EAG Evans Analytical Group

AN 455

Composition and Mapping of GeSbTe (GST) Films Using Low Energy X-ray Emission Spectrometry (LEXES)

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Introduction

Phase change memory represents a versatile emerging technology for storing digital information that can be applied to both optical and electrical data storage. Research has shown that an alloy of Ge, Sb and Te is a viable candidate. The preferred composition of the typical GST film is nominally $Ge_2Sb_2Te_5$. In order for the phase change to occur at the appropriate temperature, the composition of the GST film needs to be tightly controlled. LEXES can be used to determine the composition of the GST film with both high accuracy and precision.

Discussion

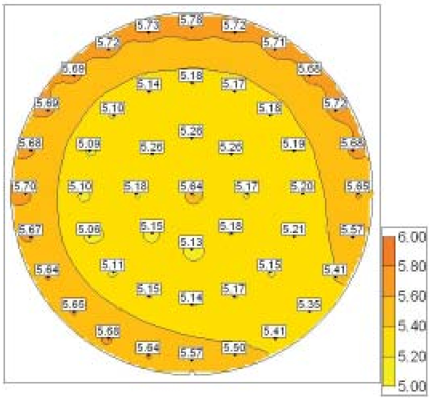
The LEXES technique utilizes an electron beam to probe the film and the characteristic x-rays that are generated for each element are analyzed using wavelength dispersive spectrometers (WDS). The physical process is the same as the one utilized for energy dispersive x-ray spectrometry (EDS) analysis, however the WDS spectrometers provide much greater wavelength resolution and higher detection sensitivity than EDS detectors. The measured x-ray intensities are converted to doses (atoms/cm^2) or concentrations (atoms/cm^3) using appropriate standards. If the sample is a wafer and multiple locations are analyzed, a map or linescan of the wafer can be generated.

To demonstrate the precision of the LEXES measurement, a total of eight measurements were performed at the center of a wafer with a GST film. These results demonstrate (typical) precisions in the range of 1% or less.

Point	Ge Dose (atoms/cm²)	Sb Dose (atoms/cm²)	Te Dose (atoms/cm²)	Ge atom fraction	Sb atom fraction	Te atom fraction
1	5.66E+16	6.54E+16	1.35E+17	0.220	0.255	0.525
2	5.66E+16	6.51E+16	1.34E+17	0.221	0.255	0.524
3	5.66E+16	6.59E+16	1.36E+17	0.219	0.255	0.526
4	5.64E+16	6.54E+16	1.36E+17	0.219	0.254	0.527
5	5.61E+16	6.51E+16	1.36E+17	0.218	0.253	0.529
6	5.63E+16	6.57E+16	1.38E+17	0.217	0.253	0.530
7	5.66E+16	6.52E+16	1.39E+17	0.217	0.250	0.532
8	5.69E+16	6.55E+16	1.40E+17	0.217	0.250	0.533
Avg	5.65E+16	6.54E+16	1.37E+17	0.219	0.253	0.528
Std Dev	2.16E+14	2.73E+14	1.93E+15	0.0016	0.002	0.0034
RSD	0.40%	0.40%	1.40%	0.70%	0.80%	0.60%

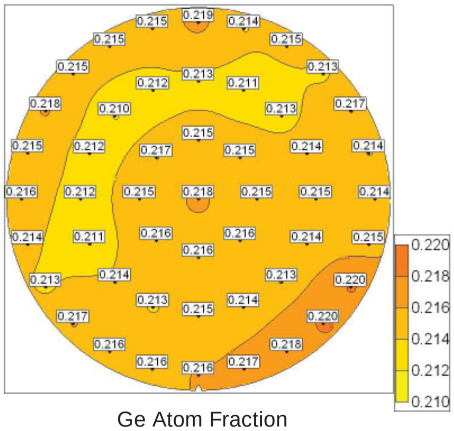
LEXES Measurements of 1000 Angstrom GST Film

By acquiring multiple points on a wafer, maps can be generated for each element. Below are the results of the analysis for Ge. The results are presented as doses (atoms/cm^2). The relative standard deviation of the Ge doses across this wafer is on the order of 5%, while the RSD of the measurement is less than 1%, so the variation across the wafer is real.

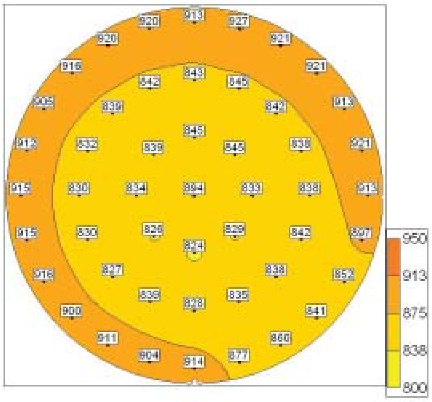


Ge Dose (x10^{16} atoms/cm^2)

By measuring Ge, Sb, and Te the dose results can be converted to atom fraction or composition. A map of the Ge atom fraction is shown below. The results show that the variation in the Ge atom fraction across the wafer is 1% or less. Therefore, the variation in the dose values is due to changes in the thickness of the GST film rather than changes in concentration. By assuming a density for the material, a map of film thickness can also be generated.



Ge Atom Fraction



GST Layer Thickness (Angstroms)

Additional elements such as carbon, nitrogen and oxygen can also be measured by LEXES in the GST film. Typical detection limits are:

Element	Detection limit (atoms/cm^2)	Detection Limit (at-%)*
C	5e15	0.5
N	1e14	0.01
O	5e14	0.05

* Assuming a film thickness of 2000 Ang and a density of 5e22 atoms/cm^3