

# Auger Electron Spectroscopy Calibration

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**Abstract** - This study presents a brief introduction to Auger Spectroscopy with experimental results taken from a spectrometer donated by Kodak in 2000. The tool has been calibrated using materials with high electron energy signals, primarily Titanium and Gold. Analysis of thin film spectra include the materials Aluminum, Gold,  $\text{Si}_3\text{N}_4$ , Germanium, and Tungsten. Depth profile measurements were made using a groove-etch technique and ion bombardment sputtering of a multi-layer metal stack. Future work will involve enabling x-Ray spectroscopy capabilities of the tool and increasing sensitivity of measurements.

## I. INTRODUCTION

**T**RENDS in current microelectronic technology call for thin films to be processed with high precision and purity. Thin film interfaces and metallurgical junctions are designed to have specific qualities that enhance the operating performance of the devices fabricated, such as mixed junctions like silicide gates or abrupt junctions like a thin gate insulator. In order to fully understand the characteristics of materials within a device several measurement techniques may be employed. Electrical measurements can be used to determine the operational qualities of a device, optical measurements of structure may be made through SEM, but the physical properties require a measurement that can identify specific elements contained within these small features. A measurement technique that has the capability to extract specific atomistic composition from a thin film sample is Auger Spectroscopy.

## II. THEORY

Auger Spectroscopy is based on a phenomena first reported by Pierre Auger in the mid 1920's. Elemental composition can be measured by the detection of the Auger electron, an energy emission due to the bombardment of an electron beam with an analytical volume of  $\sim 3 \times 10^{-19} \text{ cm}^3$ .

First an inner core electron is excited out of its energy state. Another higher level electron from the atom's electron shell drops down to occupy the empty energy state. The release of energy due to the second electron allows the Auger electron to escape the material. The measurement spectra of the escape energy is specific for each element in the periodic table.

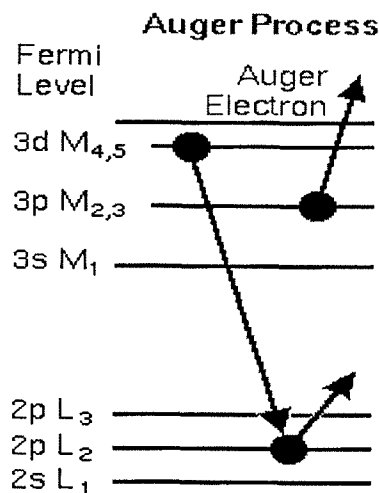


Fig 1. The Auger Excitation process from a pictorial view of energy levels within the reaction.

The escaping electrons are subjected to an electric field as they leave the sample and enter the cylindrical mirror analyzer (CMA). The inner cylinder of the CMA is held at ground while the outer cylinder is a computer controlled negative potential. The negative potential is varied changing the electric field curving the electrons of particular energies such that they pass through an aperture and specific emission intensities are detected.

Auger signals are plotted as electron signal,  $N(E)$ , versus the electron energy in eV. The differential of the plot,  $dN(E)/dE$ , arranges the measurement by linearly clarifying features. If the electron signal is multiplied by the total electron energy, upper energy signals become stronger and more readable. Finally by plotting the differential of this combination,  $d[ExN(E)]/dE$ , a clear display of Auger electron signals is produced. There are many references available with samples of spectra for every measurable elemental signal as well as charts of specific energies of those elemental signals.

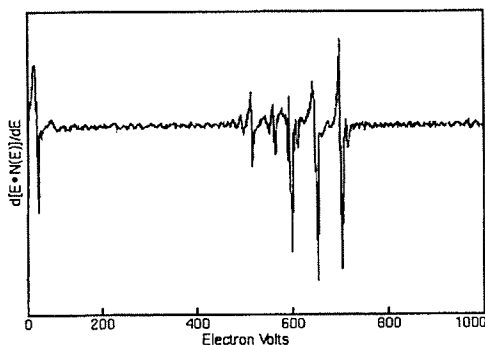


Fig 2. Generic spectra that shows the effect of manipulating measurement data for better clarity.

### III. FUNCTIONALITY

Auger Electron Spectroscopy (AES) is the primary function of the tool. AES identifies elemental composition by measuring the energies of Auger electron emissions. The spectrometer is fitted with additional capabilities that add to the utility of the system. An Ar Ion sputtering gun is a standard tool in use with Auger Spectroscopy. Ar sputtering is used to remove surface contamination and to perform depth profile analysis of sample materials. The Ar sputtering gun directs a beam of ions roughly 500 eV to 5keV at the sample. Another method available to create depth profile measurements is a mechanical groove etch similar to a groove and stain junction depth measurement. A groove is made by applying a round grinding wheel with a known radius of curvature to the sample. The Auger analytical volume is ~10nm in diameter, therefore very small lateral profiles are possible with the tool. X-ray Photoelectron Spectroscopy (XPS) is also a function of the spectrometer. XPS is similar to AES due to its surface specific limitation and ability to determine elemental composition. XPS can also determine chemical state and bonding information of the sample.

### IV. ENABELING THE TOOL

Initially the spectrometer was not functional due to a failure in a critical power supply. A power interlock circuit, controlling a power failsafe to the spectrometer, needed to be replaced. This involved removing the power unit from the control station and changing a circuit board within the unit. After fixing the power supply a vacuum system needed to be connected to the sample air-lock for introducing new samples to the measurement chamber. The vacuum system consists of a rough pump backing up a turbo-molecular pump. Once these systems were repaired the spectrometer was calibrated. Calibration consisted of taking sample measurements of specific elements that possess high electron energy signals and altering a multiplication factor within the spectrometer's LabView control software. If the calibration is not

accurate, these high energy signals may appear at the wrong electron energy and result in incorrect analysis. A method to reduce noise when taking measurements is to signal average by generating information repeatedly over the same measurement space and averaging all of the individual traces. A modification is being written into the LabView software to include signal averaging for a predetermined number of traces. In order to enable operation of the XPS function, the anode of the emission source must be reconditioned or replaced.

### IV. CONCLUSIONS

Auger Spectroscopy is operational at RIT. This measurement method provides compositional information about thin films. Samples used in this study include Gold, Titanium, Silicon Nitride, Aluminum, and Germanium. The tool was calibrated using elements with high electron energy spectra. Through the use of tools such as ion sputtering and mechanical etching information on depth profiles and interfaces can be extracted. Ion sputtering is useful in that samples are sputtered in the same chamber as measurements are taken, but etch rates are difficult to determine. Mechanical groove etching is good, but the technique creates a great deal of mechanical damage, reducing measurement reliability.

Measurements of a Germanium silicide sample were made both before and after anneal, but showed little change overall. Quantification of measurements is possible but quite difficult. Auger peak heights depend on several critical factors including primary beam energy, sample orientation, and also the energy resolution and acceptance angle of the analyzer. XPS is not currently operational, but should be functional with some repair. A signal averaging option to increase the sensitivity of measurements is being implemented into the LabView software package.

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### V. REFERENCES

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