

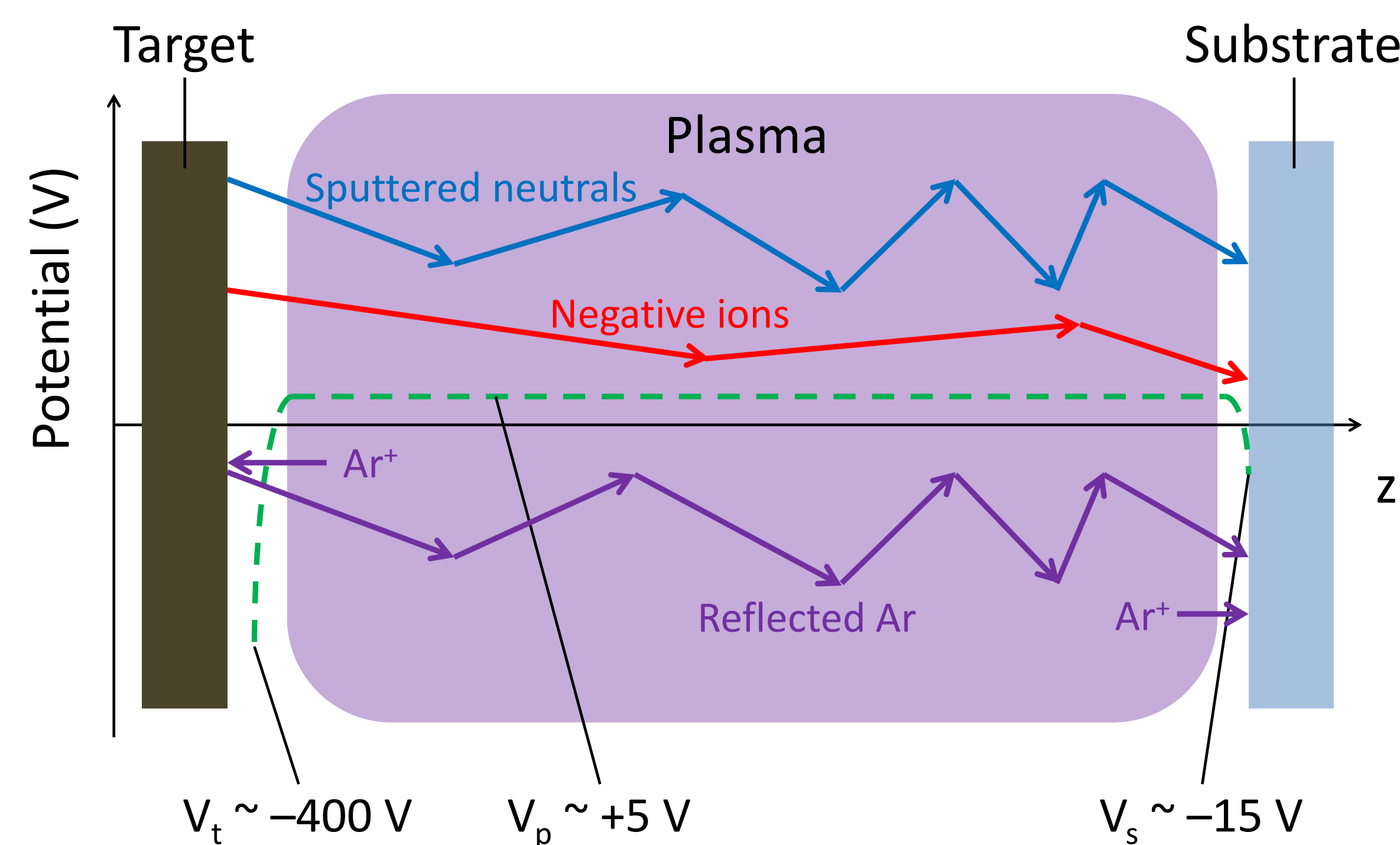
Energy-Resolved Quadrupole Mass Spectrometry in II^B-VI^A Sputtering Investigations

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Sputtering Studies Useful but not Common

- Sputtering is often treated as a black box
 - Control inputs: power, pressure, ambient composition, etc.
 - Observe film properties: crystallinity, transmittance, conductivity, etc.
- This approach does not consider complex sputtering phenomena
 - Ion/electron energy
 - Particle aggregation/film nucleation

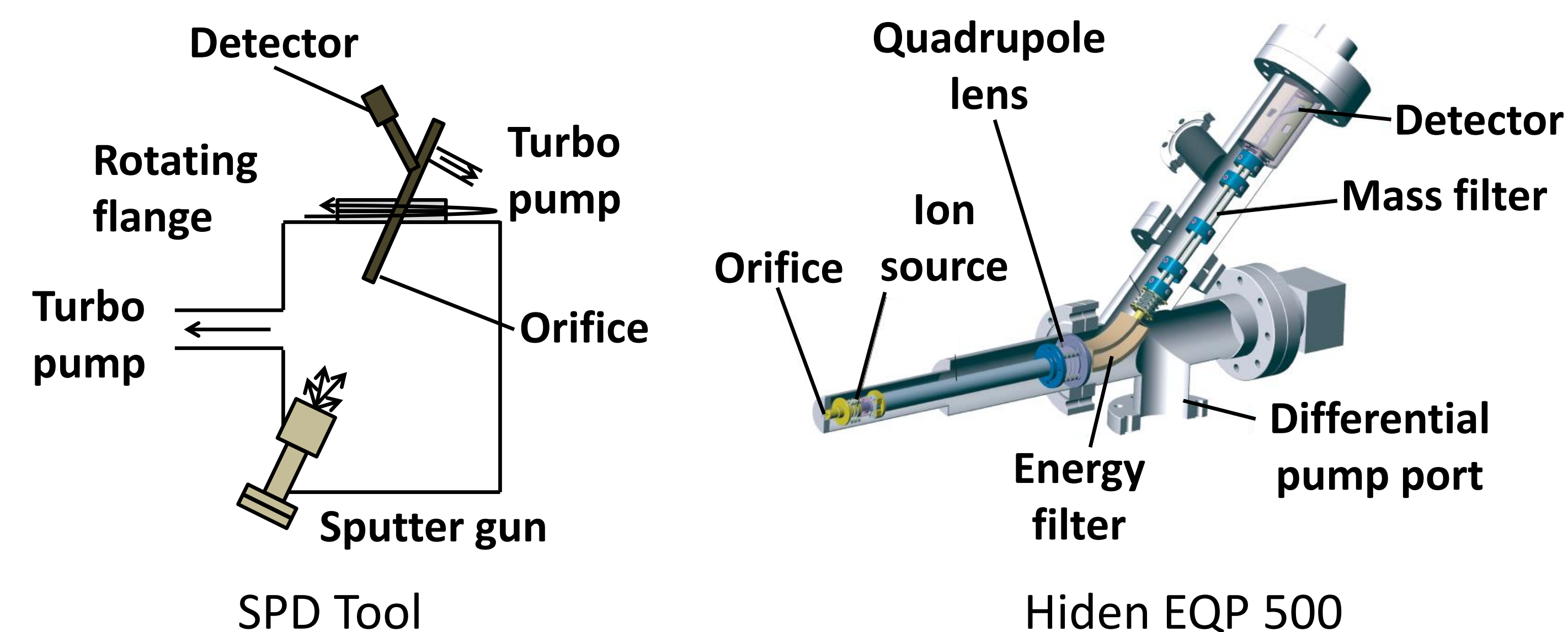


Use mass spectrometry to advance understanding

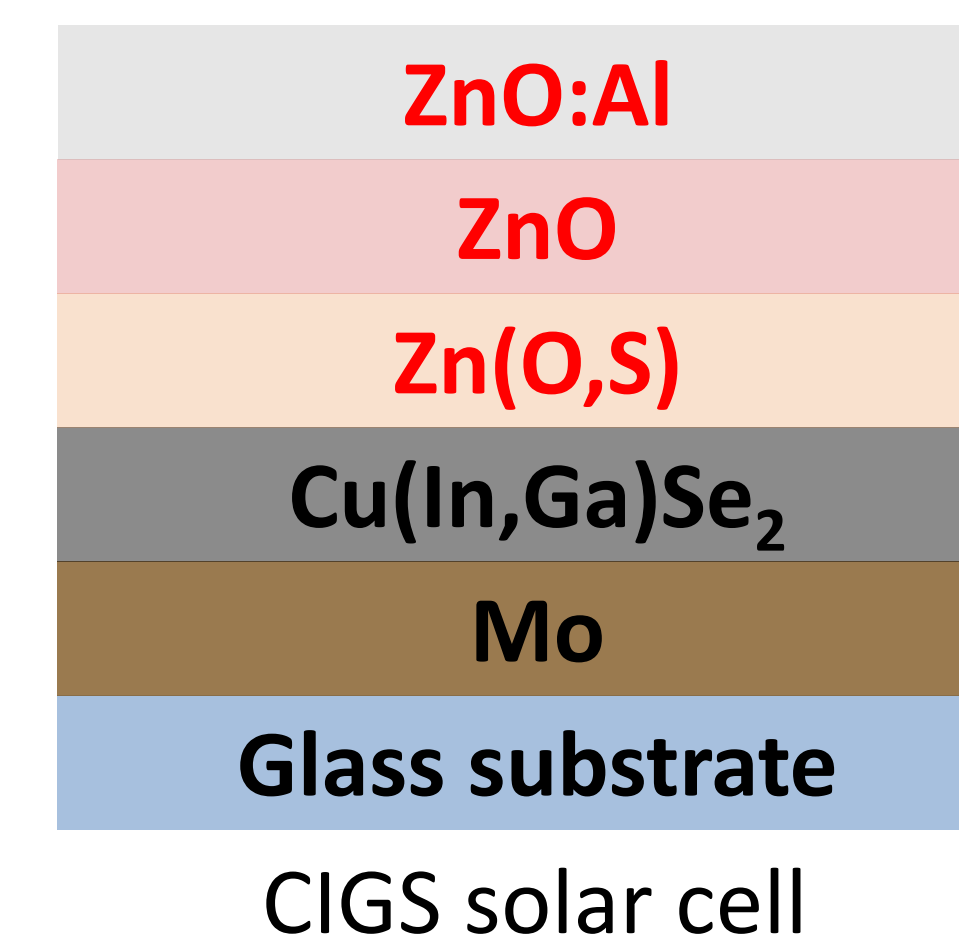
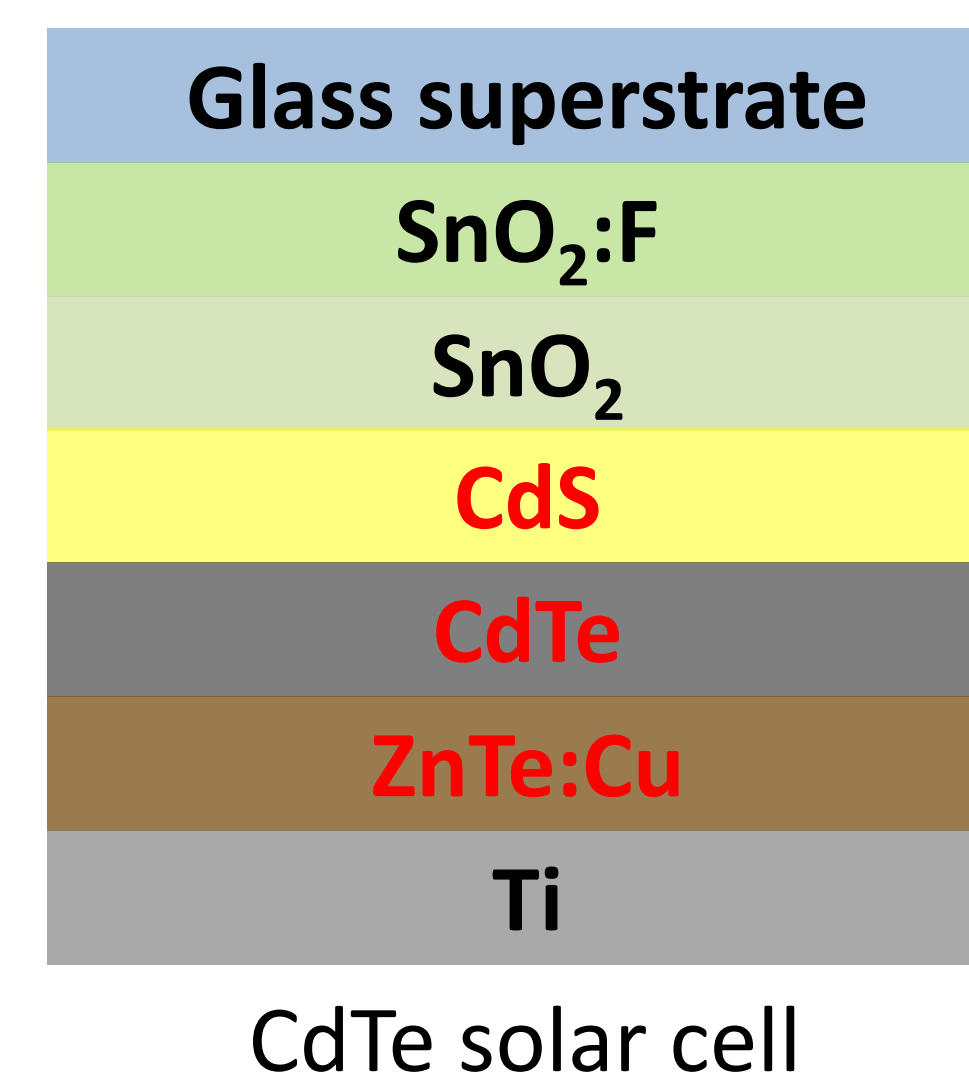
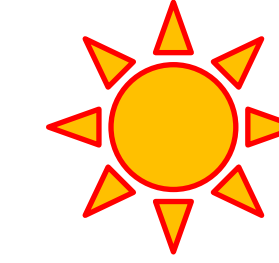
- Chemistry/composition of sputtered particles
- Critical energetics/potentials

Equipment: QMS Mounted to Sputtering Chamber

- The Sputter-Plasma Diagnostic (SPD) multi-source UHV chamber
- Hidden EQP 500 Quadrupole Mass Spectrometer
 - Mounted via rotating flange with 2-axis motion
 - Line of sight access to sputtering plasma
 - Capable of analyzing neutrals and plasma-generated ions

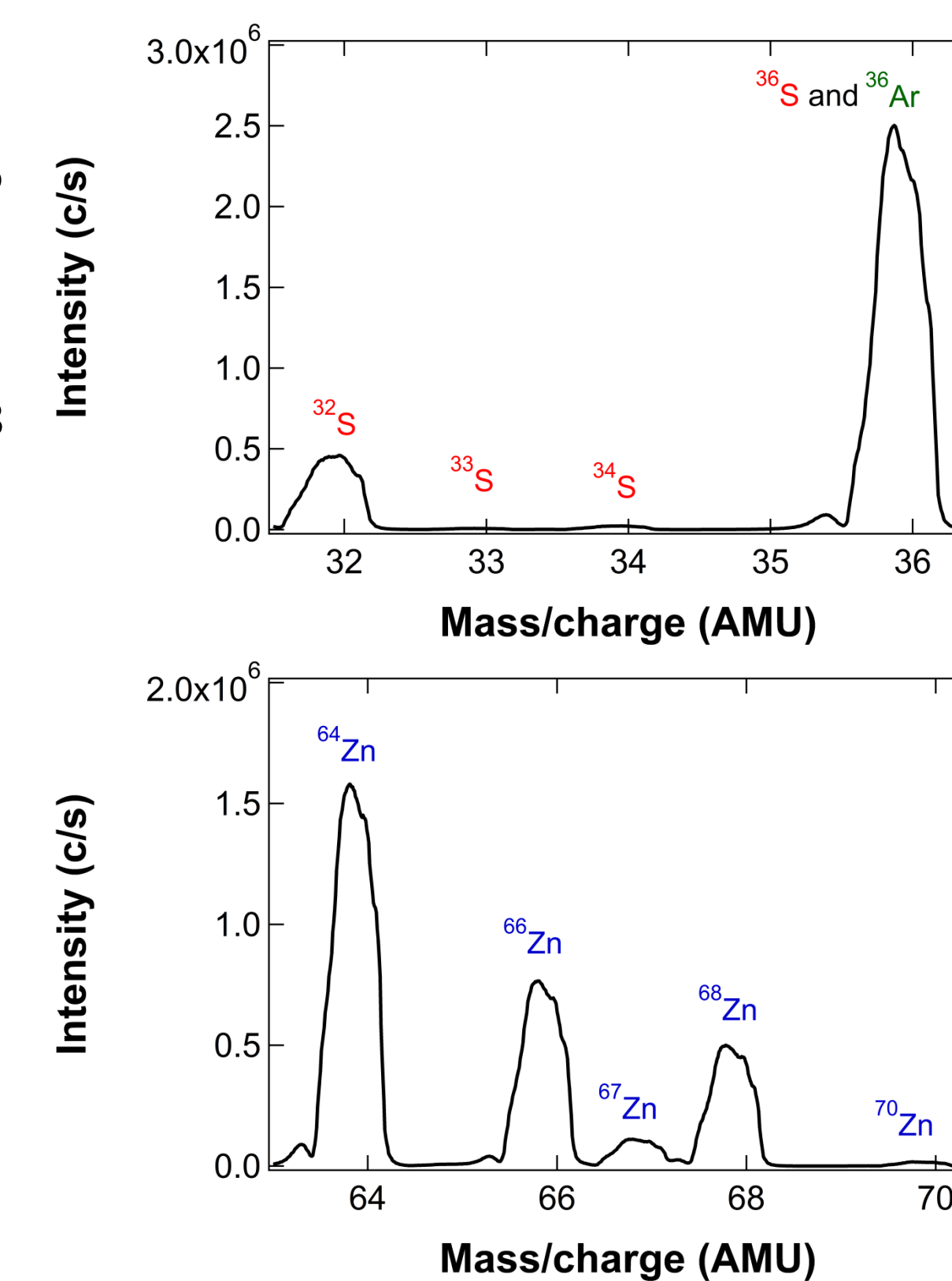
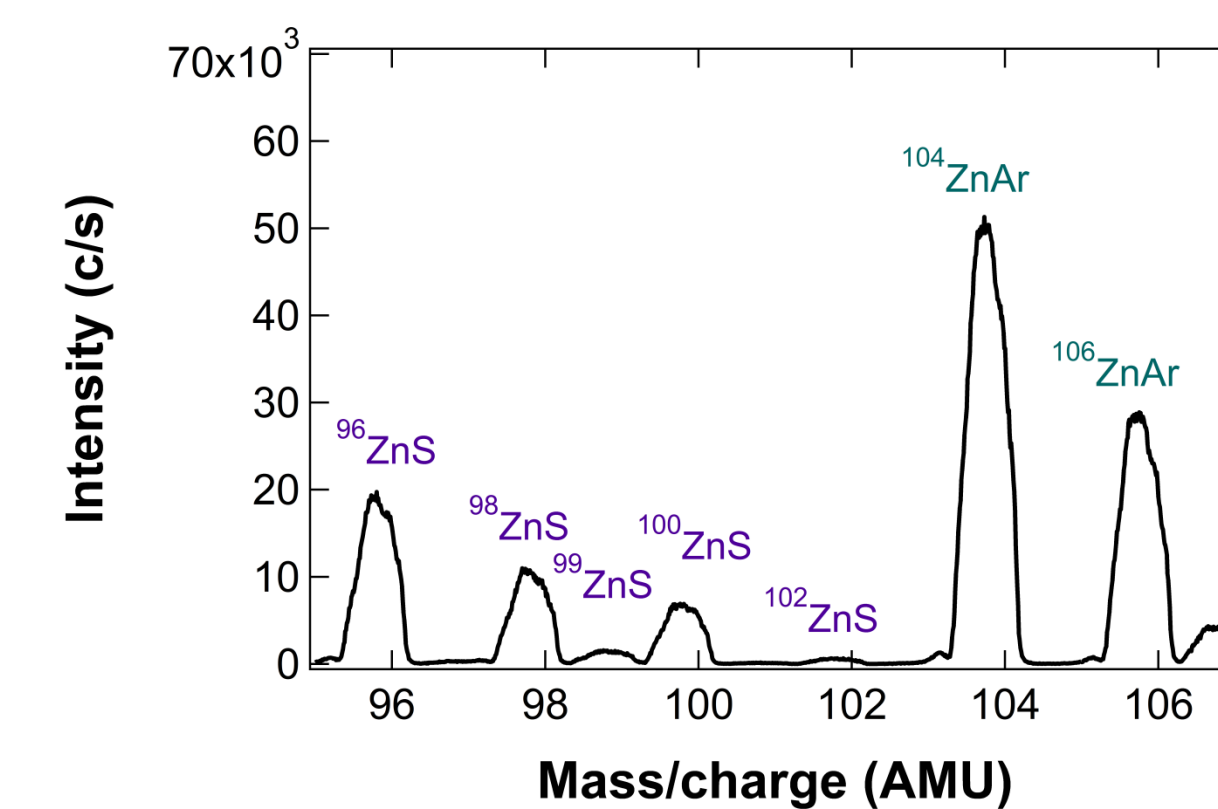
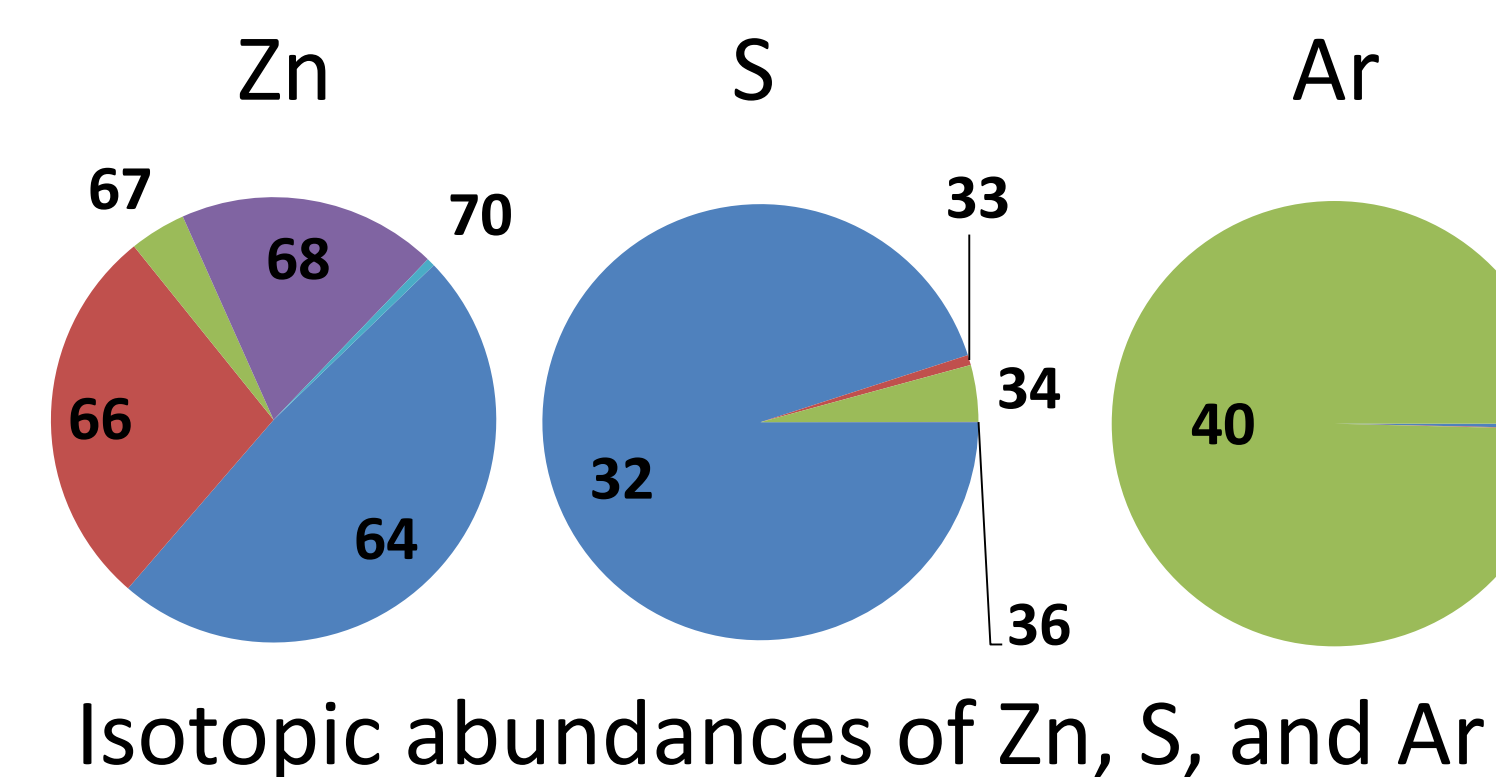


Sputtered II^B-VI^A Materials Used in Thin Film PV



Identification of ZnS Mass Spectra

- Do particles sputter atomically or in clusters?
- RF magnetron sputtered ZnS in pure Ar ambient



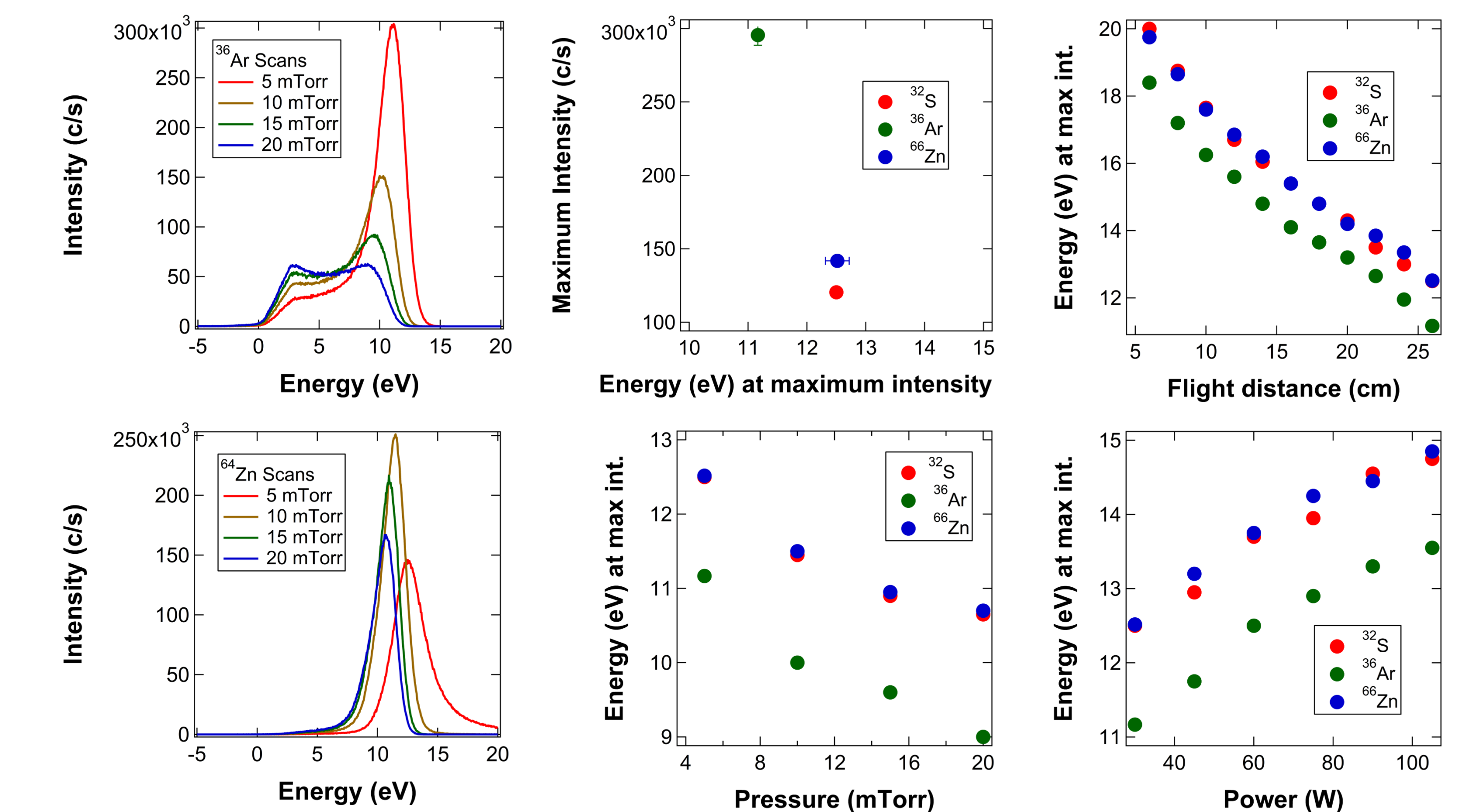
- Atomic ions more prevalent than clusters
- Ion fluxes: Ar > Zn > S > ZnAr > ZnS

Acknowledgements

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ZnS Ion Energy Distribution (IED) Scans

- Plot of Intensity vs. arrival energy of plasma-generated ions
- Peak position equal to plasma potential¹
- Electron temperature from $V_p - V_f = \frac{T_e}{2e} \left[1 + \ln \left(\frac{m_i}{2\pi m_e} \right) \right]$
- Experimental design
 - Sputter ZnS in Ar ambient
 - Investigate reproducibility, effects of flight distance, pressure, and power
 - Baseline conditions: 26 cm displacement, 5 mTorr, 30 W



- Scans show good reproducibility; plasma potential is highly variable
 - Uncertainty in peak position ~ 0.5 eV
 - Bimodal IED for Ar, single mode for Zn and S
 - Near-linear decrease in potential with increasing distance from target
 - Exponential drop in potential with increasing pressure
 - Increasing potential with increasing power

Conclusions

- Under baseline conditions, atomic sputtering dominates
- Processing conditions greatly affect arrival energy of sputtered ions

Future work

- Investigate oxygen incorporation in CdS and ZnS films
- Identify process conditions for atomic vs. cluster sputtering

References

- 1K. Ellmer, T. Welzel, Reactive magnetron sputtering of transparent conductive oxide thin films: Role of energetic particle (ion) bombardment, J. Mater. Res. **27** (2012), 765.