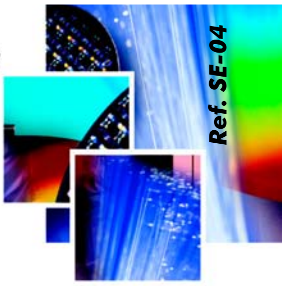
Spectroscopic Ellipsometry



Ref. SE-04

# Characterization of Chalcogenide Glasses

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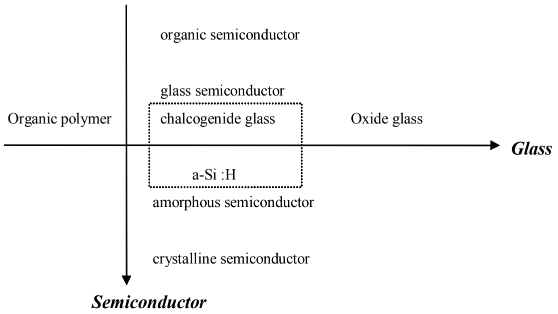
**UVISEL**

Large scale production has been the driving force in the search for more cost effective infrared optical systems. Infrared transmitting chalcogenide glasses are the ideal candidate for such applications. Their unique optical properties are very useful for the manufacture of passive and active integrated optical devices such as writing channel waveguides and the fabrication of IR lenses, windows and filters used in thermal imaging systems. High efficiency lasers, light amplifiers, and light up-converters have been successfully realized by chalcogenide glasses doped with lanthanide ions.

## Introduction to Chalcogenide Glasses

Semiconducting glasses, namely chalcogenide glasses, contain one or more of the chalcogen elements (group VI elements S, Se, Te) as alloy elements. They behave as semiconductors, or more precisely, they exhibit amorphous semiconductor behaviour with band gap energies from 1 to 3 eV. As shown by the horizontal sequence chalcogenide glasses possess properties intermediate between those of organic polymers and oxide glasses. Their overall properties are represented on the vertical sequence.



*Characterization of chalcogenide glasses and semiconductors in comparison with other materials.*

Chalcogenide glasses exhibit excellent transmission in the near and far infrared spectral region. They are high refractive index materials with a nonlinear refractive index typically x100 that of silica, with a low maximum phonon energy. The glasses have good solubility towards rare earth elements ions (REI) such as lanthanum, and also have the advantage of high chemical and thermal stability. Their low phonon energy and high refractive index provide them with a low probability of multiphonon relaxation and high radiative transition probabilities of rare-earth ions. In this way the materials have increased luminescence efficiency. The high chemical and thermal stability allows the creation of easy-to-prepare optical devices. The high solubility of REIs in the chalcogenide host makes it possible to realize thin film technologies with high concentration of REIs in active media.

Furthermore chalcogenide glasses are very important materials owing to their photo sensitivity, as this allows preparation of writing channel waveguides. The writing channel is achieved by laser illumination of the glass at a wavelength close to near the band gap of the glass. As the glasses are photo sensitive it is possible to modify the refractive index of the glass in a controlled manner. This technique is promising because it bypasses the standard photolithographic processes needed to obtain channel waveguides.

A very important advantage for using chalcogenide glasses in integrated optics is their availability as thin films. As a result it is important to know the layer thickness with high accuracy and precision. As with all optical devices it is also important to characterize the linear optical constants accurately so that their non-linear optical properties can be known.

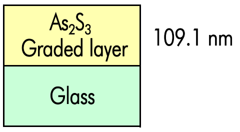
## $As_2S_3$ and $Ge_{28}Sb_{12}Se_{60}$ characterization

The non destructive characterization of various Chalcogenide Glasses was successfully carried out by Spectroscopic Ellipsometry. The ellipsometric data were collected at an angle of incidence of 70° using the Jobin Yvon UVISEL NIR Ellipsometer.

The UVISEL Spectroscopic Phase Modulated Ellipsometer is a unique instrument that provides significant advantages for display applications when compared to conventional ellipsometers. Its technology is the most suitable for making accurate thin film measurements on transparent substrates as the DeltaPsi2 ellipsometry software includes advanced methods for the automatic correction of backside reflections from transparent substrates.

# Spectroscopic Ellipsometry

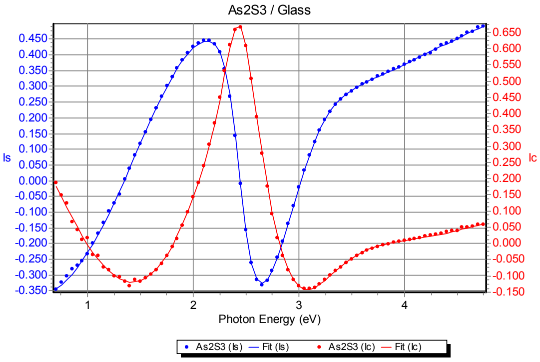
$As_2S_3$ and $Ge_{28}Sb_{12}Se_{60}$ were deposited on glass substrates by cathodic sputtering. Both the refractive index and thicknesses of each layer were extracted from the SE data analysis. The optical constants depend on the deposition technique and their composition, and were determined by using the Tauc-Lorentz dispersion formula.

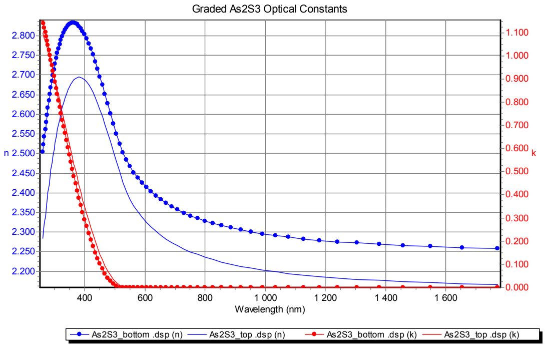


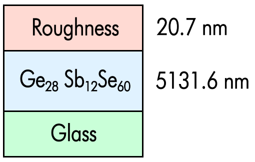
It is often the case with such materials that there is a change in optical properties through the layer. This can be included with the model by applying a graded refractive index to the structure. For this structure a great improvement to the $\chi^2$ value (goodness of fit) was found when compared to a simple index model.

The graded layer used specified one value of index at the bottom of the chalcogenide layer, and one index for the layer top. The index was calculated as a linear function between these two values.

The fit was made across the spectral range 260-1700 nm.

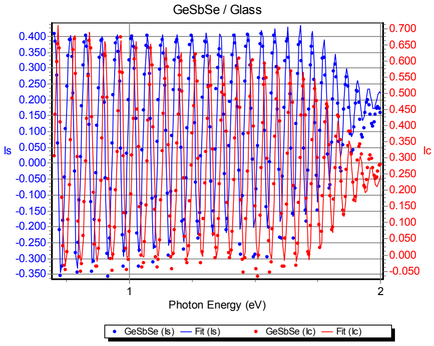


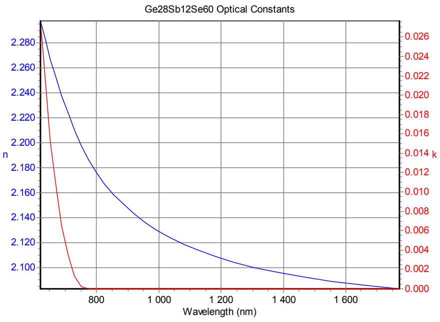




This model included a roughness layer on top of the glass. The roughness layer was described by the Effective Medium Approximation (EMA), and was calculated by as a mixture of 50% of chalcogenide glass and 50% voids.

Owing to the large number of interference fringes that are found when measuring thick films it is necessary to have an optical system that has high spectral bandpass and full control of scan step size so that the fringes can be measured accurately. The UVISEL NIR meets both of these requirements, and as the user can specify a small step size, the fringes can be measured with high precision. For this example the fit was made across the transparent part of the spectrum from 620-1700 nm (0.7-2 eV) with a very small step size.





## Conclusion

Characterization of various chalcogenide glasses was performed successfully using the UVISEL NIR Spectroscopic Phase Modulated Ellipsometer. The UVISEL NIR ellipsometer allows the determination of film thickness and optical properties with very high accuracy even where the film is many microns thick, and deposited on a transparent substrate.

The versatility of the UVISEL NIR in terms of instrument resolution, sensitivity and step size and the power of the instrument software make the UVISEL NIR the most suitable instrument for determination of these sample structures.

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