Boise State University
ScholarWorks

College of Engineering Poster Presentations

2011 Undergraduate Research and Scholarship Conference

4-11-2011

RF Sputter Optimization of Germanium Sulfide (GeS_2) Thin Films

Steven Livers
Department of Electrical and Computer Engineering, Boise State University

RF SPUTTER OPTIMIZATION OF GERMANIUM SULFIDE (GeS_2) THIN FILMS

S. Livers[1], J. van den Hurk[2], I. Valov[2], R. Waser[2], M. Mitkova[3]

[1]Department of Materials Science and Engineering, Boise State University, Boise, Idaho
[2]Institute of Materials in Electrical Engineering and Information Technology 2, RWTH Aachen University, Germany
[3]Department of Electrical and Computer Engineering, Boise State University, Boise, Idaho

Boise State University College of Engineering

RWTH Aachen University

ABSTRACT

Radio frequency sputter deposition of germanium sulfide thin films can be optimized for surface thickness homogeneity and surface roughness. Optimizing these two components are the first steps of producing memory devices that use the film as a solid electrolyte. The best films were produced using a sputter power of 16 Watts and a pressure of 0.2 mbar. Using these settings a deposition rate of 3.7 nm/min was recorded and the films had a minimum RMS surface roughness of 0.4550 nm.

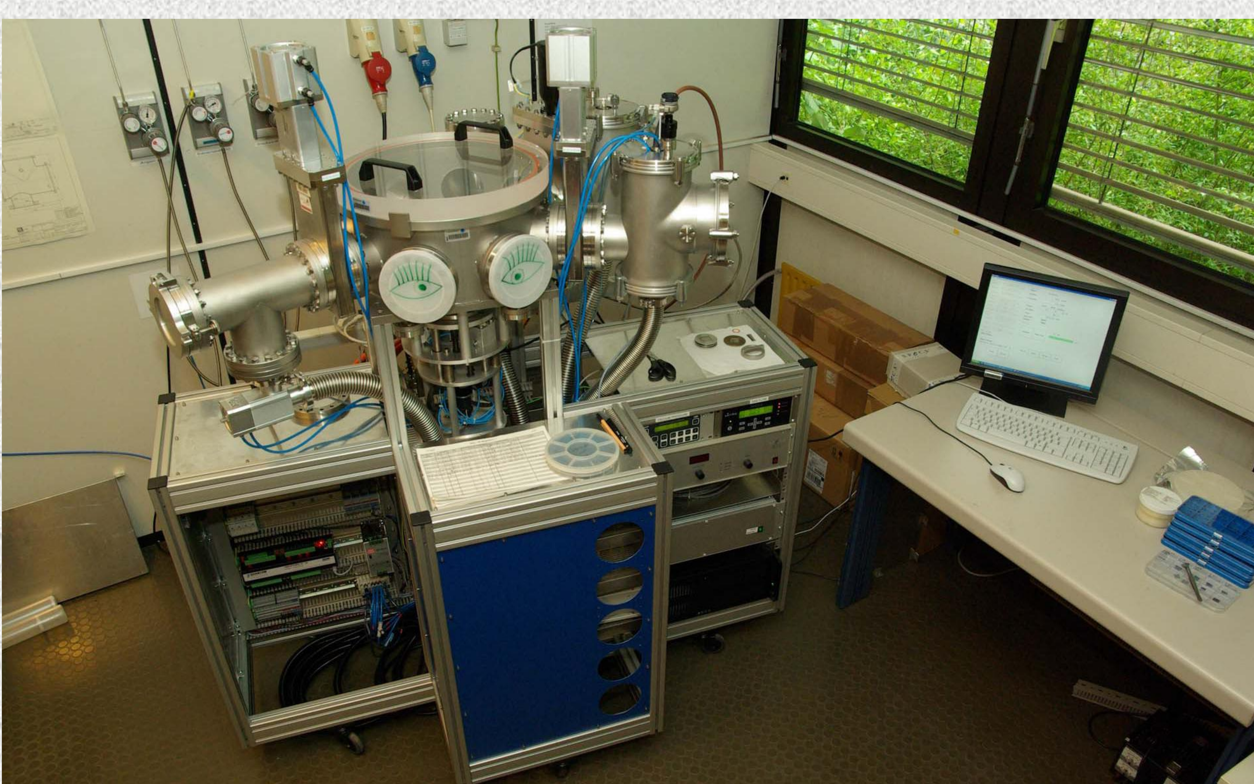
INTRODUCTION

Chalcogenide Glass

Thin films Chalcogenide glass are one of the main candidates for use as the solid electrolyte in programmable metallization cell memory. The amorphous Chalcogenide glass structure is suitable for allowing the metal links to form that are needed to change the resistance in the cell. Radio frequency sputtering of germanium sulfide is required because of its insulating nature. This type of physical vapor deposition allows the substrate material to remain overall neutrally charged during and after the sputter process.

Sputter Cluster Tool

A new cluster sputter tool was used for this project at RWTH Aachen by J. van den Hurk. The CT1000, consists of a main chamber, two sputter chambers (GeS_2 and Ag), storage chamber, entry/exit port. The system was controlled by a central computer allowing the parameters to be changed and measured accurately. The CT1000 was also designed for *in situ* sputter deposition of GeS_2 and Ag for future device processing. A one inch target of GeS_2 was water cooled and initially characterized for composition using EDS; 36 at. % germanium, 64 at. % sulfur.



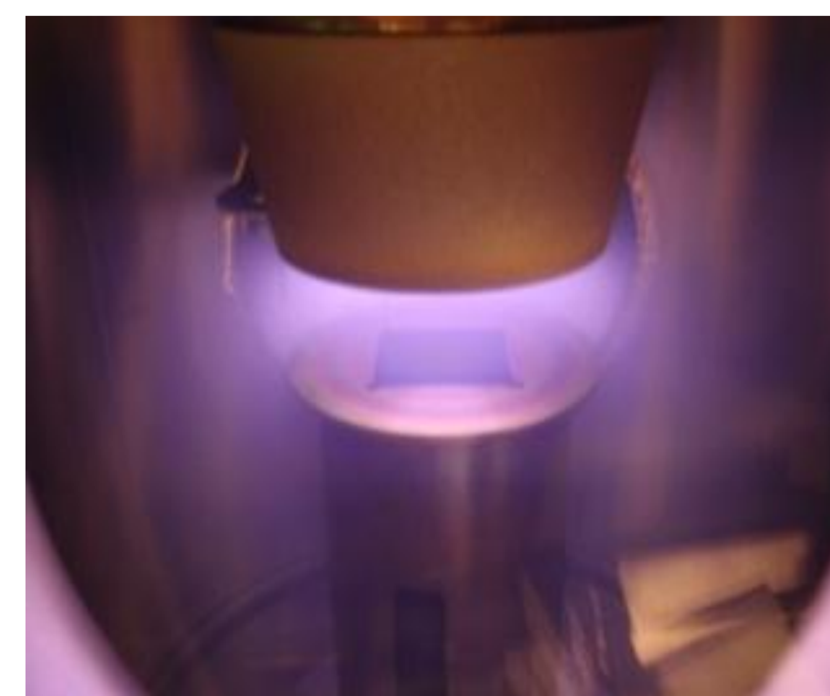
EXPERIMENTAL

Optimization of Process Parameters
- Power
- Pressure

Constants during Sputter Deposition
- Gas Flow (Argon 50 sccm)
  - Lower flow was required to reach pressures below 0.004 mbar
- Target distance from sample
- Sample size (1 inch^2)
- Time (30 minutes)

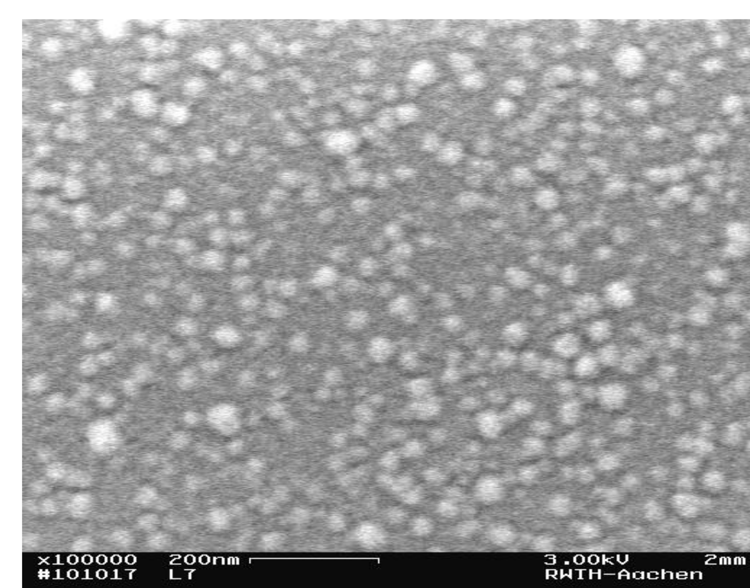
Criterion for Optimal thin films of GeS_2
- Homogeneity of film thickness across sample
- Minimize surface roughness

Characterization Methods
- X-ray Reflectivity (XRR)
  - Measured the thickness of the thin films (> 35 nm)
- Scanning Electron Microscope (SEM)
  - Visual analysis for first adjustments to parameters
- Energy Dispersive Spectroscopy (EDS)
  - Atomic concentrations of the thin films
- Atomic Force Microscopy (AFM)
  - Provided surface roughness measurements

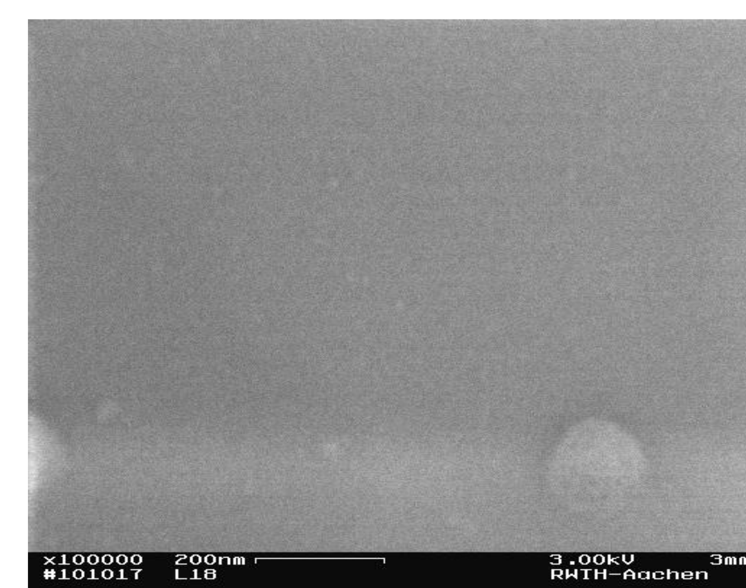


RESULTS

SEM Results
- Low pressure showed surface clusters
- Elimination of clusters seen with higher pressures



5W, 0.001 mbar, 4.8 nm/min

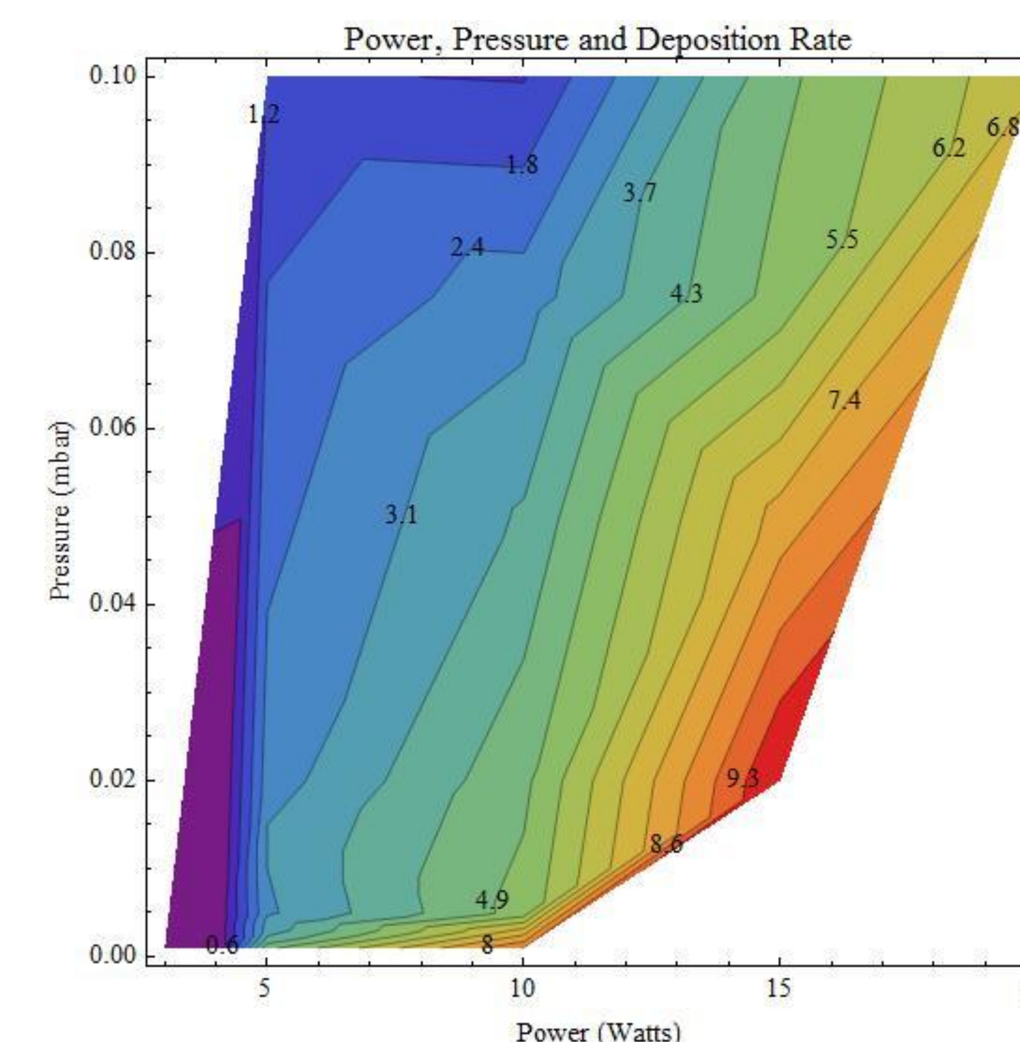


5W, 0.1 mbar, 1.33 nm/min

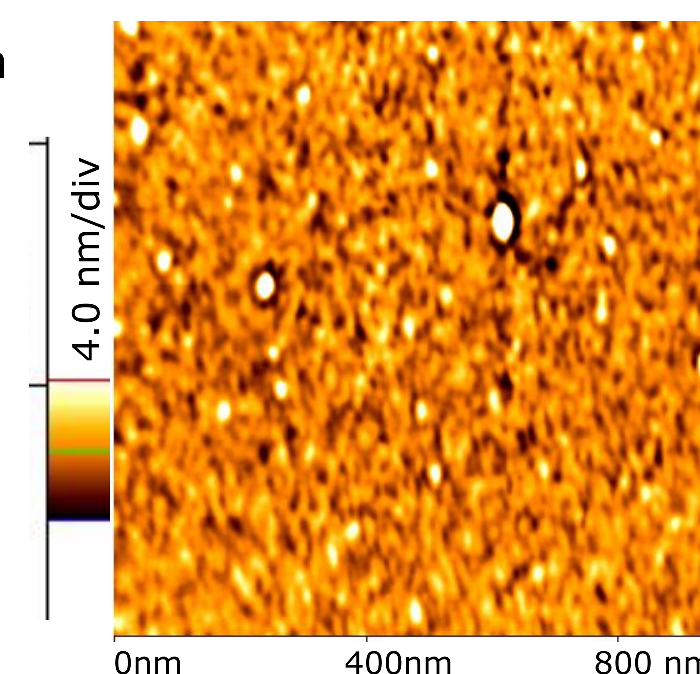
EDS Results
- Films produced at 5W and 0.1 mbar resulted in the a slight variation of the target material; 36.5 at. % germanium and 63.5 at. % sulfur
- Germanium concentration increased with increases in pressure
  - 14W and 0.2 mbar; 38.8 at. % germanium and 61.2 at. % sulfur

RESULTS (cont'd)

XRR Results
- Homogenous thickness across the 1 inch^2 sample was achieved at deposition rates of 1.5-4.0 nm/min
- Thickness variation of < 6% on 100 nm films



AFM Results
- AFM was completed on films that showed the most promise for the criterion of interest.
- RMS roughness of 0.5724 nm 14W, 0.2 mbar, 50 sccm Ar
- Lowest RMS and Average roughness of 0.4550 and 0.3091 nm at 16W, 0.2 mbar



CONCLUSIONS

Optimizing process parameters for thin films of GeS_2 can be achieved by using multiple characterization tools. Using 16 W and 0.2 mbar films can have consistent thickness and a minimal RMS surface roughness of 0.4550 nm. Further study into higher pressures could show decrease in roughness but may result in higher germanium compositions which may alter device performance.

ACKNOWLEDGEMENTS

Thanks to the professors, students and staff at RWTH Aachen University. Special thanks to Dr. I. Valov and J. van den Hurk. This work was supported by the International Materials Institute for Glass (NSF-IMI, DMR-0844014).