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Analyzing the Composition of CuInO and TiO2 Semiconductor Films Using Rutherford Backscattering Spectrometry

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ANALYSIS OF THE COMPOSITION OF CIO AND TONT SEMICONDUCTOR FILMS

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Summary

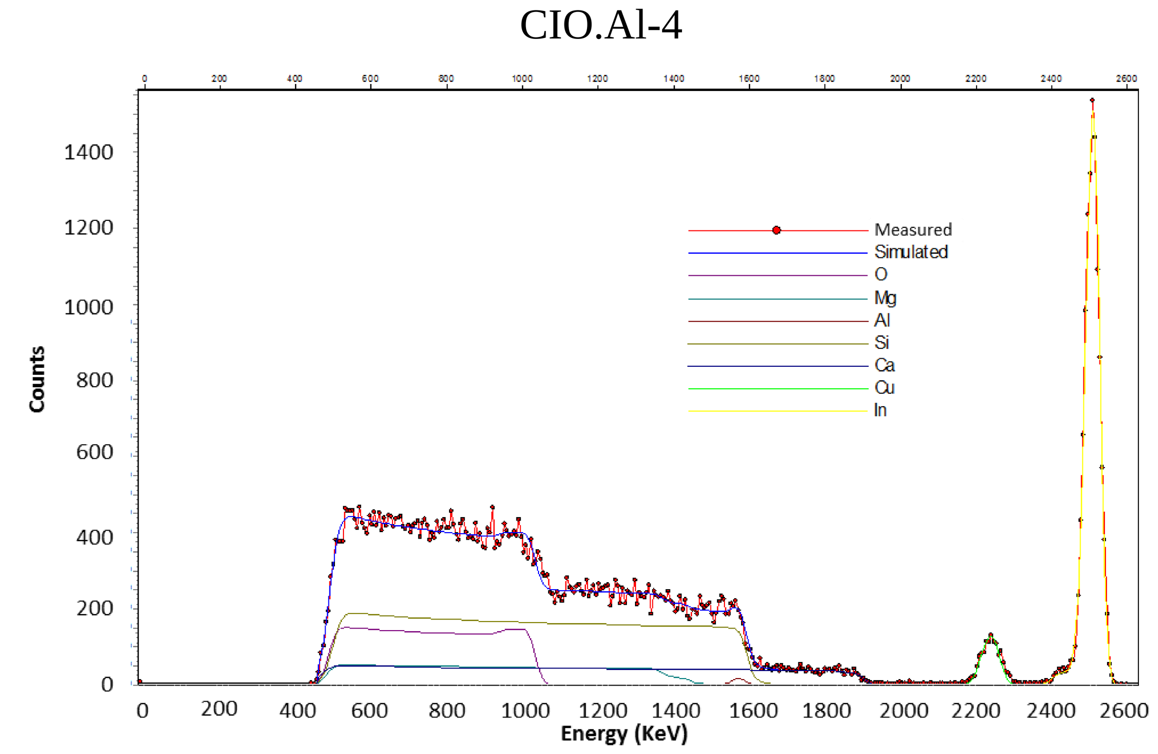
- Collaboration with a fabrication group at Union Christian College in Aluva, India
- Films were analyzed using Rutherford Backscattering Spectrometry (RBS)
- RBS analysis produced Stoichiometric information about the films
- Stoichiometry changes with depth in the film observed
- Bandgap of CIO films measured and compared

- These Semiconducting thin films are of interest due to their applications in solar cells
  - Copper Indium Oxide (CIO), nominally $CuInO_2$, is a Transparent Conductive Oxide, which is transparent to most visible light, and functions as a semiconductor which can be doped p type or n type.[1]
  - Titanium Oxide Nanotubes (TONT), nominally TiO_2, have varied and controllable photoelectochemical properties.[2]
- Samples of both types had various additives in varying amounts
- Stoichiometric depth profiles were done using RBS in the Hope Ion Beam Accelerator Laboratory
- Visual Spectrum Absorption Spectroscopy was used to find the semiconducting bandgaps of these films

1. Surya A. Mary, Bindu G. Nair, Johns Naduvath, *et al*. Journal of Alloys and Compounds. 600 (2014) 159.
2. K. A. John, J. Naduvath, S. Mallick, *et al*. Nano-Micro Lett. 8 (2016) 381.
3. M. Mayer, *SIMNRA User's Guide*, Report IPP 9/113, Max-Planck-Institut für Plasmaphysik, Garching, Germany, 1997
4. J. Tauc, A. Menth, Journal of Non-Crytalline Solids, 8-10 (1972) 569-585.
5. X. Nie, S. H. Wei, S. B. Zang, Physical Review Letters. 88 (2002) 066405.

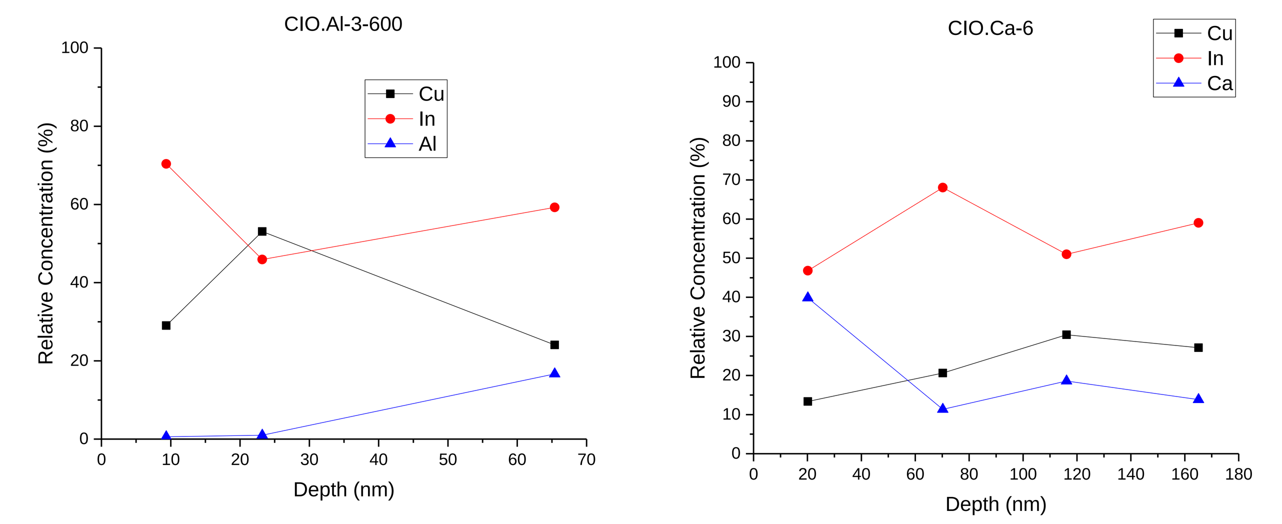
Rutherford Backscattering Spectroscopy (RBS)

- The semiconducting films were targeted with a 2.9 MeV Helium ion beam in the Hope Ion Bean Accelerator Laboratory.
- Stoichiometry was determined from modeling the measured Helium ion backscattering off of target nuclei.
- The raw data from the accelerator was analyzed using the program SIMNRA. [3]



Typical SIMNRA fit of a CIO film on a glass substrate

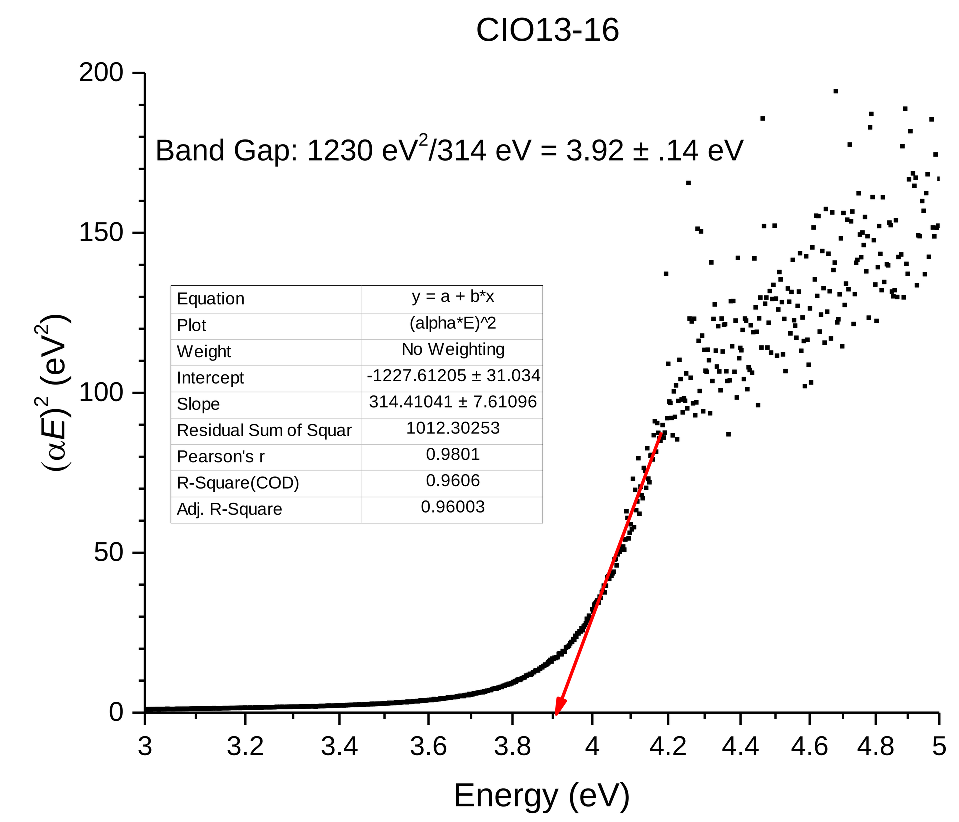
- SIMNRA produces a fit to the data made up of layers with differing stoichiometries.
- SIMNRA fits for RBS data were collated and concentration graphs were made to track the stoichiometry throughout the films.
- As it has less effect on the electrical properties and some areas were extremely oxidized, Oxygen was removed from these graphs and they show only the relative concentration of the metallic elements within the film



Examples of concentration graphs for samples with additives: Al and Ca

Absorption Spectrometry

- Absorption data were taken of the transparent CIO samples using an Ocean Optics USB4000 and transformed into a Tauc plot.
- A Tauc plot of the absorption spectrum features a linear portion which is described by $(\alpha E_{ph})^{1/m} = k'(E_{ph} - E_g)$ where α is the absorption coefficient, E_{ph} is the energy of an absorbed photon, m is a parameter describing the nature of the transition, and E_g is the bandgap. [4]
- Finding the linear portion of the curve, making a linear fit and finding the x-intercept, gives the bandgap of the material.



- This process is applicable to any transparent film on a transparent substrate such as CIO on glass.
- The bandgaps calculated using absorption spectrometry were found to not vary with additives and agree with other published values for CIO [5]

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