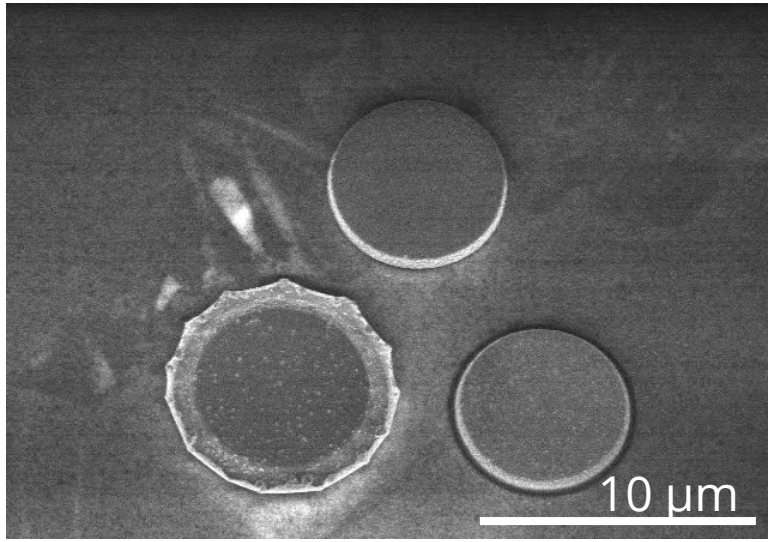
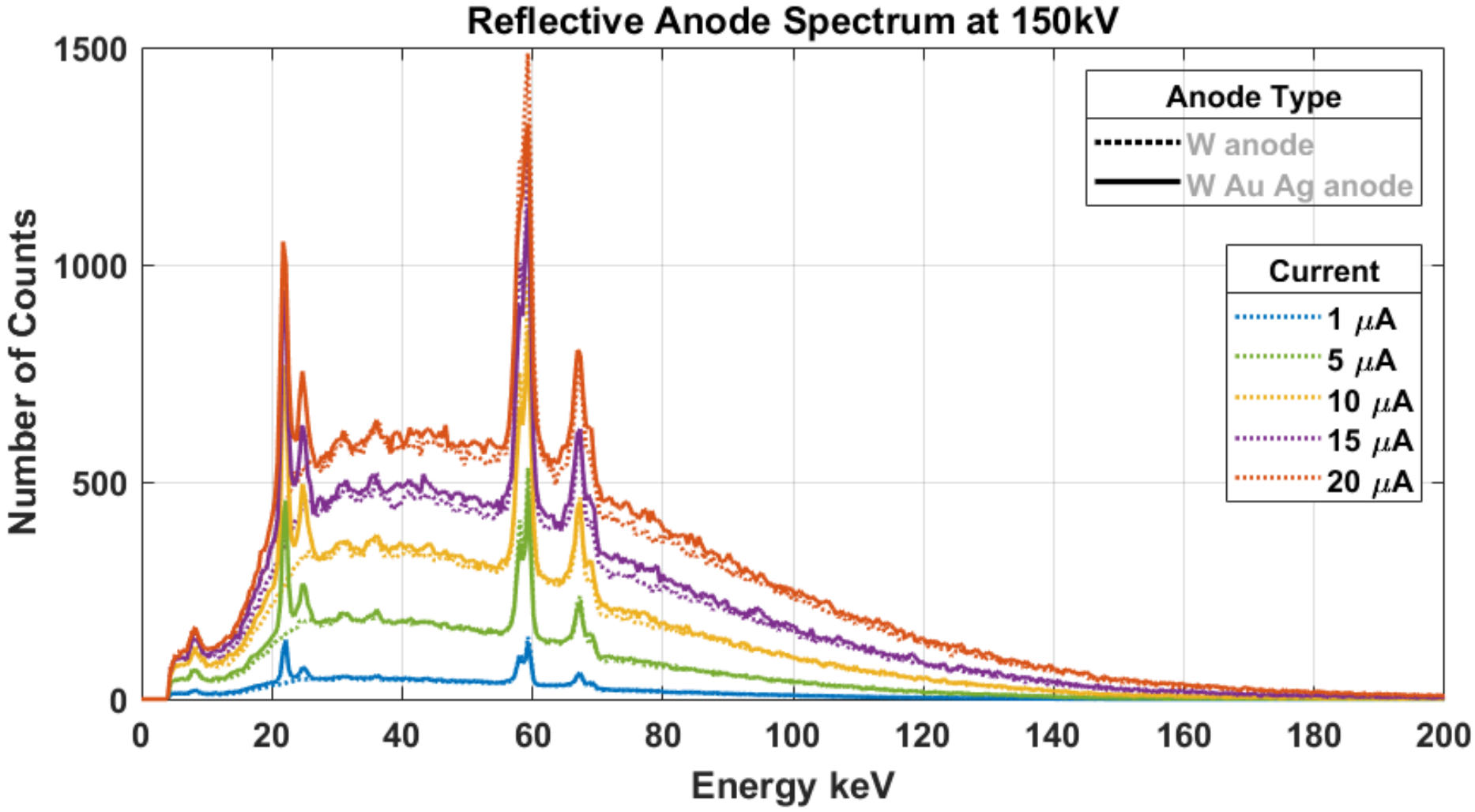
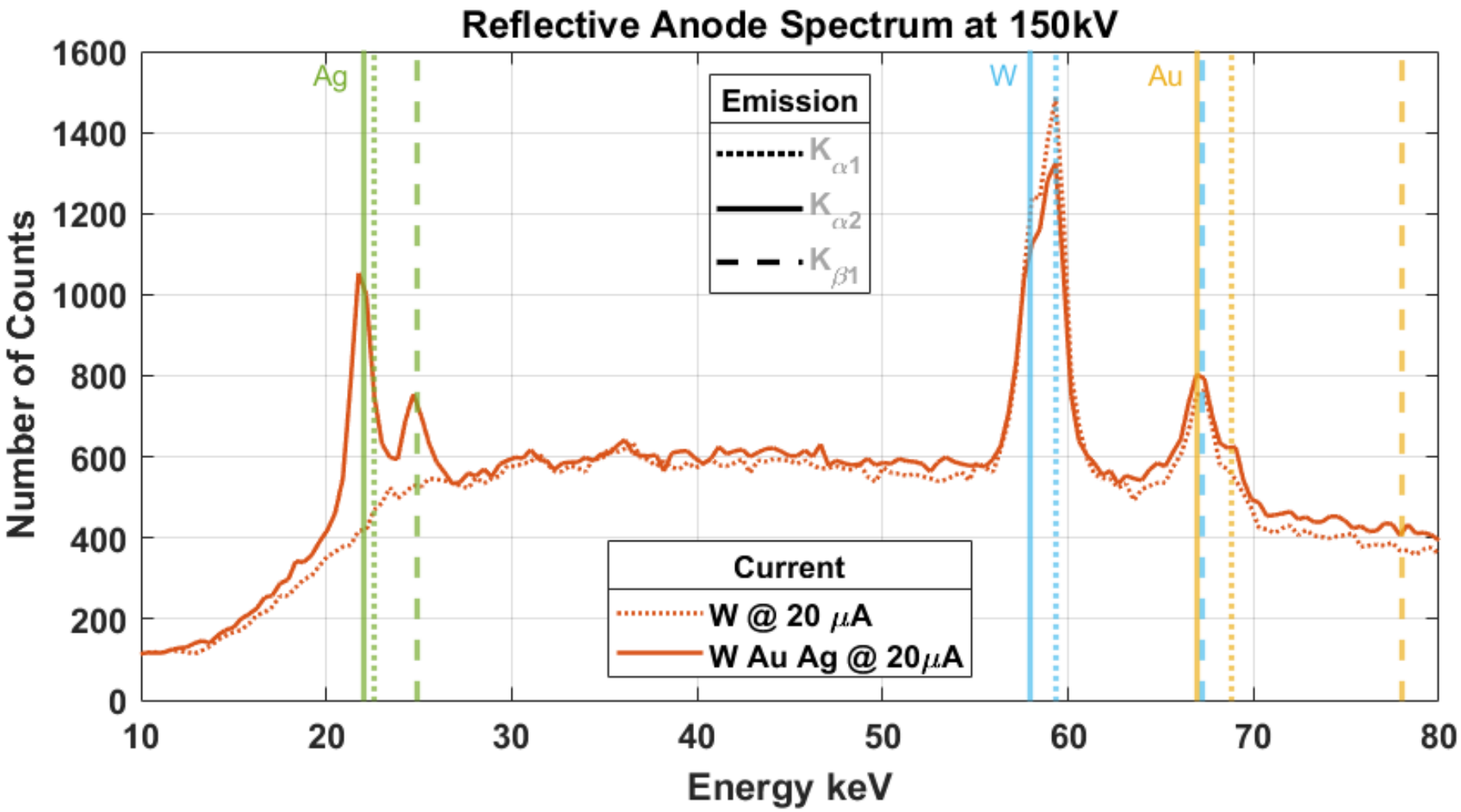


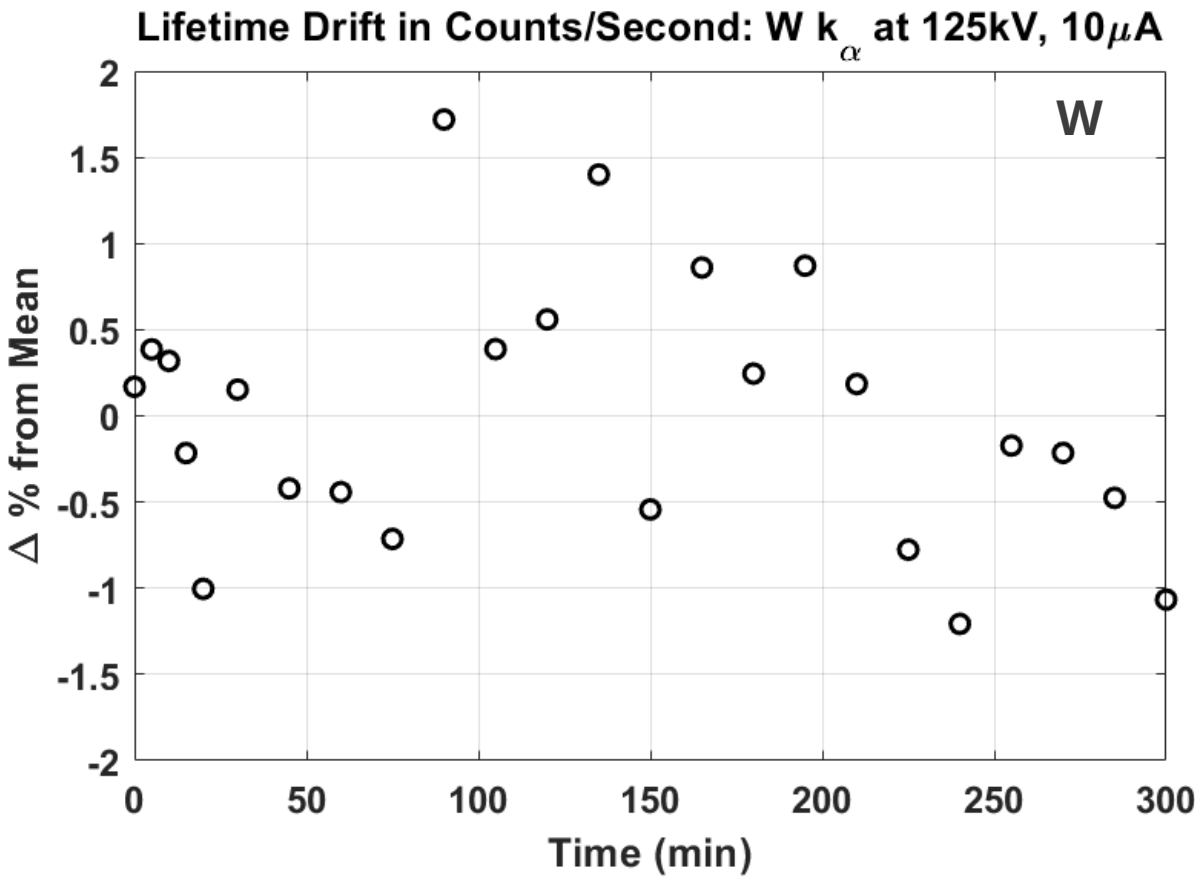
Results: Layered Reflective Anode, Emission Spectra

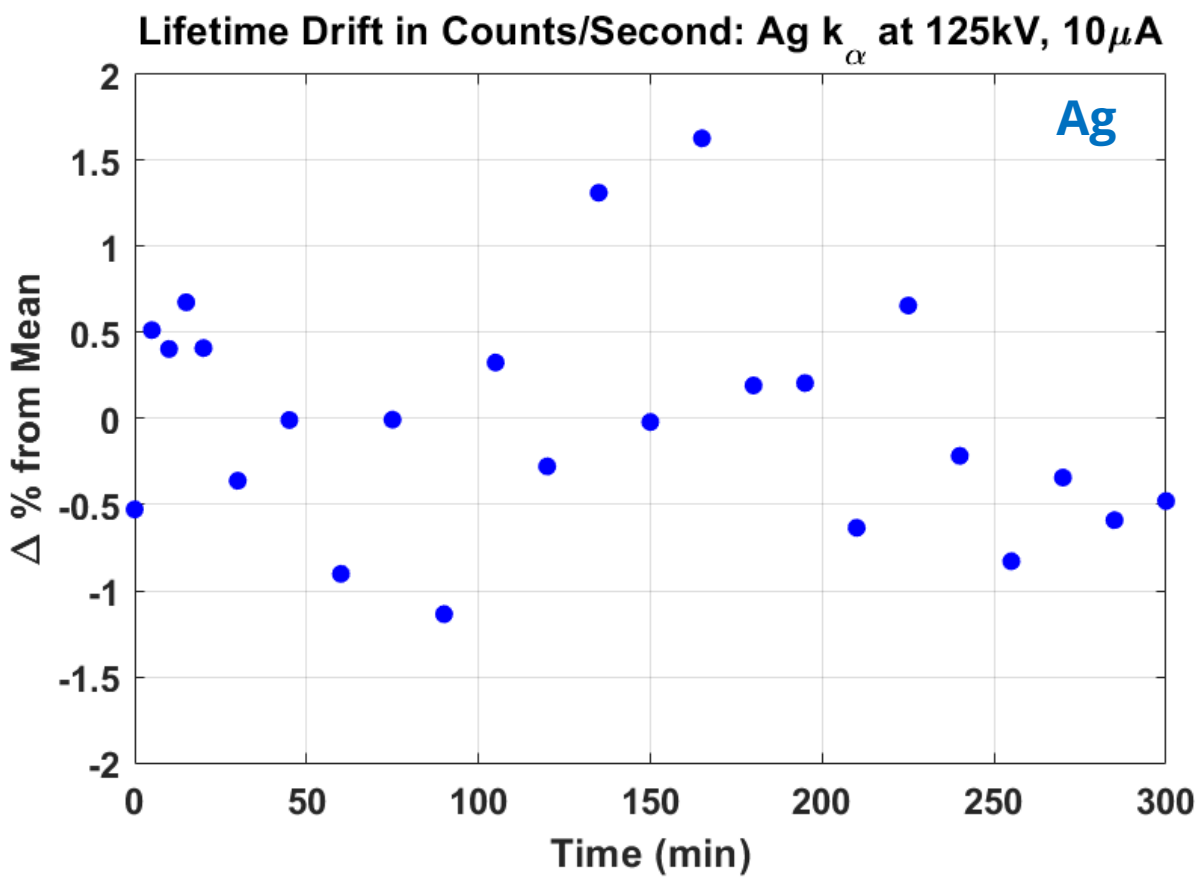


Results: Layered Reflective Anode, Emission Spectra



Results: Layered Reflective Anode, Time Response





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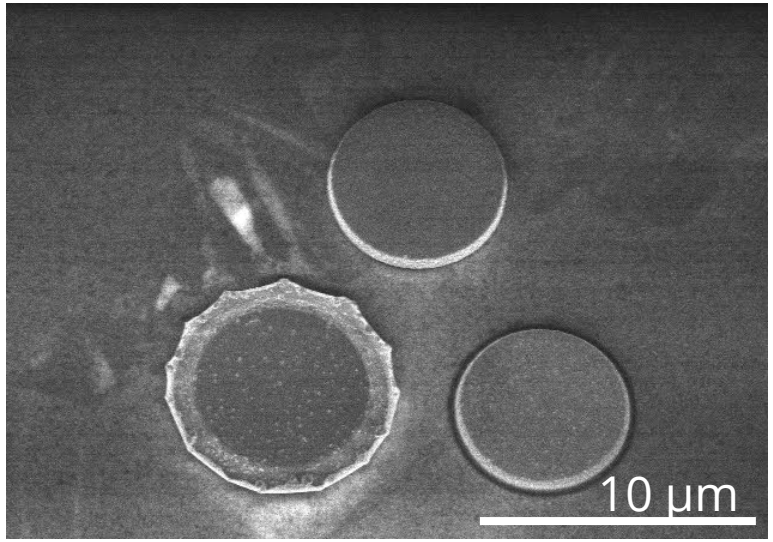

Conclusion and Future Work

Conclusions

- Layered multi-metal reflection anodes yielded emission of additional **spectral peaks corresponding to multiple separate metals simultaneously**
- Fabricated custom multi-metal patterned transmissive anodes with separate metals contained within the focal spot size of a commercial X-ray tube
- Achieved vacuum-tight solder integration into custom packaging for **compatibility with commercial X-ray tube sources**

Future Work

- Characterize multi-metal patterned transmissive anodes using newly acquired X-RAY WorX dual-head X-ray source
- Expand to additional anode metal combinations and X-ray system configurations

Questions?

Thank you!

Citations

- Dalton, G. M., Collins, N. M., Clifford, J. M., Kemp, E. L., Limpanukorn, B., and Jimenez, E. S., “Monte carlo modeling and design of a high-resolution hyperspectral computed tomogaphy system with multi-material patterned anodes for material identification applications,” in [Developments in X-Ray Tomogaphy VIII], Muller, B. and Wang, G., eds., Proc. SPIE 11840, 118400H (2021).
- Jimenez, E. S., Collins, N. M., Holswade, E. A., Devonshire, M. L., and Thompson, K. R., “Developing imaging capabilities of multi-channel detectors comparable to traditional x-ray detector technology for industrial and security applications,” in [Radiation Detectors: Systems and Applications XVII], Grim, G. P., Barber, H. B., and Furenlid, L. R., eds., Proc. SPIE 9969, 99690A (2016)
- Jimenez, E. S., Thompson, K. R., Stohn, A. M., and Goodner, R. N., “Leveraging multi-channel x-ray detector technology to improve quality metrics for industrial and security applications.,” in [Developments in X-Ray Tomography VIII], Muller, B. and Wang, G., eds., Proc. SPIE 11840, 118400H (2017).