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

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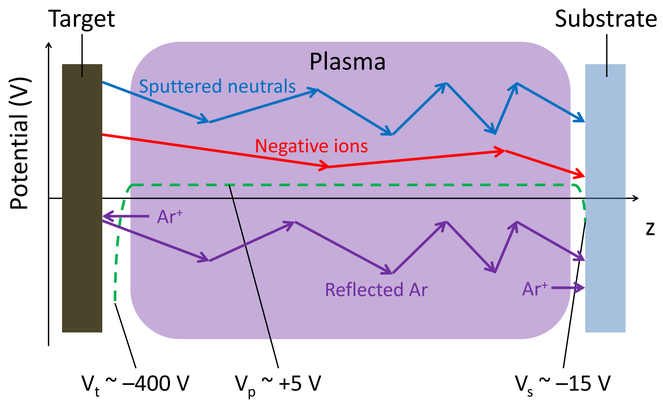
Sputtering Studies Useful but not Common

- 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

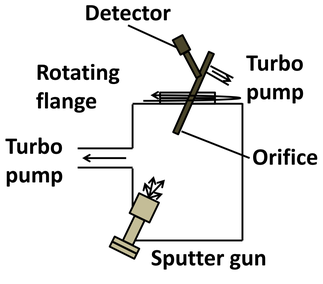


Use mass spectrometry to advance understanding

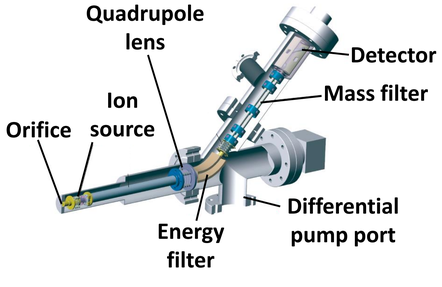
- Chemistry/composition of sputtered particles
- Critical energetics/potentials

Equipment: QMS Mounted to Sputtering Chamber

- The Sputter-Plasma Diagnostic (SPD) multi-source UHV chamber
- Hiden 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

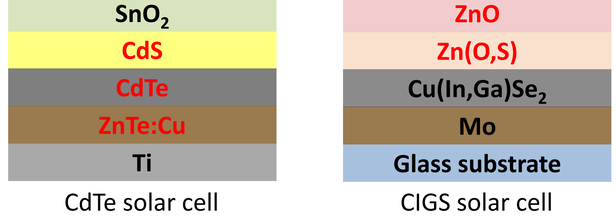


SPD Tool



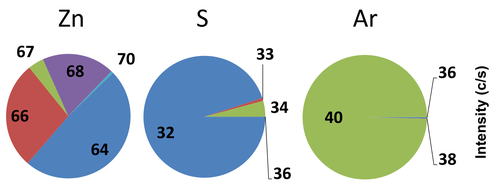
Hiden EQP 500

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



Isotopic abundances of Zn, S, and Ar

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

Acknowledgements

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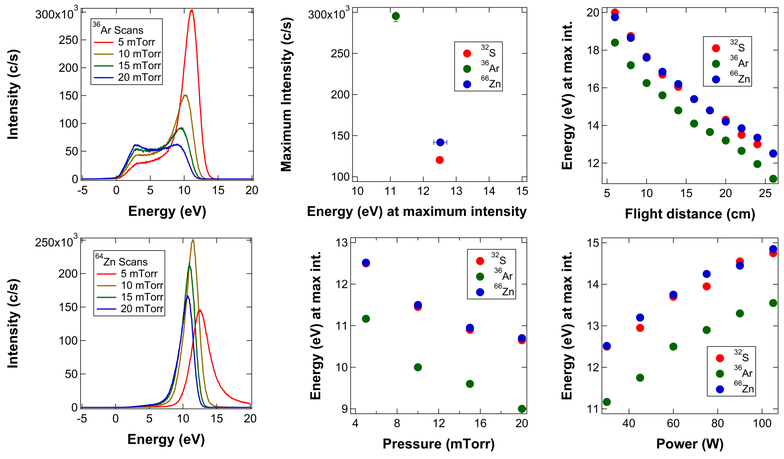
ZnS Ion Energy Distribution (IED) Scans

- Plot of Intensity vs. arrival energy of plasma-generated ions
- Peak position equal to plasma potential[1]
- 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

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

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